UNIVERSITY OF ADELAIDE LIBRARY 26/6/86

INTELLIGENCE AND ANALOGICAL REASONING

J.H. McConaghy, B.A.(Hons.)(Adelaide)

Thesis submitted to the University of Adelaide
in fulfilment of the conditions for the
Degree of Doctor of Philosophy

Department of Psychology
University of Adelaide
South Australia
1985

Awarded 14-2-86

TABLE OF CONTENTS

		Page
SUMMARY		(v)
DECLARATIONS		(ix)
ACKNOWLEDGEMENTS		(x)
CHAPTER 1		
	A REVIEW OF THE INFORMATION PROCESSING APPROACH, AS IT RELATES TO INTELLIGENCE	1
1.1	INTRODUCTION	1
1.2	HUMAN INFORMATION PROCESSING	3
	1.2.1 The Subtractive Method	8
	1.2.2 The Additive Factors Method	12
1.3	INTELLIGENCE AND HUMAN INFORMATION PROCESSING	14
	1.3.1 The Cognitive Correlates Approach	19
	1.3.2 The Cognitive Components Approach	
1.4	STRATEGIES, INTELLIGENCE AND INDIVIDUAL DIFFERENCES	23
	1.4.1 Individual Differences and Strategy Usage	24
	1.4.2 Individual Differences and Flexibility of Strategy Usage	28
1.5	CONCLUSION	36
CHAPTER 2		
	HUMAN INFORMATION PROCESSING AND MENTAL RETARDATION	39
2.1	INTRODUCTION	40
2.2	MENTAL RETARDATION AND REACTION TIME	40
	2.2.1 Simple and Choice Reaction Time Studies	43
	2.2.2 Reaction Time as a Dependent Measure	50
	2.2.3 Attentional and Motivational Factors	53
2.3	MENTAL RETARDATION AND SHORT-TERM MEMORY	56
2.4	MENTAL RETARDATION, STRATEGIES AND TRAINING	56
	2.4.1 Control Processes, Knowledge Base and Metacognition	63
	2.4.2 Strategy Training, Maintenance and Generalisation	79
	2.4.3 Mental Retardation and Spontaneous Strategy Usage	85
	2.4.4 Mental Retardation, Strategies and Task Complexity	90
2.5	CONCLUSION	

Page

CHAPTER 3

A DESCRIPTION OF STENBERG'S COMPONENTIAL METHOD

3.1	INTRODUCTION	93
3.2	THE NATURE OF A COMPONENT	93
3.3	THE METHODOLOGY OF COMPONENTIAL ANALYSIS	97
	3.3.1 Four Models of Analogical Reasoning	98
	3.3.2 The Basis of Component Parameter Estimation	102
	3.3.3 Types of Analogies	105
3.4	A DESCRIPTION OF THE PEOPLE PIECE ANALOGY EXPERIMENT	108
	3.4.1 Experimental Design	108
	3.4.2 Results	110
3.5	THE COMPONENTIAL METHOD, AGE AND ABILITY LEVEL	116
3.6	CONCLUSION	120

CHAPTER 4

TWO ATTEMPTS TO REPLICATE THE ORIGINAL RESULTS OF THE PEOPLE PIECE ANALOGY EXPERIMENT

4.1	INTRODUCTION TO EXPERIMENT 1	122
4.2	METHOD	124
	4.2.1 Subjects	124
	4.2.2 Apparatus	124
	4.2.3 Design	125
	4.2.4 Procedure	127
4.3	RESULTS AND DISCUSSION	131
	4.3.1 Interval Scores	131
	4.3.2 Component Scores	137
	4.3.3 Error Rates	160
4.4	CONCLUSION	162
4.5	INTRODUCTION TO EXPERIMENT 2	166
4.6	METHOD	167
	4.6.1 Subjects	167
	4.6.2 Apparatus	167
	4.6.3 Design	168
	4.6.4 Procedure	168
4.7	RESULTS AND DISCUSSION	170
	4.7.1 Interval Scores	170
	4.7.2 Component Scores	175
	4.7.3 Error Rates	185
4.8	CONCLUSION	186
4.9	OVERALL CONCLUSION	189

Page

CHAPTER 5

THE EFFECT OF REMOVING THE PRECUED FIGURES ON THE ABILITY TO REPLICATE STERNBERG'S ORIGINAL RESULTS

5.1 INTRODUCTION TO EXPERIMENT 3 194
5.2 METHOD 198
5.2.1 Subjects 198
5.2.2 Apparatus 199
5.2.3 Design 199
5.2.4 Procedure 200
5.3 RESULTS AND DISCUSSION 203
5.3.1 Interval Scores 203
5.3.2 Component Scores 206
5.3.3 Error Rates 213
5.4 CONCLUSION 214
5.5 INTRODUCTION TO EXPERIMENT 4 219
5.6 METHOD 221
5.6.1 Subjects 221
5.6.2 Apparatus 222
5.6.3 Design 222
5.6.4 Procedure 222
5.7 RESULTS AND DISCUSSION 225
5.7.1 Interval Scores 225
5.7.2 Component Scores 227
5.7.3 Error Rates 237
5.8 CONCLUSION 239
5.9 OVERALL CONCLUSION 242

CHAPTER 6

THE EFFECTS OF STRATEGY TRAINING ON THE PERFORMANCE LEVEL OF MENTALLY RETARDED SUBJECTS

6.1 INTRODUCTION TO EXPERIMENT 5 246
6.2 METHOD 250
6.2.1 Subjects 250
6.2.2 Apparatus 251
6.2.3 Design 251
6.2.4 Procedure 252
6.3 RESULTS AND DISCUSSION 257
6.3.1 Interval Scores 257
6.3.2 Component Scores 260
6.3.3 Error Rates 273
6.3.4 Ravens Progressive Matrices 275
6.4 CONCLUSION 275

Page

CHAPTER 7

THE EFFECTS OF STRATEGY TRAINING AND THE MODIFIED METHOD OF PRECUEING ON THE PERFORMANCE LEVEL OF MENTALLY RETARDED SUBJECTS

7.1 INTRODUCTION TO EXPERIMENT 6 281
7.2 METHOD 284
7.2.1 Subjects 284
7.2.2 Apparatus 285
7.2.3 Design 285
7.2.4 Procedure 285
7.3 RESULTS AND DISCUSSION 290
7.3.1 Interval Scores 290
7.3.2 Component Scores 293
7.3.3 Error Rates 304
7.4 CONCLUSION 305

CHAPTER 8

R.J. STERNBERG'S COMPONENTIAL METHOD: SUMMARY AND CONCLUSIONS

8.1 INTRODUCTION 310
8.2 A SUMMARY OF EXPERIMENTAL PROCEDURES 310
8.3 THE VALIDITY OF THE COMPONENTIAL METHOD AS A MEANS OF STUDYING ANALOGICAL REASONING 313
8.3.1 Interval Scores and Nonretarded Subjects 314
8.3.2 Model Fitting, Parameter Estimates and Nonretarded Subjects 317
8.3.3 Conclusions Concerning the Nonretarded Subjects and the Componential Method 322
8.4 THE APPLICABILITY OF THE COMPONENTIAL METHOD TO THE INVESTIGATION OF MENTAL RETARDATION 323
8.4.1 Interval Scores and Below Average and Retarded Subjects 323
8.4.2 Model Fitting, Parameter Estimates and Below Average and Retarded Subjects 325
8.4.3 Conclusions Concerning the Below Average and Retarded Subjects and the Componential Method 330
8.4.4 The Broader Implications for Training the Mentally Retarded 334
8.5 THE COMPONENTIAL METHOD AND CRITICISMS MADE OF THE SUBTRACTIVE METHOD 336
8.6 THE COMPONENTIAL METHOD, ANALOGICAL REASONING AND COGNITIVE PROCESSING 342
8.7 OVERALL CONCLUSIONS AND DIRECTIONS FOR FUTURE RESEARCH 344

APPENDICES

REFERENCES

SUMMARY

This thesis investigated the componential method of analogical reasoning developed by R.J. Sternberg using both nonretarded and retarded subjects. Sternberg proposed that five processes were used in analogical reasoning, encoding, inference, mapping, application and preparation-response. He also proposed four additive models which included each of the five above processes. The models differed in how many of the processes were assumed to be exhaustive or self-terminating. To separate the processes from each other, Sternberg used a method called precueing, in which progressively more information was provided in the first half of the trial, so less processing was required in the second half of the trial. To test his method, Sternberg used People Piece Analogies in which analogy terms were composed of four binary attributes (height, weight, sex and colour). Sternberg found Model III, the partially exhaustive, partially self-terminating model, best explained how his subjects of above average intelligence, solved the People Piece Analogies.

In the first experiment, subjects of above and below average intelligence performed the People Piece Analogy task. It was found to be necessary to provide the below average group with an additional initial practice session to ensure that they understood the nature of the task. Model III was found to best explain the data for the above average intelligence subjects and Model IV proved the best explanation for the below average intelligence subjects. However, both groups were much slower and more variable in solving the analogies than Sternberg's subjects and appeared to be making little use of the information provided in the first half of the trial, thus making the

estimates of each process less reliable. No specific instructions had been given to use the precued information (presented in the first half of the trial) as there was no evidence in the publications of Sternberg that special instructions were required.

Experiment 2 consisted of providing more specific instructions to the subjects to use the precued information. In addition, since Experiment 1 had shown that subjects of below average intelligence were able to solve the analogies, a group of borderline and mildly mentally retarded subjects was used. So that both nonretarded and retarded groups received the same quantitative amounts of practice, the nonretarded group also participated in an initial practice session. Models III and IV explained the nonretarded subjects' data equally well while Model III best explained the retarded subjects' data. However, both groups were still much slower than Sternberg's subjects at solving the analogies, even though the nonretarded subjects had received an extra session of practice. In addition, even with more specific instructions to use the precued information, both groups, but especially the retarded group, appeared not to do so.

Experiment 3 introduced an experimental manipulation that forced the use of the precued information by the subjects. In previous experiments and in those by Sternberg, the precued information remained present in the second half of the trial. In this experiment, the precued information was removed after the end of the first half of the trial, so that the second half of the trial consisted of the nonprecued information only.

This method was successful in producing use of the precued information by the nonretarded subjects and thus allowed the reliable estimation of each of the

processes. These subjects were again found to be using Model III. It was found, however, that even with an additional practice session and very explicit instructions, a mentally retarded group was unable to perform this task. In Experiment 4, therefore, a simplified task was constructed so that it could be used in conjunction with the modified method of precueing described above. It was found that the mentally retarded group were able to perform this task. Model III was found to provide the best explanation of the data obtained from both groups of subjects.

In Experiments 5 and 6, only borderline and mildly retarded subjects were used. A training procedure was developed to examine whether this could be used in conjunction with the simplified task, to improve the ability of any of the models to explain the data obtained from mentally retarded subjects. The training procedure consisted of two sessions in which the subjects were instructed to verbally elaborate the relationship between the first two analogy terms and then the second two analogy terms and to decide if these relationships were the same.

In Experiment 5, the original rather than the modified method of precueing was used. It was hoped that the use of the simplified task, with specific instructions to use the precued information, might induce the subjects to use the precues. The ability of the models to explain the subjects' data was improved suggesting that training had made the performance of these subjects more consistent. There was also some evidence that these subjects had made more use of the precued information in the first half of the trial but this did not occur to the same extent as when the modified method of precueing was used.

In Experiment 6, the modified method of precueing was used in conjunction with the training procedure and simplified task. Here the most successful results using mentally retarded subjects' were obtained. The ability of the models to explain the retarded subjects' data was slightly improved over those in Experiment 5, and use of the precued information was obtained. Model II was found to best explain the mildly retarded subjects' data. Thus their processing became more exhaustive with both training and the introduction of the modified method of precueing.

Two other findings that were evident throughout this series of experiments are important. One is the relative duration of each of the processes when separately estimated. Sternberg found that better reasoners produced longer times for encoding but shorter times for subsequent processes than poorer reasoners. In this series of experiments, this was also the case, with nonretarded subjects producing longer encoding times and shorter durations for subsequent processes than the below average and retarded groups. Secondly, it was very difficult to choose between the alternative models, their ability to account for the data being very similar. This was the case even though all models represented different combinations of the exhaustive and self-terminating forms of the five proposed processes. It was suggested that subjects might be flexible in their use of the exhaustive and self-terminating forms of each process and that this would depend on the ability level of the subject and the difficulty of the particular analogy.

The broader implications of this series of experiments for understanding the analogical reasoning processes of nonretarded and mentally retarded persons were also discussed.

DECLARATIONS

This thesis contains no material which has been accepted for the award of any other degree or diploma in any Univsersity and to the best of my knowledge and belief, it contains no material previously published or written by another person, except where due reference is made in the text of the thesis.

I consent to this thesis being made available for photocopying and loan, if applicable, if accepted for the award of the degree.

Julie H. McConaghy
May, 1985

ACKNOWLEDGEMENTS

Firstly, I would like to thank my supervisor, Dr. Neil Kirby for his invaluable guidance, encouragement and support during the course of preparing this thesis.

Secondly, I am grateful to the undergraduate students of the University of Adelaide and the employees of Bedford Industries Rehabilitation Centre for their patience and enthusiasm in the experiments they participated in. I am also grateful to the staff of Bedford Industries Rehabilitation Centre for allowing me to obtain subjects and conduct my experiments within their midst.

Thirdly, I would like to thank Professor R.J. Sternberg for his correspondence and for allowing me to present Figures 3.1 to 3.6 in Chapter 3 and Dr Ted Nettelbeck for his helpful comments.

Fourthly, I am indebted to Adrian Barnett, Bob Willson, Mark Brown and Tim Walwyn for their expert assistance with statistical analyses and computer programming. I am also grateful to Lyn Brewer and Judy Fallon for their efforts in typing this thesis and in preparing the Tables and Figures.

Finally, I would like to thank Carlene Wilson for her assistance in all facets of this thesis and her friendship and Stephen Harrison for his unflagging support over the past four years.

CHAPTER 1

A REVIEW OF THE INFORMATION PROCESSING APPROACH, AS IT RELATES TO INTELLIGENCE

1.1. INTRODUCTION

The purpose of this thesis was firstly, to investigate the validity and reliability of the componential approach to information processing as developed by R.J. Sternberg (1975, 1977a) and secondly, to investigate the performance of intellectually retarded persons using this approach. This chapter will consider the areas and studies that were influential to this approach, Chapter 2 will provide information relevant to mental retardation and a detailed discussion of the componential method will be presented in Chapter 3.

1.2 HUMAN INFORMATION PROCESSING

The information processing model of human performance has been influential both to R.J. Sternberg's componential approach and to research into mental retardation. This model of human behaviour gained importance in psychology in the mid to late 1960s due primarily to two developments - the greater sophistication of experimental measurement techniques and the advent of the computer. Computer technology has in more recent years also provided more accurate and flexible measurement techniques but it's major contribution in the 1960s was a conceptual framework for discussing the existence and organisation of cognitive events.

The greater sophistication in measurement techniques made it posssible for more reliable estimates of Reaction Time (RT) to be made. Reaction Time

can be operationally defined as the (hypothesised) duration of a series of processes taking place between the presentation of a stimulus and the making of a response to that stimulus. Measures of RT have tended to be of two types in human information processing. The first type concerns the measurement of RT per se (Neisser, 1963; Smith, 1968; Taylor, 1968). Investigations of this type have attempted to delineate the factors that affect RT, for example, stimulus intensity and duration (S. Sternberg, 1969), stimulus-response compatibility (Broadbent and Gregory, 1965; Sanders, 1970) and response organisation (Sanders, 1970). This method has also been especially useful in the investigation of mentally retarded persons' cognitive processes, as shall be discussed in Chapter 2. The second type of measure has been concerned with the use of RT as a dependent variable in investigations of tasks which are thought to require the use of certain cognitive processes, for example memory processes. In addition, there is generally some theoretical background to the development and use of the particular tasks. Examples here include the work of Chase and Clark, (1972) , Posner and Mitchell (1967), Posner, Boies, Eichelman and Taylor (1969), S. Sternberg (1969) and most of the more recent investigations in human information processing including that of R.J. Sternberg, the subject of this thesis.

Two methodologies are associated with the use of RT as a dependent variable; the subtractive and additive factors techniques. The subtractive technique is of primary interest here as it is the method on which R.J. Sternberg's componential approach is based. The characteristics of the two methods will be described in greater detail in the next two sections. However the essential differences between them are that the subtractive method involves the direct deletion or addition of given processes in a particular task

while the additive factors technique consists of identifying processes or stages indirectly from the pattern of statistical main effects and interactions between experimental variables. The additive factors technique never involves the deletion or addition of a stage (or process). Instead, to measure the length of a stage of interest, the number of times that stage is used in a given experimental setting is varied.

1.2.1 THE SUBTRACTIVE TECHNIQUE

The Subtractive Technique was first developed by Donders (1896). The essence of his technique was the measurement of RT on two tasks, one task requiring the use of all the cognitive processes used in the other task plus an additional process. Thus the difference in observed RTs was hypothesised to be a measure of the time taken by that additional process. Use of the method entailed the acceptance of two assumptions. Firstly, what has become known as the assumption of pure insertion, that is, that tasks can be constructed that reflect the deletion and addition of certain cognitive processes without affecting the remaining processes and therefore the original task. If other processes are affected, any difference in obtained RTs between the original and modified tasks can not be said to measure only the process under investigation. Secondly, the assumption of additivity. If it is assumed that a process can be added or deleted without affecting the remaining processes, it must also be assumed that the processes occur serially and that total RT will reflect the sum of each of the processes added together.

The method was originally discarded approximately two decades after its development by Donders because introspective methods suggested that it might be difficult to develop tasks that represented the deletion or addition of

a single process. Therefore the assumption of pure insertion was likely to be violated. Another problem was the high variability of introspective reports regarding RTs provided by subjects (S. Sternberg, 1969 a).

With the recent development of more "objective" and accurate measurement techniques and computer technology, Donder's method has been viewed with renewed interest. Two examples of recent adaptions of Donder's method will now be discussed. Both sets of investigators were interested in understanding and identifying the processes used in the analysis of visually presented semantic stimuli and both had a fairly well developed theoretical framework from which they elaborated their subtractive tasks.

The first example is the letter identification task developed by Posner and his colleagues (Posner and Mitchell, 1967; Posner et al, 1969). Subjects were simultaneously presented with two letters which were identical physically and in name (e.g. aa) or identical in name and not physically (e.g. Aa) or different in name but not physically (e.g. AB) or different both in name and physically (e.g. Ab). The subject's task was to respond "same" or "different" as quickly as possible after the two letters appeared. Two conditions were of most interest - where the subject must respond "same" if the two letters were identical physically and in name (AA) or if the two letters were identical in name only (Aa). Posner et al found that the difference in RT between the former Physically Identical (PI) condition and latter Name Identical (NI) condition was between 70-100 msecs, the latter condition being of longer duration. Posner et al (1969) postulated that the retrieval of the name code from memory produced this longer RT for the NI condition. With regard to Donders assumptions, it was assumed that the NI condition included all the processes

involved in the PI condition plus the additional process of retrieving a name code from memory.

The second example is that developed by Chase and Clark (1972). Here, a simple sentence (ie Star is above plus) is presented followed by the presentation of a picture of the relationship ($\overset{*}{+}$) (or $\overset{+}{*}$, if the relationship is not positive). The subject's task was to decide if the sentence and picture both represented the same relationship. Other sentences presented included the word "below" rather than "above", or a negative form (e.g. star <u>isn't</u> above plus). Clark and Chase (1972) postulated that the word "below" required additional semantic processing compared to the word "above", suggesting that it was "linguistically marked" in the internal representation of the sentence in memory. In addition, the negative form of the sentence (where the word "isn't" was used) required additional sematic processing as it was transformed into a positive sentence and then labelled as a false form of the positive sentence in the internal representation. Thus, longer RTs would be produced when sentences included these additional processes.

Clark and Chase (1972) also assumed that like the sentence, the picture was transformed into a semantic internal representation and these two semantic representations were compared. They found that it took approximately 100 msecs additional time to process the word "below" as opposed to "above", that it took approximately 600 msecs longer to process a negative as opposed to a positive sentence and that false (a mis-match between sentence and picture) items took approximately 150 msecs longer than true items.

Again, it was assumed that the addition of such features as "below" and "isn't" introduced additional processes which left unchanged the original processes and made additive contributions to total RT.

Renewed interest in the subtractive technique also bought a renewed account of its weaknesses. For example, Pachella (1974) has described two major criticisms - the questionable validity of the assumption of pure insertion and the fact that the use of the method requires a relatively sophisticated initial conceptualisation of the processes involved in a given task. With regard to the latter Pachella (1974) writes that "such sophisticated knowledge is rarely available" (p. 47) and that the processes are more often a product of the logical or intuitive powers of the investigator than based on empirical evidence. Pachella suggests that the conclusions drawn from such data therefore have no more validity than the investigator's original conceptualisation. There is also no evidence available as to whether the assumption of pure insertion is validated in the tasks developed by Posner et al (1969) and Chase and Clark (1972). Chase (1978) questions the validity of this assumption in the task developed by Clark and Chase (1972) where the deletion and insertion of processes is required on a trial by trial basis, and Pachella (1974) has written "there is nothing in the application of the method itself, or in the data selection therefrom, that can justify this assumption" (p. 48).

A third criticism has been raised by Chase (1978) regarding the assumed additivity of the processes investigated. For example, an implicit assumption in the interpretation of RTs obtained using Posner et al's task is that the physical code must be accessed prior to accessing the name code. Thus the RT difference reflects the additional retrieval process of the name code in the NI condition. However, it is quite possible that the retrieval processes proceed in parallel for the two codes and that the RT difference is therefore due to the name code requiring longer to be accessed than the physical code. Recent

theoretical and experimental investigations by Miller (1982, 1983), McClelland (1979), Sanders (1980), Stanovich and Pachella (1977), and Taylor (1976, 1977) all describe instances where hypotheses and empirical data are suggestive of processes occuring in parallel or partial temporal overlap.

Another problem alluded to by both R.J. Sternberg (1977) and Chase (1978) is that the technique does not distinguish between alternative models of the processes involved in a particular task. Both Chase (1978) and Hunt (1980) describe another model proposed by Carpenter and Just (1975) to explain the processes used in the sentence verification task. This model differs from that proposed by Chase and Clark (1972) in that where Chase and Clark propose separate processes for linguistic marking, Carpenter and Just propose only one process.

As Hunt (1980) writes "both models can be shown to account for better than 90% of the variance in the time required to verify different types of sentences" (p. 460). R.J. Sternberg (1977) has suggested that this lack of distinguishability may in some cases be due to confounded parameter estimates, the processes identified having unidentified processes concealed within them. One can relate this to the criticism made by Pachella, mentioned previously, that information drawn from experimental data is only as good as the investigator's original conceptualisation of the task. Unidentified processes may be those not intuitively guessed at by the investigator or not logically obvious. R.J. Sternberg suggests that an unusually large parameter estimate for a particular process indicates the possibility of confounded parameters.

However, while applications of the subtractive method can and usually do raise

problems, they can also make important contributions to our understanding of cognitive processes, because even if they are eventually proved incorrect, they have encouraged further empirical research and a more sophisticated approach to theory development.

1.2.2 THE ADDITIVE FACTORS TECHNIQUE

A brief description of S. Sternberg's (1969a, 1969b) additive factors technique will be presented here as it has been influential in the area of human information processing and provides a compliment to the subtractive technique. It has also been used successfully with retarded subjects, as will be discussed in Chapter 2. Experimental applications of this method by other investigators using nonretarded subjects are also discussed later in this chapter and these require an understanding of the basic elements of the additive factors technique.

There are two ways in which the additive factors technique has been used. Firstly, as a means of identifying processing stages using RT studies per se (S. Sternberg, 1966, 1969a) where variables such as stimulus intensity and stimulus response compatibility are varied to determine which stages they are affecting in an attempt to confirm the presence of the particular stages themselves (Pachella and Miller, 1973; Sanders, 1970; S. Sternberg, 1966, 1969a). Secondly, as a means of identifying the processes involved in a memory scanning task and specifically to ascertain whether the process of scanning short-term memory is exhaustive or self-terminating in nature (S. Sternberg, 1969b).

The most significant difference between the subtractive and additive factors techniques is that the latter avoids the problem of the assumption of pure

insertion. As Chase (1978) writes "in Sternberg's revision, no stages are actually inserted or deleted" (p. 34). What Sternberg did was to vary the number of times the process (or stage) of interest occurred in a given task thus varying its duration as opposed to constructing two tasks one of which included all the processes of the other plus an additional process. Sternberg uses the word stage rather than process. Although there is some ambiguity regarding the precise relationship between a stage and a process, it is now generally assumed that a series of processes are organised into a stage, thus a stage can consist of a number of processes (Sanders, 1980). However, Sanders (1980) also writes that "the concept of a stage remains a hypothesis, the usefulness of which should be proven, as well as its possible range of application" (p. 333).

S. Sternberg proposed that the duration of a stage had certain properties, these being temporal independence both from the duration of any stages preceeding it and from the transformation taking place in that particular stage (Pachella, 1974). Thus, a stage might be concerned with scanning short-term memory. The duration of this stage would be affected by the number of items present in short-term memory but the actual operation would remain the same. These two properties have certain consequences for the interpretation of empirical data. Firstly, if two variables are found to have a statistical main effect on RT but not interact then their effect is assumed to be additive and they therefore belong to different stages. Secondly, if two variables produce a statistically interactive effect on RT then they are assumed to be affecting the same stage. Thus the extrapolation of stages rests on the pattern of interactions of variables using investigations of RT.

A number of criticisms of the additive factors method have been made (Chase, 1978; Pachella, 1974; Sanders, 1980; R.J. Sternberg, 1979). One of the major criticisms is that the method does not altogether avoid the problem of the assumption of pure insertion. Manipulating the number of times a process occurs may affect the task and the other processes in it in much the same way as the addition of an extra process might in the subtractive technique.

As Pachella (1974) writes "from a procedural point of view, the difference between the subtractive method and the additive factors method can be quite subtle" (p. 57). Similarly, the assumption of additivity held here as in the subtractive method may also be violated. It is possible to conceive of circumstances where stage duration may be influenced by the duration or output of previous stages or the function of the stage in question. For example, Stanovich and Pachella (1977) and Miller (1983) both describe experimental situations where the temporal overlap of stages has occurred. Another criticism alluded to by both Pachella (1974) and Sanders (1980) is that the lack of an interaction between two variables and therefore the postulation of additivity and two separate stages is equivalent to accepting the null hypothesis. They both suggest that caution must be exercised when this is the case because the null hypothesis can never be proved, only disproved. As Pachella concludes "the data needed in order to demonstrate true additivity requires a precision that few RT experiments obtain" (p. 57).

The task used by S. Sternberg (1969b) to demonstrate the additive factors method was a memory scanning task where subjects were presented with a set of from one to N items (usually letters or numbers and usually between one

and six items) and then a probe item. The subject's task was to indicate whether the probe item was a member of the previously presented set of items.

S. Sternberg (1969b) conducted a series of experiments where the number of variables affecting RT was varied. The variables tested included the quality of the stimulus (degraded or not degraded), the size of the memorised set, the type of response required and the relative frequency of the response type. Sternberg found that all these variables produced a main effect on RT and, in addition, that five of the possible six combinations of these variables produced no significant interactions. These results led S. Sternberg to postulate the existence of four stages, an encoding stage(where the stimulus was encoded into memory), a comparison stage (where the probe item was compared to the items in memory), a response-choice stage (where a decision was made regarding the probe item), and a response-execution stage (where the appropriate response was initiated). The stage duration that Sternberg was most interested in was that of the comparison stage. He found that the slope of the RT function which reflected this stage increased linearly with increasing set size for both positive and negative (a probe item not in the memorised set) items equally. This led Sternberg to postulate that scanning through short-term memory was exhaustive rather than self-terminating in nature, a result that may not have been intuitively predicted. (The possibly more intuitive prediction of a self-terminating scan would assume that positive items would take, on average, half the time taken by negative items and thus produce a different, less steep slope).

The intercept of the RT function was assumed to reflect all other stages i.e, encoding, response choice and response execution. This finding of an

exhaustive scan of short-term memory in the comparison stage has remained a robust one in subsequent literature. (Clifton and Tash, 1973; Sanders 1970; S. Sternberg, 1975.)

It is obvious from the preceeding review that there are advantages and disadvantages to both the subtractive and additive factors methods. Problems concerning the violation of the assumptions of pure insertion and additivity with regard to both techniques have been raised, together with other problems. However, the findings using both techniques and actual experimental applications have tended to be robust, at least in the tasks described here. It is the interpretation of results and justification of the investigators' original task conceptualisation that can, and have been, questioned in some instances. Another problem, that will be considered in greater detail subsequently, is that the processes identified in these types of investigations have tended to be task-specific. Thus they provide information concerning only a limited aspect of overall cognitive processing. Similarly, the tasks discussed here have all been primarily investigations of memory processes (short and long-term). While these processes are important to cognition there are other processes not related or only indirectly related to memory that are also of consequence (some will be discussed later in this chapter). For these and other reasons to be indicated, a shift away from the study of cognitive processes per se and towards the study of cognitive processes in relation to specific areas such as intelligence and personality differences has occurred.

1.3 INTELLIGENCE AND HUMAN INFORMATION PROCESSING

The human information processing approach has in recent years been adopted

by many interested in the study of intelligence. Previously, theories and experimental investigations of intelligence tended to depend on the factor analytic method, using this to describe and explain subjects' performance on psychometric tests. This is an indirect approach to understanding intelligence and proved of limited although influential success (Spearman, 1927; Thurstone, 1938; Guilford, 1967). Developments taking place at the time in human information processing, using the subtractive and additive factors methods appeared to show more promise, with its emphasis on time estimates of cognitive processes. The work tended to take an individual difference approach initially, because early investigators were able to compare performance on information processing type tasks with performance on existing psychometric tests. A later trend has been towards developing information processing type tasks that directly identify the cognitive processes used on specific types of problems in psychometric tests, for example, analogies, series completions and spatial transformation.

Pellegrino and Glaser (1979) have distinguished between these early and later investigations. They label the early investigators as using a cognitive correlates approach and, as mentioned above, suggest that their interest has been in comparing individuals (usually scoring at extreme levels of certain abilities on psychometric tests) on human information processing tasks. They describe the latter work as a cognitive components approach which represents a more sophisticated method of identifying the cognitive processes underlying intelligence. These latter investigations have attempted to develop tasks which represent human information processing type task-analyses of the abilities identified by psychometric tests. In other words, they are attempting to identify directly the cognitive processes involved in performing psychometric tests and therefore intelligent behaviour.

1.3.1 THE COGNITIVE CORRELATES APPROACH

The work of Hunt and his colleagues (Hunt, Frost and Lunneborg, 1973; Hunt, Lunneborg and Lewis, 1975; Hunt 1978, 1980; Lunneborg, 1977) perhaps best typifies the cognitive correlates approach. Hunt investigated subjects identified as of high or low verbal ability ("high" and "low verbals") on a number of human information processing type tasks including the letter identification task developed by Posner et al (1969), S. Sternberg's (1969b) memory scanning task and the sentence verification task developed by Clark and Chase (1972).

Hunt et al (1973) found using Posner's task, that "low verbal" subjects produced significantly longer RT differences between their Physically Identical (PI) and Name Identical (NI) scores compared with high verbal subjects of a similar overall level of intelligence. (These differences were 86msecs and 33msecs for low and high verbal subjects respectively). This led Hunt et al to suggest that high verbals were able to access a name code faster than low verbals. This result was confirmed in a study by Hunt et al (1975) where the respective differences were 63 msecs for high verbals and 88 msecs for low verbals. Hunt et al (1973) also found different scanning rates for high and low verbal subjects using S. Sternberg's memory scanning task, the high verbals producing less steep slopes with increasing items in the memory set. They suggested this was due to high verbals carrying out a faster search of short-term memory. However, this result was queried by Hunt et al (1975) because the slope values for both groups were much higher than had been found in previous experiments (S. Sternberg, 1969b). They suggest that this may be due to not using subjects who were as practiced as in previous studies. They conclude that the finding is "disturbing".

Chiang and Atkinson (1976) also investigated ability differences using S. Sternberg's memory scanning task. They failed to find any slope differences between subjects of differing ability levels. A further study by Keating and Bobbitt (1978) investigated children of differing ages and abilities (9, 13, and 17 years, with average and above average ability at each age level) using the Posner letter identification task, Sternberg's memory scanning task and measures of simple and two-choice RT. Subjects were selected on the basis of their performance on the Standard Progressive Matrices test. This psychometric test is considered to be a measure of general intelligence or "g" rather than a measure of specific abilities. Those scoring highest and lowest on the above test at each age level were then presented with the three above tasks and the Advanced Form of the Ravens Progressive Matrices. Keating and Bobbitt obtained significant interactions between age and the RT and Posner tasks and between ability and the Posner and memory scanning tasks. Thus younger and less able subjects produced larger NI-PI differences on the Posner task, than older and more able subjects. In addition, less able subjects produced steeper slopes than more able subjects on the memory scanning task. The lack of an interaction between age and the memory scanning task was surprising as previous developmental studies (Herman and Landis, 1977; Naus and Ornstein, 1977) had obtained results suggesting slope differences with age. Keating and Bobbitt suggest this may be due to task differences but concede that the result is puzzling.

Hunt et al (1975) also investigated the performance of high and low verbals (with an overall comparable level of intelligence) using the sentence verification task developed by Clark and Chase (1972). As previously described, the theoretical basis of the task is that subjects convert the sentence (star is above plus) into an internal linguistic representation and then

do the same with the picture (*+). Thus one would predict that high verbal subjects would perform this task more quickly. Hunt et al found this was indeed the case. They also found that low verbals were differentially affected when the sentence involved a negation (Star isn't above plus) which lead them to suggest that the high verbals were better able to manipulate linguistic material of greater complexity than the low verbals.

Thus, while there are inconsistencies with regard to some findings (S. Sternberg's memory scaning task, for example) there does appear to be evidence in favour of process differences between individuals of differing ages and ability levels in a qualitative as well as quantitive sense. In order to determine whether these differences are worthy of further investigation some of the above authors have attempted to correlate their subjects' performance on information processing type tasks with their scores on psychometric tests (Chiang and Atkinson, 1976; Hunt, 1978; Keating and Bobbitt, 1978). However, these correlations have in general been disappointing. Chiang and Atkinson failed to obtain any significant correlations, while Keating and Bobbitt found the information processing measures accounted for only 15% of the variance on the ability scores, although this did amount to a significant percentage of variance explained. Hunt (1978) writes that in a number of studies by himself and his colleagues, a correlation of about-.30 has been obtained between the NI-PI difference and measures of verbal ability. He further writes " if this correlation accounts for only 10% of the variance, one is justified in wondering whether the effect is of sufficient magnitude to be of interest" (p. 113).

Lunneborg (1977) has obtained similar results in a study comparing subjects performance on two-choice RT tasks (plus other tasks) with psychometric

ability measures, the latter including verbal comprehension, numerical reasoning, hidden figures and Ravens Progressive Matrices tests. Lunneborg found small significant negative correlations between the psychometric and choice RT tasks for one high school group, but not for a second high school group and a group of university subjects. Lunneborg suggested that these findings may have been due to two factors. Firstly, the university students represented a limited range of intellectual ability and secondly, the second high school group was of higher intellectual ability than the first high school group. This latter suggestion was based on the fact that the second high school group obtained very similar scores, on the psychometric tests used, to those obtained by the university group. The first high school group scored lower than both these groups on the psychometric tests. For example, the university group scored 27.5 on a measure of numerical ability, the second high school group, 26.2 and the first high school group 15.8. One contributing factor to this difference may be the selection procedures used to obtain subjects. The first high school group was obtained via a community job line facility while the university and second high school group were obtained from those who had completed the Washington Pre-College (WPC) Testing battery.

This led Lunneborg to suggest that the use of individuals of high and approximately equivalent ability will mask any process differences that might exist. He concludes "great care must be given to the definition of the subject population" (Lunneborg, 1977, p. 329). This is a statement reiterated by Hunt (1980). He points out that while the NI-PI difference between low and high verbal subjects was statistically significant, it was relatively small, "about 30 msecs in a task in which the mean NI condition RT (was) between 550 and 600 msecs"(p. 451). Hunt (1980) further suggests that a much stronger relationship

between verbal ability and information processing type tasks can be found when "groups that span the whole range of mental competence"(p. 452) are used. This type of approach, however, can lead to other problems as discussed in the next chapter.

Four conclusions can be drawn from the previous discussion. Firstly, while individual differences in ability can be identified using information processing type tasks, they are no better and are sometimes worse than psychometric tests at revealing these differences between individuals or explaining them. This may be because they sample a narrower range of cognitive ability than do psychometric tests. Secondly, and related to the first, correlations between psychometic tests and information processing tasks are, while sometimes statistically significant, usually low and explain only small amounts of variance. This may be due to the fact that the two methods are not measuring the same processes. Psychometric tests were, in the main, developed from and for clinical application, were not theoretically based and were designed to measure more general abilities. Information processing tasks were often based on a model, specific to a particular area of research (e.g. long or short-term memory) and were dependent on the investigator's inductive suppositions. As Hunt (1978) has written "process measurements are defined relative to a particular model. If information processing theories are to be applied to the analysis of individual differences, we must know which models apply to which individuals" (p. 124). Thirdly, information processing type investigations tend to be task-specific, they do not identify general cognitive processes. What is made is a comparison between subjects' performance on psychometric tests and the information processing tasks available, both of which were developed to investigate different abilities or processes in different areas. Finally, significant correlations appear to

be far more likely if groups representing extreme ranges on the intelligence continuum are used.

1.3.2 COGNITIVE COMPONENTS APPROACH

Pellegrino and Glaser (1979) have suggested that a solution to some of the above problems is a direct analysis of the cognitive processes used in tasks designed to assess mental abilities. They call this the cognitive components approach and suggest that this type of approach has already been instigated by some investigators, such as, Cooper (1982), Mulholland, Pellegrino and Glaser (1980), Shepard (1975), and R.J. Sternberg (1977a, 1977b).

An extensive series of experiments investigating the processes underlying spatial transformations has been conducted by Shepard and his colleagues (Cooper and Shepard, 1973; Metzler and Shepard, 1974; Shepard, 1975). The task used involved the presentation of two stimuli, the second being either identical to the first (the standard) but in a rotated form or similar but not identical to the standard (e.g. a mirror image). The subject's task was to decide whether the test stimulus was a rotated image of the standard or a completely different image. Shepard and his colleagues major finding was that mean RT was a linear function of the number of degrees of angular disparity between the standard and test stimuli. They suggested this was due to subjects performing an internal rotation of the standard to the degree of angular disparity of the test stimulus and then comparing the two. Thus the slope of the RT function would increase as the angular disparity of the two items increased. The intercept was postulated to reflect encoding and decision processes. Shepard and his colleagues also found that RT was influenced by the type of stimuli used, for example, whether the stimuli were two (alphanumeric) or three-dimensional.

A difference in both intercept and slope parameters for two and three-dimensional stimuli was found. Shepard and his colleagues suggested that the difference in intercept reflected the greater time spent in encoding the more complex three-dimensional figures. It might also be suggested that alphanumeric characters are largely overlearned stimuli and therefore more quickly accessed in long-term memory, thus requiring less encoding time. The steeper slope for three-dimensional figures lead Shepard and his colleagues to suggest that the rotation and decomposition processes were different for three-dimensional and alphanumeric stimuli. They describe two experiments by Just and Carpenter, (1976; Carpenter and Just, 1978) in support of their view. Just and Carpenter examined eye movements in the performance of three-dimensional rotation tasks. From the eye movement and latency data, Just and Carpenter were able to identify certain subprocesses within the rotation process. These included an initial search process, to identify equivalent elements in the two presented stimuli, followed by transformation and comparison of one particular part of the stimuli, then a confirmation of the remaining parts of the stimuli to see that they followed suit. Each of these subprocesses evidenced general monotonic increases in RT as a function of the degree of angular disparity and thus contributed to the overall slope of the RT function.

Mulholland, Pellegrino and Glaser (1980) have investigated the processes involved in geometric analogy solution. Mulholland et al examined analogies from psychometric tests and attempted to identify the elements that contributed to item difficulty. They found two factors to be influential , the number of elements in each analogy term and the number of transformations taking place from each element of each analogy term to the next. This lead them to suggest that when solving geometric analogies, subjects performed at

least two processes, the encoding and decomposition of analogy terms into their constituent elements (e.g. circles, squares, triangles, lines) and the discovery of the transformation rules relating pairs of analogy terms (i.e. A to B and C to D) (e.g. the addition or subtraction of elements, the rotation or reflection of elements, size and shading changes). Mulholland et al then constructed a set of geometric analogies which systematically varied the number of elements included and the number of transformations between analogy terms with regard to these elements. They found that RT increased serially both according to the number of elements and the number of transformations. In addition, the number of transformations contributed more to item difficulty (and therefore RT) than the number of elements. Using a simple linear model where the numbers of elements and transformations were additive (RT = T + E where T = number of transformations and E = number of elements) 95% of the variance was accounted for. A slightly more complex model (RT = T + E + TE) was found to account for 97% of the variance, a statistical improvement on the simple additive model. Mulholland et al suggested that this model provided a better fit to the data because of an interaction between item difficulty (as measured by the number of transformations) and the limited capacity of the processing system (i.e. short-term memory). As the number of elements and transformations increased so did the load on short-term memory. Mulholland et al suggested that when this occurred, subjects spent more time "updating and maintaining the accumulated contents of working memory"(Mulholland, Pellegrino and Glaser, 1980, p. 265), in addition to continuing to extract the elements and transformations in the remaining analogy terms.

Pellegrino and his colleagues have also endeavoured to conduct a similar analysis of verbal analogies. However, a task-analysis here is more

problematic due to the ambiguity of verbal items. It is difficult to specify systematically (i.e. numerically) the elements and transformations required in the solution of verbal analogies. Pellegrino and Glaser (1979) in attempting to reduce this ambiguity, have suggested that the majority of verbal analogies can be classified according to a fairly limited set of semantic relations or features such as class membership, location, function, property, conversion, and order in time.

Pellegrino and Glaser (1980) constructed a set of analogies which varied systematically according to these semantic relations and found that RT depended on the "congruence" between these semantic features in the AB and CD analogy terms. RT also varied according to the particular semantic relationship presented in each analogy, and to the degree of constraints on the set of possible answers. High constraint, occured when the first three terms elicited only one possible D term, therefore making the analogy easier to solve. Conversely, low constraint occured when the first three terms elicited a number of possible D terms, thus making the analogy more difficult to solve. Pellegrino and Glaser (1980) suggested that with items of high constraint, subjects used a working-forward strategy which included a scan of the first three terms and then a simple search of the answer options provided. With items of low constraint, a working-backwards strategy was used. Here, the subjects, after a brief scan of the first three terms, then used the answer options provided to guide the extraction of the most appropriate relationship.

It is difficult as yet to evaluate the success of the cognitive components approach as most of the relevant research is still ongoing. However, certain preliminary conclusions can be made. Firstly, the approach does appear to

have the potential to identify the cognitive processes involved in tasks directly developed from psychometric tasks. Secondly, this approach highlights as Pellegrino and Glaser (1979) have suggested, the importance of the distinction between content and process, a distinction especially important with regard to mentally retarded subjects, as will be discussed in Chapter 2. Content refers to the informational form of the stimuli and the knowledge it accesses in the individual. For example, alphanumeric and geometric stimuli access different knowledge bases in long-term memory. Similarly, specific alphanumeric or geometric stimuli may be more easily accessed than other stimuli of the same type. Process refers to the actual processes used. As has been demonstrated in the studies by Shepard and his colleagues, with two and three-dimensional stimuli and Pellegrino and Glaser, (1979; Mulholland et al, 1980; Pellegrino and Glaser, 1980) in their studies of geometric and verbal analogies, there is an interaction between content and process, the informational content of the stimuli affecting the subprocesses used. It is also probable that content, in addition to process factors, contributes to individual differences in performance in that the informational form of the stimuli used may access different knowledge in each individual. What is now important is to empirically investigate whether these cognitive processes are task-general as opposed to task specific and to ascertain the extent of individual differences in their use.

1.4 STRATEGIES, INTELLIGENCE AND INDIVIDUAL DIFFERENCES

Some of the more recent investigations into the use of strategic behaviour will be presented here, for this area has relevance to information processing investigations of intelligent behaviour and the explanation of individual

differences. The relevance of these points will be considered in detail with mentally retarded subjects in the following chapter, where the work of Campione and Brown and their colleagues (Campione, Brown and Murphy, 1977; Brown and Barclay, 1979; Campione, Brown and Ferrara, 1982) and Belmont and Butterfield, (1977; Butterfield and Belmont 1977; Belmont, Butterfield and Borkowski, 1978) will be presented. These authors have consistently found that retarded subjects do not spontaneously use task-specific strategies or evidence a general predisposition to be strategic in the same way that nonretarded adults do.

1.4.1 INDIVIDUAL DIFFERENCES AND STRATEGY USAGE

Individual differences in strategy usage have been examined by Cooper and her colleagues (Cooper, 1976, 1980a, 1980b; Cooper and Regan, 1982; Cooper and Podgorny, 1976) using a visual comparison task. Subjects were required to discover whether two successively presented random polygons were the same or different in shape. Different items were systematically rated in their similarity to the standard. Two different patterns of RT, corresponding to two identifiable groups of subjects were found. For the larger group, "different" RTs decreased as the degree of dissimilarity between standard and test items increased, while "same" RTs were faster than the slowest "different" RTs but slower than the fastest "different" RTs. For the smaller group, "different" RTs were unaffected by the degree of dissimilarity between the standard and the test shapes and average "same" RTs were faster than average "different" RTs. The mean RTs of the latter group were also significantly faster than those of the former group. However, error rates decreased monotonically with increasing dissimilarity in both groups.

The differences between the two groups RTs led Cooper and her colleagues to

suggest that the groups were using different strategies to perform the task and therefore different processes. They suggested that the former group were using an "analytic-comparison strategy" comparing serially the features of the test item with that of the mental representation of the standard item. Thus the fewer features the two items had in common, the sooner, on average, the two items were identified as different. The latter group were using a more "holistic-comparison strategy", performing a "parallel, template like comparison" to identify the degree of sameness of the two items (Cooper and Regan, 1982, p. 154). Thus, "same" RTs would be faster than "different" RTs and "different" RTs would be unaffected by degree of dissimilarity because differences would be identified by "default" (Cooper & Regan 1982).

The importance of these points can be demonstrated by consideration of a study by MacLeod, Hunt and Matthews (1978). They were interested in testing the validity of the one parameter model proposed by Carpenter and Just (1975) concerning the sentence verification task developed by Clark and Chase (1972). The task as described previously, involved subjects being presented with a simple sentence to comprehend (Star is above plus) and then a picture of the sentence ( or) and deciding whether the relationship described by both sentence and picture were identical. The task varied from that previously used in that subjects were given as much time as they required during the sentence comprehension phase, resulting in a RT MacLeod et al labelled as comprehension time. Subjects, as in previous experiments were also given as much time as they required to make a decision in the second phase of the experiment after presentation of the picture. MacLeod et al called this RT, verification time. MacLeod et al fitted the mean verification RTs of all subjects to the model proposed by Carpenter and Just (1975) and

found that 89.4% of the variance was accounted for. This, while impressive, was not as high as expected given the results of previous research (Carpenter and Just, 1975; Clark and Chase, 1972; Hunt, 1978; Hunt and Lunneborg and Lewis, 1975) where the usual amount of variance accounted for wasbetween 95 and 99%. This result prompted MacLeod et al to reanalyse the data, producing models fit for each subject separately. From this analysis they identified two groups of subjects, the larger group showing a good fit to the model, similar in magnitude to previous experiments (97.8% of the variance accounted for) and a smaller group showing a poor fit. MacLeod et al found significant main effects for negation and linguistic markedness on the verification RTs of the well fit group, consistent with the use of a linguistic strategy. This was not the case for the poorly fit group, where no significant effects of negation or markedness on these subjects' verification RTs were found. This led MacLeod et al to suggest that, for these subjects, negation and markedness had been dealt with prior to the verification stage. Examination of the two groups' comprehension and verification RTs confirmed this suggestion. The poorly fitted subjects produced significantly longer comprehension RTs but significantly shorter verification RTs than the well fit group (comprehension RTs of 2579 and 1652 secs and verification RTs of 651 and 1210 secs were obtained for the former and latter groups, respectively).

MacLeod et al concluded that the two groups were using different types of strategies to solve the task. The larger, well fit group was using a linguistic strategy, where the sentence was translated into its propositional structure during comprehension time. During verification time, the picture was first encoded and then translated into the propositional structure of the sentence it would be, thus "the burden of translation", as Macleod et al write, was located

here. The smaller group, Macleod et al suggested was using a pictorial strategy, where the sentence was comprehended and translated into a pictorial image during the comprehension stage, placing the burden of translation here for this group. The verification stage consisted of a simple comparison between the pictorial image of the sentence and the physically present pictorial image.

Macleod et al also compared the scores obtained by both groups on the verbal and spatial subscales of the Washington Pre-College Test (WPC), a test they suggest is similar to the group administered Scholastic Aptitude Test (SAT). Their hypothesis was that choice of strategy could be predicted by psychometric ability. Specifically, McLeod et al postulated that high negative correlations between the well fit, linguistic strategy users' verbal ability scores and their verification RTs would be expected. Conversely, high negative correlations could be expected between the poorly fit, pictorial strategy users verification RTs and their spatial ability scores. These predictions could be made since high verbal ability should be related to the same processes as those occuring in the verification RTs of the linguistic strategy users, while spatial ability will be related to the processes occuring in the verification RTs of pictorial strategy users.

The mean verification RTs of the well fit group were significantly negatively correlated to their verbal subscore on the WPC (-.52), while the poorly fit group showed a significant negative correlation between their spatial subscores and verification RTs (-.68). However, while these results are suggestive of a relationship between psychometric ability and the processes identified in human information processing type tasks, they should be treated

with caution as Macleod et al also obtained negative although non-significant correlations between the well fit groups' verification RTs and their spatial ability scores (-.32) and the poorly fit groups' verification RTs and their verbal ability scores (-.33).

The results of this study strongly reinforce the importance of the experimenter's preconceived model of task solution and the influence this has on the analysis of experimental data. The sentence verification task was widely assumed to be a measure of linguistic processing with the pictorial stimuli being converted to a linguistic internal representation and the two linguistic representations then being compared. While the validity of these models as explanations of linguistic processing is not questioned, the importance and difficulty of designing tasks that adequately reflect the investigator's aims are highlighted.

1.4.2 INDIVIDUAL DIFFERENCES AND FLEXIBILITY OF STRATEGY USAGE

From both preceeding studies it can be seen that investigations of strategy usage are useful for identifying process differences among individuals. A related question to that of individual differences in strategy usage is the flexibility of that usage. Can subjects who would spontaneously use a particular strategy, successfully adopt an alternative strategy if so instructed or trained to do so? This type of research may begin to explain why different individuals use different strategies.

This question has been addressed by Mathews, Hunt and Macleod (1980). Subjects were of either high or low spatial ability but all had the same level of verbal ability. During the first session, subjects were free to use the strategy

of their choice to solve the sentence verification task (Clark and Chase, 1972). During the second session, however, half the subjects in each spatial group (high or low spatial scores on the WPC) were instructed in the use of a linguistic strategy while the other half were trained to use a pictorial strategy. In the third session the, instructions for these groups were reversed, those having received instruction in the use of a linguistic strategy now being instructed to use a pictorial strategy and vice versa. From the first session, 21 subjects were identified (out of a total of 32) as using a linguistic strategy while the remaining 11 subjects' data conformed to that of a pictorial strategy. Thus, unlike Macleod et al (1978), no significant relationship between the use of a pictorial strategy and high spatial ability was found. Six of the 16 "high spatial" and five of the "low spatial" subjects constituted the group identified as using a pictorial strategy. Mathews et al (1980) suggested that this was due to all subjects being university students and therefore of above average verbal ability in regard to the general population and thus "biased toward (the) choice of verbal strategies" (p. 540).

With regard to the adoption of a linguistic strategy after training (Sessions two and three combined), no significant differences between high and low spatial groups were found. All subjects appeared able to adopt a linguistic strategy and its use by instructed subjects was indistinguisable from its use by those who spontaneously adopted it in the first session. This result could, however, be partially due to the fact that approximately two thirds of the subjects spontaneously adopted a linguistic strategy. It would be of interest to obtain results from subjects with high spatial and low verbal scores.

This flexibility of strategy usage did not, however, extend to all subjects when

they were instructed to adopt a pictorial strategy. Specifically, Mathews et al found six subjects who failed to adopt the pictorial strategy, and not surprisingly, these six subjects had previously spontaneously adopted a linguistic strategy. However, more difficult to explain was the fact that this subgroup consisted of four "low spatials" and two "high spatials". This inconsistency, Mathews et al suggested, may have been due to high and low spatials being identified by their scores on the WPC collected more than two years previously. They therefore reassessed the spatial ability of their subjects using the Three Dimensional Spatial Test (from the Multiple Aptitude Test Battery) designating the 16 subjects scoring highest on this test as the "high spatial" group and the 16 remaining subjects (which included the six previously mentioned) as the "low spatial" group. Reanalysis of linguistic and pictorial strategies adopted by high and low spatial groups identified on this measure indicated that while both groups were equally able to adopt a linguistic strategy, there were differences between the groups in both pictorial strategy use and acquisition. "Low spatial" subjects spent significantly less time on the comprehension phase of the task and significantly more time on the verification phase, results which were consistent with the use of a linguistic strategy, even after instruction to use a pictorial strategy. In addition, "low spatials" showed significant improvement across blocks in their use of the pictorial strategy, indicating slower acquisition. Thus while Matthews et al (1980) concluded that with adequate instruction and practice subjects can learn and change strategies for solving a simple comprehension task they also acknowledged that at least in this experiment, this statement was truer for linguistic as opposed to pictorial strategy adoption. As mentioned previously this result may have been altered if low and high verbal ability subjects had been used.

R.J. Sternberg and Weil (1980) using linear syllogisms (X is taller than Y, Y is taller than Z, who is tallest?) hypothesised that the strategies subjects used to solve these problems would be related to their verbal and spatial abilities. Subjects were identified as using either a linguistic or spatial strategy. R.J. Sternberg and Weil found that the RTs of those using a linguistic strategy correlated significantly with their verbal ability but not spatial ability scores (-.76 and -.28 respectively) while the reverse was true of the RTs for those using a spatial strategy (-.08 and -.61 for verbal ability and spatial ability scores respectively). Considering the results obtained by Macleod et al (1978) in this area, however, further empirical research is required before a direct relationship between scores on psychometric tests and strategy usage can be concluded.

A study by Bethell-Fox, Lohman and Snow (1984) is also relevant here. They were interested in examining strategy usage both within and between individuals doing the same task rather than just across individuals as in previous experiments. Bethell-Fox et al examined the performance of subjects on geometric analogies using a forced-choice format, providing either two or four response alternatives. The analogies were also presented in two conditions. In the 0 cue condition, no analogy terms were presented in the first half of the trial while in the 2 cue condition the A and B terms were presented in the first half of the trial. The full analogy was presented in the second half of the trial in both conditions. Bethell-Fox et al made use of R.J. Sternberg's (1977) models of analogical reasoning and also examined both within and between subject differences in strategy usage and eye movement data. Bethal-Fox et al introduced two new processes, spartial inference and spatial application, in addition to the ones described by Sternberg, to take into

account the longer solution times obtained when spatial transformations were included in the geometric analogies. They suggested that Sternberg's models conformed to a constructive-matching type strategy where a mental image of the correct D term is constructed from the processing of the A,B and C terms and is then compared to the response alternatives provided. They contrasted this with a response-elimination strategy which required comparing successive features of the correct D term with the answer alternatives provided in a "back-and-forth" type strategy.

Bethell-fox et al found all models of analogical reasoning accounted for a large percentage of the variance, approximately 91% for two response alternative items, and 94% for four response alternative items. Models I and II were slightly favoured in the latter case while Models II to IV were favoured in the former. Model I is an exhaustive model where all elements in each analogy term are processed exhaustively, while Models II to IV include increasing numbers of self-terminating processes. Thus, only as many elements will be processed as are required to obtain a correct solution. These models are essential to R.J. Sternberg's componential method and thus will be described in detail in Chapter 3. Bethell and Fox et al favoured Model I and Model IM (a variant of the former) because each was as good as the self-terminating models in accouting for the variance and was less complex in terms of extraction of the relevant processes. However, of greater interest was Bethell-Fox et al's conclusion that use of particular models can vary both within and between subjects. They found after individual difference analysis, that a large percentage of the variance was accounted for by Model IM, the model they favoured, for some subjects but not for others. In addition, evidence was found that some processes were used on some items but not on others. For example, spatial inference and application were only used for

those analogies which included spatial transformations and another process, justification, was only used when there was some ambiguity concerning the correct response alternative (the justification process consisted of a check that the chosen alternative was the best of those available). The more difficult analogies which required these extra processes also tended to produce use of the response-elimination strategy while the simpler items were solved using the constructive-matching strategy. Bethell-Fox et al suggested this might be due to an increased load on short-term memory. The response-elimination strategy would make less use of memory than the constructive-matching strategy because an image of the correct D term would need to be constructed from processing of the A, B and C terms. Finally, Bethell-Fox et al's analysis of eye movements during analogy solution suggested that subjects looked back to the A and B terms or just the B term on the more difficult items only. They also found evidence that subjects scoring higher on measures of fluid ability (i.e. the Ravens Progressive Matrices, Memory-for-Design, Paper Folding and Copying) were more likely to use a constructive-matching strategy rather than a response-elimination strategy, the latter being used by subjects scoring lower on measures of fluid ability.

Thus, Bethell-Fox et al concluded that using one model to explain all subjects and all methods of processing and using the same set of processes to explain all types of analogical reasoning is too limited. They suggested that there were individual differences in the use of certain strategies of processing and in the processes used for certain analogies.

Finally, R.J. Sternberg and Ketron (1982) using the componential method found their subjects could be trained to use either a fully exhaustive, fully

self-terminating or mixed (partially exhaustive, partially self-terminating) strategy to solve figural analogies with integral or separable elements (Garner, 1974). Integral elements are those which are essential to the figure in that they can not be removed without altering the nature of the figure (i.e. height or sex). Separable elements however, are those that can be removed; they are not essential to the figure (i.e. hat, gloves etc).

Results revealed that subjects could be trained to adopt different processing strategies if integral figural analogies were used. However, this was not the case for separable figural analogies, all subjects using a self-terminating model, irrespective of the type of training they received. This result, however, contrasted with the actual verbal reports of the subjects who said that they were using the strategy they were trained to use, a striking finding and one referred to again in Chapter 3 with regard to training studies using children and retarded young adults. In Sternberg and Ketron's experiment, a control group of untrained subjects were found to spontaneously use a fully self-terminating model for both integral and separable analogies, suggesting that this is the strategy adopted by individuals in uninstructed situations. Sternberg and Ketron also found that latencies (RTs) for those trained to use the fully self-terminating model were fastest, followed by the mixed model and finally the fully exhaustive model also suggesting that the fully self-terminating model is that most easily used. This is most probably due to this model placing the least load on memory and therefore being easier to carry out. This model also produced the lowest error rates. Again, this may be due to less load being placed on memory since the greater the load on memory the more likely an error is to be made. The failure of subjects to adopt the instructed strategy in separable analogies (even though they were unaware of their failure) and in contrast, the subjects' success in

adopting the instructed strategy when integral analogies were used, led Sternberg and Ketron (1982) to conclude that "success of training appears to interact with the nature of the stimulus to be included in the analogy terms"(p. 411)".

The above type of result can be related to an observation made by Cooper (in Cooper & Regan, 1982) who suggested that "in the visual comparison task subjects could not modify their natural strategies by mere instruction about the nature of the alternative strategy." (p. 155). Cooper (1980a, 1980b) therefore attempted to alter strategy choice by structuring the task in such a way that certain strategies would be favoured. Subjects were presented with three different types of stimuli in a visual comparison task. Firstly, the usual task stimuli (i.e. polygons) were used, with subjects having to identify the approximate location of the different feature. Secondly, multidimensional stimuli (two alternative shapes of two alternative sizes and colours) were used and thirdly, stimuli consisting of photographs of human faces varying in their rated similarity. Cooper hypothesised that the use of an analytic strategy was more suitable in the first two tasks, while in the third, a holistic strategy would be more applicable. She found that some spontaneously holistic strategy users adopted an analytic strategy when presented with the first task, because the deletion of differing features was consistent with an analytic but not holistic strategy, that all subjects adopted an analytic strategy when presented with the second task, presumably because the stimuli were composed of separable dimensions which couldn't be processed using a holistic strategy and, finally that almost all subjects adopted a holistic strategy in the final task because the features of faces were difficult to analyse in terms of their component parts (Carey and Diamond, 1977). In addition a contributing factor in this last task may be the fact that the

human face is very familiar and therefore readily available in long-term memory as a whole and does not need to be decomposed into separate features to be analysed.

Thus, again with this study as in those previously discussed, a degree of flexibility in strategy usage was found. However this flexibility appears to be limited by both the ability level of the individual and the type of stimuli used. As Hunt (1980) writes, given Mathews et al's study that university level subjects could be instructed to use a strategy different from the one they typically used in a sentence verification task "whether or not less talented subjects would display the same flexibility in strategy choice is an open question" (p. 464). For example, it is difficult to predict the degree of flexibility likely to be evidenced by retarded subjects given the finding that they are generally nonstrategic (Belmont and Butterfield, 1977; Campione and Brown, 1977; Cavanaugh and Borkowski, 1979).

1.5 CONCLUSION

The following conclusions can be drawn from the information presented in this chapter. Firstly, that if used judiciously, the subtractive technique has great flexibility of application and can provide important information about cognitive processes. Three applications of the subtractive technique were described (the letter identification task, the sentence verification task, and the memory scanning task), each of which has provided empirical evidence of particular cognitive processes and each of which has been used to investigate a number of different though related hypotheses. This latter statement is especially true of the Clark and Chase (1972) sentence verification task.

Secondly, the technique has also provided information regarding individual differences in intelligence. While a direct correspondence between psychometric test scores and performance on human information processing tasks may be questioned, the existence of a trend toward comparability is suggested, especially where a wide range of intellectual abilities is used. Further experimentation is required, using such tasks as those developed by R.J. Sternberg (1977a, 1977b), Mulholland et al (1980) and Cooper (1980a, 1980b) before the full extent of the relationship can be known.

Thirdly, applications of the technique to the investigation of strategy differences are also important as these differences appear to indicate both differences in general ability (Macleod et al, 1978; Mattews et al, 1980; R.J. Sternberg and Weil, 1980) and individual differences in the cognitive processes used for performing a given task that are not related to ability differences (Bethall-Fox, Lohman and Snow, 1984; Cooper, 1980a; R.J. Sternberg and Ketron, 1982.)

One major problem with the approach is the influence the experimenter's conceptualisation of the processes involved can have. Thus, as previous discussions of Clark and Chase (1972) and Carpenter and Just's (1975) models of linguistic processing suggest, there is often more than one explanation for obtained experimental data. However, an awareness of this problem and numerous experimental replications by other investigators of the results obtained, may help to overcome this problem.

An attempt to answer some of the questions raised in this chapter is made in this thesis. The task-analytic, componential method developed by R.J.

Sternberg is investigated. R.J. Sternberg's approach is similar to that of Mulholland et al (1980) in that he attempted to study analogical reasoning by systematically varying the number of transformations occuring between the A and B and A and C analogy terms. Sternberg also uses the subtractive technique to construct subtasks that he hypothesises reflect successively less processes but do not alter the actual processes used. Sternberg predicts performance with regard to four models or strategies which vary according to whether the processes they contain are fully exhaustive, fully self-terminating or partially exhaustive and partially self-terminating. Thus, he postulates a detailed initial conceptualisation of the processes actually involved in analogical reasoning. In addition, this thesis investigates nonretarded and retarded performance on the analogical reasoning task to examine whether the models of processing used vary according to ability level, and if indeed Sternberg's conceptualisation of the processes involved in analogical reasoning can be applied to retarded individuals. The following chapter is concerned with a discussion of some of the pertinent findings obtained using the information processing approach with retarded compared to nonretarded subjects.

CHAPTER 2

HUMAN INFORMATION PROCESSING AND MENTAL RETARDATION

2.1 INTRODUCTION

As mentioned in Chapter 1, the human information processing approach has been influential in the investigation of mentally retarded invdividuals' cognitive processes. This chapter therefore, presents a review of some of the relevant findings in this area. It is divided into three sections. Firstly, the findings from RT studies where RT has been used as a dependent variable (for example, S. Sternberg's memory scanning task), secondly, some findings related to memory deficits in the retarded and particularly to the existence of a short-term memory deficit, and finally studies which have investigated the use of strategies in retarded subjects and the effects of strategy training.

The definition of mental retardation adopted by the American Association of Mental Deficiency is an individual scoring two or more standard deviations below the mean on a standard intelligence test and in addition, being low on adaptive behaviour or social competence. As Ellis (1978) points out, however "these criteria define a heterogeneous group, behaviourally and biologically" (p. 41). It is, therefore, usual in experimental studies using cognitive tasks to use retarded sugjects who are classified as either mildly or moderately retarded (IQ score range 70-65 or 55-40 respectively) or to use groups whose mean IQ score is approximately 70. In addition, subjects should be classified as familiarly retarded, that is have no known organic cause of mental retardation and also have no associated sensory or other deficits. In this way, it is hoped that some of the heterogeneity of the group is avoided.

2.2 MENTAL RETARDATION AND REACTION TIME

2.2.1 SIMPLE AND CHOICE REACTION TIME STUDIES

RT studies have been used extensively to study the cognitive processes of the mentally retarded. Baumeister and Kellas (1968) present a succinct review of the early research in this area. In simple RT studies, subjects (both nonretarded and retarded) would usually be presented with a warning signal to indicate that a stimulus was about to be presented, followed by a short time interval and then the presentation of the stimulus (usually either in visual or auditory form). The subject would then make a response to this stimulus, usually by lifting a finger off a home key or pressing a key. Simple RT was the time elapsing between the onset of the stimulus and the making of a response. In measures of choice RT, the number of stimulus and/or response choices would be increased and the effect these changes had on RT would be examined. Baumeister and Kellas drew a number of conclusions from the studies they reviewed. These included 1) that retarded subjects produced longer RTs than nonretarded subjects for both simple and choice RT tasks; 2) that retarded subjects were more affected by changes in the intensity of the stimulus than nonretarded subjects. As the intensity of the stimulus was increased simple RTs for these subjects were decreased; 3) that retarded subjects were more effected by changes in response complexity. As response complexity increased so did the retarded subjects RTs. Both nonretarded and retarded groups were affected by increases in stimulus complexity; 4) that temporal factors such as the length of the interval between the warning signal and the stimulus, the length of the warning signal and the psychological refractory period (PRP, the length of the time between two successive stimuli)

affected retarded subjects RTs more than nonretarded subjects. With regard to the PRP, when this time was short the RT to the second stimulus was relatively slower because the subject appeared to require a certain period of time in which to recover from the previous stimulus; finally, 5) that the variability of RTs was greater for the retarded subjects. Baumeister and Kellas suggested that retarded subjects' RTs were spread over a far wider range and were more positively skewed. Some retarded subjects produced RTs that were as fast as those produced by nonretarded subjects but they could not maintain these faster speeds over time. This was evident both in individual and group data.

Nettelbeck (1980) and Nettelbeck and Brewer (1981) present some of the findings from more recent studies. While the conclusions drawn by Baumeister and Kellas (1968) are corroborated, more recent findings, especially with regard to choice RT are discussed. These choice RT studies highlight the importance of stimulus - response translation difficulties experienced by retarded subjects. These difficulties become evident when changes in the correspondence or compatibility of the stimuli and response equivalents are made. Nettelbeck and Brewer have conducted a series of RT experiments which highlight this point (Brewer, 1978; Brewer and Nettelbeck, 1977; Nettelbeck and Brewer, 1976). Nettelbeck and Brewer used an eight-choice RT task, the stimuli consisting of eight lights set in a horizontal array and the response apparatus of eight keys also set in a horizontal array. In one experiment, the stimulus array was moved from directly in front of the subject to 2.8m away (but still facing the subject) (Nettelbeck and Brewer, 1976). In another experiment, a central line that separated the stimulus array into two groups of four lights was removed (Brewer and Nettelbeck, 1977). Nettelbeck and Brewer found that mildly retarded subjects were significantly more affected by these two alterations, in that their RTs became considerably

slower, than the nonretarded subjects. They also found that retarded subjects RTs for their middle and ring fingers were significantly slower than those for their index and little fingers (the nonretarded subjects showed a similar but much less marked result). Nettelbeck and Brewer suggested that this was due to the subjects having difficulty locating the stimuli corresponding to the middle and ring fingers in the stimulus array. This suggestion gained support from the finding that in the experiment where the central line was removed RTs to the central lights (those responded to using the index fingers of each hand) were also significantly increased for the retarded subjects. Nettelbeck and Brewer suggested that these findings were consistent with the retarded subjects experiencing difficulties in translating a stimulus into the appropriate response. A study by Brewer (1978) gave considerable support to this. He presented nonretarded and retarded subjects with two conditions in which to perform an eight-choice RT task. In one condition, the typical choice RT apparatus were used, the eight stimulus lights being adjacent to the eight response keys. In the other condition, no lights were used, the stimuli consisting of direct stimulation to the fingers resting on the response keys. In this way translation of the stimulus into an appropriate response was drastically reduced. Brewer found that the difference between the two groups was reduced from 170 msecs in the first condition to 40 msecs in the second condition. He suggested that this remaining difference was probably due to peripheral motor control factors but that the major difference was in the central translation processes.

Kirby, Nettelbeck and Tiggerman (1977) added further support to this finding when they examined the RTs produced by nonretarded and retarded groups under conditions where the compatibility of the stimulus and response arrays

was altered. A two-choice RT task was used, the stimulus and response arrays consisting of two lights and two keys. Subjects performed under two conditions, responding using either the index fingers of each hand or the index and middle fingers of the preferred hand. Kirby et al found that the retarded subjects were disproportionately slower than the nonretarded subjects when the fingers of the same hand were used (i.e. the index and middle fingers). Thus, retarded subjects were not only affected by changes to the stimulus array but also to changes in the response requirements. This finding was confirmed in studies by Kirby, Nettelbeck and Western (1982) and McConaghy (1980) who found that if additional non-operational lights were added to the stimulus array in a four-choice RT task (so that the stimulus array consisted of eight lights but the two lights at either end of the array were never used) retarded subjects were significantly affected. But they were even more affected when additional non-operative keys were added to the response array (in the same way as the additional lights were added) and the subjects were required to place their nonused fingers on these additional keys. This suggested that selection of the appropriate response was even more difficult than discrimination of the correct stimulus. All these studies discussed above suggest that not only are retarded subjects slower and more variable in their response rate, but also that they are more adversely affected by increases in the complexity of the task, than nonretarded subjects.

2.2.2 REACTION TIME AS A DEPENDENT MEASURE

Jensen (1979, 1980, 1981, 1982a,b) has investigated nonretarded and retarded subjects' performance on a choice RT task and psychometric measures of "g" (using the Ravens Progressive Matrices test). The task used by Jensen was a

modification of a typical choice RT task. Jensen's modified apparatus consisted of nine lights and nine keys, eight lights and their associated keys being set an equal distance from the ninth home light/key in a semicircular array. The subjects held their finger on the home key until one of the eight lights was activated, whereupon they moved their finger from the home key to the key associated with the activated light, thus switching it on. This corresponds to an eight-choice RT task, with two and four-choice alternatives being possible by the masking of appropriate numbers of the eight lights and keys.

This arrangement allowed Jensen to separate total RT into two parts - decision time (DT) and movement time (MT), the former being the time elapsing from the onset of a stimulus light and the subject lifting their finger form the home key and the latter being the time to move the finger from the home key to the activated light's corresponding key and terminating it. The assumption is that DT consists of a number of processes including encoding of the stimulus, location of the activated stimulus in the array and translation of the stimulus information into the appropriate response. Conversely, MT consists of the actual execution of the motor response. Hick (1952) has previously found that RT increases as a linear log function of the number of choices available. This relationship is now known as Hicks Law.

Jensen (1979, 1982a,b) used the two, four and eight-choice RT tasks described above to examine RT diferences between groups of markedly different intellectual abilities including severely retarded, mildly and borderline retarded, average and above average school age children, average young adults and above average young adults. He found that the slope of the RT function corresponded to Hick's law for all but the severely retarded group and that

both the intercept and slope increased for both age and ability, children and retarded adults producing steeper slopes and higher intercepts than older and higher ability subjects. Jensen also found a significant correlation of -.40 between RT and "g" as measured by the Ravens Progressive Matrices, for third grade girls of high and low ability (Jensen and Munro, 1979) and for university students. (This latter study is mentioned in Jensen's 1979 and 1982a,b articles but is not referenced).

Interestingly, Jensen also found that DT was more correlated with "g" for higher ability and older groups (university students and average young adults), while MT became the "more important correlate of "g" in children and retarded adults" (Jensen, 1982a, p. 111). Jensen (1979) writes "it seems puzzling that there should be any correlation between intelligence test scores and MT, when MT is unrelated to the amount of information" (p. 25). It seems possible that the developmentally young and intellectually retarded are performing the actual RT task in a different manner to that of the older and intellectually more mature. Specifically, children and retarded adults may be lifting their finger from the home key prior to reaching a complete decision regarding the location of the stimulus and therefore the appropriate response, and continuing these processes as they move their finger to the correct key. Thus, MT would contain processes that are in adults included in DT. A similar suggestion was made by Nettelbeck and Kirby (1983) in a replication of Jensen's study using retarded and nonretarded subjects, where they found a similar negative correlation. However, Kirby, Nettelbeck and Tiggerman (1977) did not find any evidence for this when examining sequential effects in a two-choice task but this would need to be confirmed for reaction time tasks with more than two choices (i.e. of greater complexity).

A recent critique by Longstreth (1984) questions the methodology used by Jensen, his interpretation of the results he obtained, and his theoretical assumptions. With regard to methodological problems, Longstreth suggests that Jensen does not adequately take into account the effects of practice, order, response bias and visual attention and that all these factors will significantly effect the steepness of the slope obtained for decision time (DT) in Jensen's task. With regard to the first two factors, Longstreth suggests that practice and order are confounded in Jensen's experimental design because subjects commence each session with the simplest RT task (simple RT with one stimulus and one response) and proceed to the most complex (eight-choice RT with eight stimuli and eight responses). Jensen states that there is no effect of practice across sessions separated by days or months but reports no supporting data and does not mention whether there is a practice effect within sessions (i.e. from the first to the last trials). Longstreth reports a study conducted by himself using Jensen's apparatus where he found a significant effect for both practice and order. Practice reduced RT and the order of presenting each RT task also affected RT.

With regard to the effects of response bias Longstreth suggests that Jensen's apparatus with a central home key and response keys set equidistant from it may not avoid the problem of some responses being more easily performed than others. Longstreth suggests for example, that a left movement of the hand may take longer to prepare and execute than a right hand movement. In an experiment designed to examine the effects of response bias using Jensen's apparatus and the four-choice RT task, Longstreth found the third response position (central and slightly to the right) to be more readily responded to than the outer response keys and the central key slightly to the left. In a

similar fashion, Longstreth suggested that the design of the apparatus might cause some stimuli to be more readily identified than others. This is most likely to occur in the eight-choice task, where the two most outer lights lie almost at a right angle to the subject's body who is facing straight ahead. Jensen states that this is not a problem because of the brightness of the stimuli, however, Longstreth suggests that if Jensen is incorrect in this assumption, the steepness of the slope for decision time will be affected.

Longstreth concludes that while these problems question the validity of Jensen's findings, they are at least potentially solvable by making changes to the experimental design and apparatus. He suggests that it is Jensen's interpretations of the data that are most questionable. Specifically, Longstreth suggests that Jensen (1979, 1982a,b) makes two important claims that are not supported by his experimental data. The first is that of a significant negative correlation between intelligence and decision time (DT) and secondly, that this correlation increases as the size of the positive set to be remembered (ie stimulus complexity) increases. Longstreth refers to Jensen's (1979) article where he compares the slopes and intercepts of seven groups of subjects of varying levels of intellectual ability. Jensen asserts that a comparison between any two of these groups yields a significant difference except for the comparison between the university students and the adolescent group. Longstreth, however, suggests that the slope differences between all the groups excluding the mildly and severely retarded subjects are minimal and probably not significant. He points out that Jensen offers no support for his claim. Thus, while the mildly and severely retarded subjects may produce different slopes to the nonretarded groups the differences in slope within this

latter group are minimal and in fact the former group produces less steep slopes than the latter group, a direct contradiction to Jensen's suggestion that higher ability level subjects produce less steep slopes. Longstreth suggests the same is also true of the increase in the negative correlation with increasing stimulus complexity. This is only the case when extreme groups on the intelligence continuum are compared. If the retarded groups are removed, the negative correlation shows little or no increase with set size. Detterman (1979) and Nettelbeck and Kirby (1983) have both discussed this problem and caution that results obtained from the comparison of extreme groups is not always valid.

Finally, Longstreth (1984) criticises Jensen's work on theoretical grounds. Two of these criticism will be mentioned here. One criticism is that mentioned previously, of a negative correlation between decision time and movement time suggesting that these two measures are not independent. The other is that the reaction time task may not simply be a measure of mental speed but may also be affected by cognitive factors such as memory and strategies. Nettelbeck and Kirby (1983) have also suggested that this may be the case. As both Longstreth (1984) and Nettelbeck and Kirby (1983) conclude, the use of Jensen's method and apparatus raises a number of difficulties both in terms of methodology and the theoretical base for that methodology. In addition, Longstreth suggests that the claims concerning the relationship between intelligence and reaction time as measured by Jensen are not supported by the experimental data.

One quite consistent empirical finding in studies using S. Sternberg's memory scanning task is that of slope differences between nonretarded and retarded subjects. (Dugas and Kellas, 1974; Harris and Fleer, 1976; Maisto and Jerome, 1977; Silverman, 1974). Retarded subjects have been consistently found to

produce steeper slopes (and higher intercept values) in comparison with nonretarded subjects. However, Phillips and Nettelbeck (1984) have shown that this result may be dependent upon the amount of practice given. They compared mildly retarded young adults' performance with that of young adults matched for chronological age and young children matched for mental age. They found similar results to those obtained previously, the retarded subjects producing steeper slopes and higher intercepts than the nonretarded young adults. The mental age controls also produced results similar to the retarded subjects.

Phillips and Nettelbeck (1984) then gave all three groups seven sessions of practice on the memory scanning task. They found that while nonretarded subjects showed little improvement, suggesting near asymptotic performance for these subjects after one session, the retarded subjects and their mental age controls improved steadily over the seven practice sessions. This improvement was evident in both a reduction in slope and intercept. By the seventh session there was little difference between the nonretarded adults and childrens' slopes and intercepts. The retarded subjects still produced a higher intercept and steeper slopes but their data showed that they had not yet reached asymptotic performance while the nonretarded adults and children had. This suggested that with still further practice the differences between the retarded and nonretarded groups may have been further reduced.

Silverman and Harris (1982) also point out that while experiments using this paradigm with nonretarded adults have found no relationship between intercept and slope, studies using retarded and younger nonretarded subjects have tended to find a negative correlation between these two parts of the RT function (see also Maisto, 1978 and Phillips and Nettelbeck, 1984). This

contradicts the theoretical assumption on which the memory scanning task is based, that stage durations are independent of each other. Silverman and Harris (1982) suggest that the inverse intercept/slope relationship may indicate strategy differences between groups of differing ability. However, they also write "if slope and intercept values are related, high speed scanning tasks may be of limited utility for making individual and/or group contrasts, as clear interpretation of quantitative group differences may not be possible" (p. 97).

2.2.3 ATTENTIONAL AND MOTIVATIONAL FACTORS

Other factors that affect the RTs of retarded subjects are motivation, fatigue and loss of attention. In their review article, Baumeiser and Kellas (1968) point out that a number of studies have found inducements can be used to significantly improve the performance of retarded subjects. They cite instances where praise, monetary reward, sensory stimulation and reprimand have been used to improve the RTs of these subjects. Zigler and Balla (1981) have suggested that retarded children are more responsive to social reinforcement. They suggest this may be due to their lower expectancy of success and their higher expectancy of failure, which in turn is due to their more frequent experiences of failure.

While most researchers acknowledge there is a problem of loss of attention and fatigue which is more pronounced in retarded subjects, few have systematically studied the effects of these factors on task performance. As Krupski (1979) writes "Expressions such as 'inability to concentrate', 'short attention span', 'distractability' or 'attention deficit' are often used to characterise mentally retarded youngsters" (p. 1). Krupski (1977) examined nonretarded and educable mentally retarded subjects' performance on a simple

RT task. She measured both RT and the degree of eye contact made by the subject with a visual warning signal presented just prior to the presentation of the actual visual stimulus. This latter measure, Krupski suggested, indicated the degree of overt attention the subject was paying to the task just prior to the stimulus presentation. Three measures of eye contact were taken; 1) continuous, where the subject did not look away from the warning light during its presentation or only glanced away for less than one second; 2) intermittent, where the subject glanced away from the warning signal one or more times, each time for greater than one second and; 3) no contact, where the subject made no eye contact at all with the warning signal.

Krupski found that the retarded subjects produced longer RTs and larger standard deviations. In addition, of a total of 20 trials on which eye contact was measured, 19.6 trials could be classified as continuous for the nonretarded subjects, .3 trials could be classified as intermittent and .1 trials as no contact. Thus, for these subjects most of the examined trials could be classified as continuous, suggesting good attention to the task. For the retarded subjects, however, only 3.7 trials could be classified as continuous, 9.4 trials as intermittent and 6.9 trials as no contact. Thus, the retarded subjects spent most trials making intermittent or no eye contact with the warning signal. Krupski suggested that this pattern of results lent support to the suggestion that at least part of the retarded subjects poorer performance in terms of obtained RT data could be explained by this lack of attention to the warning signal. Further support for this would be provided if an experiment investigating eye contact during the actual presentation of the stimulus obtained similar results.

A recent unpublished study by Nettelbeck, Robson, Walwyn, Downing and

Jones is such an investigation. They measured eye movement for retarded and nonretarded subjects prior to the presentation of a stimulus and during stimulus presentation on an "inspection time" task in a first experiment. Inspection time was originally developed by Vickers, Nettelbeck and Willson (1972) and was defined by these authors as the minimum time required by the subject to take one sample of a presented stimulus which will result in correct identification of that stimulus. The task used is a very simple one requiring the subject to discriminate which is the shorter of two vertical lines (generally presented tachistoscopically). The exposure duration of the stimulus is varied experimentally and is followed immediately by a backward mask to prevent further sampling of the stimulus. A number of studies have found that mildly retarded subjects produce longer inspection times than nonretarded chronologically matched controls, their inspection times being approximately 250 msecs and 100 msecs respectively (Lally and Nettelbeck, 1977; Nettelbeck and Lally, 1976, 1979).

Nettelbeck et al (unpublished report) found that inspection times were longer for retarded subjects. Inspection of video recorded patterns of eye movements for both groups revealed that the retarded subjects made more off-task glances than nonretarded subjects. Nettelbeck et al concluded that this could provide an explanation for the slower inspection times obtained for this group. Two further experiments, using the inspection time task, qualified this finding. Though the retarded subjects showed more off-task glances than nonretarded subjects in the first part of the preparation interval by the end of the preparation interval just prior to the onset of the stimulus, the retarded subjects evidenced efficient orientation to the stimulus area. This lead Nettelbeck et al to conclude that while an attentional deficit may partially explain the poorer performance of retarded subjects on attention demanding tasks, there are also other factors involved.

Krupski (1979) has also examined the degree of distractibility in retarded subjects in a classroom situation. She found that retarded subjects, in comparison to nonretarded subjects, spent more time out of their seats and "looking busy" but not working and were less attentive when performing academic tasks than when performing nonacademic tasks. This latter finding may be related to Zigler and Balla's (1981) suggestion that retarded subjects perform worse on academic tasks because of their history of failure on these types of tasks. These studies, therefore, suggest that retarded subjects are less attentive than nonretarded subjects and this may in part explain their poorer performance on attention-demanding tasks.

2.3 MENTAL RETARDATION AND SHORT-TERM MEMORY

The pertinence of memory studies to analogical reasoning tasks is that working or short-term memory is required to solve analogies. Each new analogy term must be encoded into short-term memory, as must the relationship between the first two analogy term. In addition this information must be maintained in short-term memory while processing of the remaining two analogy terms proceeds. A number of studies have found that the short-term memory of retarded subjects is less efficient than that of nonretarded subjects. (Baumeister and Kellas, 1967; Borkowski, 1965; Brown, 1974). Detterman (1979) has provided a succinct review of the most relevant findings in this area. One of the earliest theoretical explanations of the poorer short-term memory evidenced by retarded subjects was proposed by Ellis (1963) and became known as the stimulus trace theory. Ellis suggested that the mentally retarded had a poorly integrated nervous system which lead to a faster loss of stimulus information from memory compared to nonretarded individuals. Thus, while retarded subjects might have equivalent memory for a stimulus over a short time interval, faster decline of the stimulus trace lead to

poorer memory over longer periods of time. This theory was subsequently criticised for not taking into account the mnemonic strategies subjects might use to improve the entering and retention of items in short-term memory. From these criticisms Ellis (1970) developed a theory which placed emphasis on the influence of these mnemonic strategies. Specifically, he suggested that retarded subjects evidenced a rehearsal deficit which meant that they were not active in seeking to encode and maintain information in short-term memory when compared to nonretarded subjects.

In support of this suggestion Ellis (1970) conducted a series of experiments using a serial recall task with retarded and nonretarded subjects. He found that both groups evidenced a recency effect (good recall of the final few items presented in the list) but the retarded subjects were much worse at remembering the earlier items. Ellis found evidence which suggested that while the nonretarded subjects actively sort to maintain the earlier times in short-term memory through rehearsal, the retarded subjects did not. Ellis also varied the time interval between each trial from zero to two seconds. He found that the nonretarded subjects performed better in the latter condition because they used this time interval to rehearse the previously presented items. The retarded subjects, however, showed no difference in their performance under both conditions. Thus, even when provided with the opportunity to enhance recall, the retarded subjects did not do so.

Self-paced tasks have also found that retarded subjects do not make use of strategies to aid recall. For example, Belmont and Butterfield (1969) found that nonretarded subjects would rapidly present the first three or four items in a list to be recalled, then pause for a longer period during which they presumably rehearsed these items. Subjects would then quickly present the

last few items making use of the recency of these items to aid recall. Retarded subjects, however, showed no evidence of the use of such a complex strategy. They presented the items quickly and for a similar duration.

Spitz (1970, 1973) presented an alternative theory which concentrated on the retarded subjects' seeming inability to organise incoming information in a way that aided recall. He found that while nonretarded subjects might group incoming items into categories or chunks of information the retarded subjects did not. This in turn, meant that they had a greater load on short-term memory. Spitz and Webreck (1972) found that presenting the stimuli in a grouped fashion enhanced the performance of the retarded subjects. Wanschura and Borkowski (1975) using a different approach found that retarded subjects' performance could be improved by the use of a mediator - a word that was attached to the words to be recalled and acted as a trigger to recall. Similarly, Buckholt, Mahoney and Paris (1976) found that elaboration (verbalisation) of the words to be recalled improved the performance of retarded subjects.

Thus, the performance of retarded subjects on memory tasks can be improved by experimental interventions but they do not appear to spontaneously or actively make use of task variables to enhance their recall. Put another way, these studies seem to indicate that retarded subjects are nonstrategic in their approach to cognitive type tasks. However, from none of the preceeding studies is it possible to say that the retarded are nonstrategic because of a deficiency in the actual capacity of short-term memory or because they have failed to learn to use task appropriate strategies. In the mental retardation literature, a deficiency in capacity would be described as a structural deficiency where the architecture or physiology of the system is affected.

Conversely, a functionalist view would be that the retarded have failed to learn to make use of strategies (although supporters of this view would probably not deny the possibility of a structural deficiency as well). The functionalist view implies that with training, the retarded can be taught strategies and therefore, perform at an improved level. This view has in recent years gained considerable support in the investigation of memory and mental retardation. A review of the major studies in this area will therefore be described in detail in the following section.

2.4 MENTAL RETARDATION, STRATEGIES AND TRAINING

2.4.1 CONTROL PROCESSES, KNOWLEDGE BASE AND METACOGNITION

There are two levels on which the use of strategies have been discussed in the training literature and in literature not necessarily related to mental retardation. At the first level is the use of specific strategies or control processes for particular tasks. At the more general level is the present interest in so called "metacognitive skills", skills that are common to a wide variety of tasks. Atkinson and Shiffrin (1968) first introduced the term "control processes" in their description of the memory system, defining these processes as processes that are under the control of the subject. Belmont and Butterfield (1977) have described them as "cognitive tactics" while Campione and Brown (1978) suggest they are "the rules and strategies available to the thinker for memorizing, understanding, solving problems, etc." (p.144). The dominant characteristics of control processes are that they are task-specific, acquired or learned and consciously performed by the subject.

Metacognitive skills have in previous years been referred to as "the

homoculus" or "ghost in the machine" (Posner, 1978). More recently, they have been labelled "metamemory" (Flavell, 1970) in the developmental literature, the "executive" or "executive functions" (Belmont and Butterfield, 1982; Campione, Brown and Ferrara, 1982) in memory research into mental retardation; metacommunication in communication research (Robinson and Robinson, 1982); and metacomponents in the work of Sternberg (1980). These skills can be described as the processes that control the control processes, they are the subject's awareness of his/her own cognitive machinery and operations.

The concept was first introduced by Flavell (1970, 1971) in his work concerning memory development in children, and was defined as "an individual's knowledge of and awareness of memory or of anything pertinent to information storage and retrieval" (Flavell and Wellam, 1977, p. 4). Campione and Brown (1978) describe metacognition as recognition of one's own cognitive limitations, being aware of the strategies suitable to a given task, being able to identify the current problem, planning and implementing strategies and monitoring the effectiveness of those strategies. Similarly, Butterfield and Belmont (1977) describe metacognition as the ability to appropriately select, discard and evaluate task-specific strategies.

While Flavell has been primarily concerned with the normal development of metacognitive skills, the latter authors have been in the forefront of applying the term to the investigation of mental retardation. Both have come to the conclusion that it is in this area that the retarded are most deficient and that this is the cause of the differences in performance found between intellectually disparate groups. Detterman (1982) has argued, however, that the investigation of metacognitive skills are not as important as the

investigation of lower-order processes. He suggests that recourse to explanations of intellectual functioning in terms of metacognition are nonproductive and that as knowledge of the interactions between lower-order processes becomes greater the need for metacognition as an entity "will go away".

One other term that appears in the training literature is the concept of a "knowledge base". This term was first introduced by Chase and Simon (1973) in their study of chess players. They found that the knowledge base of an expert chess player was much larger than that of a novice. Speaking in terms of "chunks" (pieces) of information, they found that an expert chess player may have chunks consisting of patterns of up to six chess pieces, while a novice might have a chunk consisting of only two pieces. An individual's knowledge base can be described as the knowledge they have available for a given task. Chi (1976) has described this as the complexity of the semantic network of an individual or their degree of familiarity with, for example, words and numbers. She suggests, further, that a child's knowledge base can be identified by three factors; 1) the presence or absence of recognisable chunks of information; 2) the size of each chunk, and; 3) the accessibility of that chunk. Flavell and Wellman (1977) have described the knowledge base as to do with the "relatively direct, involuntary and usually unconscious effects of one's attained level of general cognitive development" (p. 4) while Campione et al (1982) suggest it is "the extent and organisation of relevant knowledge available to the learner" (p. 400).

Chi (1981) has suggested that many developmental differences in intellectually normal children of different ages can be accounted for in terms of a differential knowledge base, without recourse to metacognitive skills or control processes. In fact Chi has argued that the extent of strategy usage is

a direct result of the individual's knowledge base, "how much you know determines what you do with that information" (from Campione et al, 1982, p. 410). To support this notion Chi (1981) studied situations where children were the experts and adults the novices, i.e. where the knowledge base of the child was greater than that of the adult. Chi found that child chess experts remembered more chess related information and were better able to predict the power of their memory for chess, than adult novices.

Campione et al (1982) have suggested that while knowledge base differences are important, the assertion by Chi is an extreme one. However, they take the opposite view, proposing that knowledge base differences are due to differences in the efficiency of metacognitive skills. They point out that studies comparing retarded and nonretarded children show that retarded children do not recall lists of words as well as nonretarded children, nor do they organise their recall within categories as nonretarded children do. However, attempts to assess the organisation of their knowledge about these categories based on automatic processing reveals similarities rather than differences. For example, they describe studies by Sperber, Ragain and McCauley (1976) and Winters and Cundari (1979) who found similar results in a semantic priming task for nonretarded and retarded children. Both were faster to identify the second word in a pair if this word came from the same category as the first word (e.g. cat and horse) as opposed to a different category (i.e. cat and house). While this may well be the case, other studies (Chi, 1976, 1981) have found that young children and retarded subjects do have a less well developed knowledge base than adults as regards words and numbers. Campione and Brown would suggest that for retarded subjects these differences are due to deficient metacognitive skills rather than to a less well developed knowledge base. Campione et al have in fact, more recently

suggested that control processes and metacognitive skills can be subsumed under the heading of a general knowledge base in that they are part of the knowledge an individual brings to a task. However, they point out that in the literature these concepts have been treated as separate entities, with the concept of a knowledge base having a more rigorous and limited meaning similar to that described by Chi (1976). In addition, while Flavell and Wellam (1977) have suggested that a knowledge base is acquired involuntarily and unconsciously, if one adopts the broader meaning of Campione et al (1982) then one can also propose that a knowledge base must or can contain skills acquired voluntarily and consciously ie. those control processes or strategies acquired by retarded subjects in successful training studies. Chi's assertion has been in essence, an attempt to redress the balance between the influence of knowledge base differences on the one hand and metacognitive skills on the other. She points out that the findings from a number of training studies are questionable due to the fact that no attempt has been made to assess the probable knowledge base differences between intellectually disparate groups.

In one of their more recent articles (Campione et al, 1982) Campione and Brown also make a distinction between metacognition, the term they prefer, and executive control, the term used by Belmont and Butterfield (1977) to descirbe metacognitive type processes. They suggest that metacognitive skills should refer to knowledge about cognition, and executive control to "the overseeing, management functions". Campione et al describe the former as "the ability to reflect on one's own cognitive processes, to be aware of one's own activities while reading, solving problems" (p. 433), while in the latter they are referring to "the self-regulatory mechanisms used by an active learner during an ongoing attempt to solve problems" (p. 434). These may include "checking the outcome of any attempt to solve the problem, planning one's next move, monitoring the effectivenss of any attempted action and

testing, revising and evaluating one's strategies for learning" (p. 434, Campione et al's emphasis). The reason for Campione et al's distinction is the fact that being aware of one's memory and its limitations does not always ensure one's use of this information on a given task. For example, Brown (1978) describes the work of Kreutzer et al (1975) who, using questionaire techniques, found that middle-school aged children possessed an awareness of certain self-management skills. However, when presented with a task requiring the use of these skills, the subjects performed poorly. In addition, children who predicted that studying longer and more actively (i.e. using strategies) would lead to better recall, didn't necessarily say they would act this way themselves. This absence of a link between awareness and actual use is reflected in a study of young normal and educable mentally retarded (EMR) children by Brown et al (work in progress, 1978).

They found that the retarded children (mental age six and eight) were able to indicate the superiority of an active strategy when asked to predict which modelled activity would lead to higher recall, whereas normal preschool and first grade children could not. However, given the actual task to perform immediately following the viewed models, only a small number of retarded children actually used the active strategy. Thus, having some task relevant information available does not always presuppose its use by intellectually impaired or developmentally immature individuals. Findings such as these have lead Campione and Brown (Brown, 1978; Brown and DeLoache, 1978; Campione et al, 1982) to identify the use of self-regulatory skills (executive functions) in a learning or problem solving situation as essential to adequate performance rather than just the awareness of the value of these skills. This type of finding can also be related to the knowledge base data. In fact, as Campione and Brown (1978) have pointed out, the ease with which simple

strategies can be trained suggests that retarded subjects have the necessary knowledge available but just do not integrate this knowledge to produce task efficient strategies. This may be due to the amount of effort required by the retarded subjects to use the strategy. Nonretarded do not always use the most effective strategy but use one that is, while less effective, requires less effort to carry out, for example in terms of short-term memory load.

The training studies to be discussed here are mainly concerned with the instruction of task-specific strategies or control processes. However some of the more recent studies attempting to instruct metacognitive skills will also be presented. A training study usually consists of a number of steps. Firstly, a retarded and nonretarded group are given the same task to perform. The task used generally requires the effective and spontaneous use of a strategy such as rehearsal for adequate performance. The typical finding is that the retarded group performs poorly and this is found to be due to their nonstrategic approach to the task. Training in a strategy appropriate to the task is then introduced to the retarded group with the purpose of examining whether this training improves performance. The value of the training study is that it requires a fairly rigorous task-analysis to develop a training program that is likely to be successful, and that it provides the retarded subject with a new skill (however, as will be discussed later, the general value of the acquired skill may be limited because it is only relevant to that particular task). A training program that is successful suggests that the task-analysis and training method have indeed been rigorous and that the retarded subject has a functional rather than a structural deficiency. An unsuccessful training program can be due to either (and these will be indistinguishable, on the basis of the results) a poor task-analysis and/or training procedure, or a structural and therefore unmodifiable deficiency in the retarded

subject. Campione et al (1982) have suggested that training studies fall into three categories - blind, informed and self-control. They can be distinguished both by the time when the studies were carried out and by the amount of information regarding the value of the trained strategy that was provided to the subject.

Blind studies provided no information regarding the value of the strategy to the subject and were the earliest training studies conducted. From the results of these studies either directly or indirectly more information regarding the value of the strategy was provided to the subject. Campione et al called them informed studies. From the results of these studies, comes the present day interest in providing instruction in both a task-specific strategy and self-regulatory skills such as monitoring, checking and evaluating that strategy. Campione et al (1982) called these self-control studies.

Two concepts in the strategy training literature are essential to the assessment of the effectiveness of a training program, these being "maintenance" and "generalisation". Maintenance refers to the durability of the trained strategy. The better a strategy is learned the more likely it is to be performed each time the task used for training is presented, irrespective of the time elapsing between the initial training session and subsequent testing sessions. Generalisation refers to the application of the trained strategy, appropriately modified, in all tasks where it would improve performance. Generalisation shows a parrallel growth in interest to that of self-regulatory skills as it is in these areas that it is most relevant. Maintenance however, relates to the acquisition of control processes.

2.4.2 STRATEGY TRAINING MAINTENANCE AND GENERALISATION

Brown, Campione, Bray and Wilcox (1973) in an early blind study compared

retarded and nonretarded subjects on a keeping track task, where four pictures of particular items were presented on each trial, the items coming from four possible categories (i.e. animals, food, clothing or vehicles). The subjects were asked to recall an item from a particular category at the end of each trial. As Campione et al (1982) suggest, the most efficient strategy in this type of task is to rehearse the four presented items, keeping them available until the test occurs. Brown et al (1973) obtained the following results; 1) the retarded subjects did not spontaneously rehearse the experimental items but when instructed to rehearse, did so and significantly improved their performance, producing accuracy and latency patterns similar to untrained nonretarded subjects; 2) nonretarded subjects showed use of spontaneous rehearsal strategy and performed well. However; 3) if prevented from rehearsing, the nonretarded subjects' performance significantly declined, producing accuracy and latency patterns similar to those of untrained retarded subjects. The retarded subjects averaged 58% correct prior to training while the nonretarded (prior to their being prevented from rehearsing) averaged 90% with the inclusion of a filler task to reduce their performance from 100% accuracy and possible ceiling effects. After training, the accuracy level of the retarded subjects rose to 85%. Brown et al do not present data for the nonrehearsing nonretarded group, however, they do point out that they found it very difficult to prevent these subjects from rehearsing and contrast this with the fact that retarded subjects required intensive training to produce adoption of a rehearsal strategy.

An experiment by Butterfield, Wambold and Belmont (1973), mentioned briefly previously, reinforces this point. In this study, retarded subjects received extensive training in the use of appropriate strategies on a task requiring a

combined rehearsal/recency strategy. Sequences of six letters were presented successively on a screen. The duration of each letter presentation was fixed but the time interval between letters was controlled by the subject. At the end of each trial, one of the letters was presented, the subjects' task being to indicate the position of that letter in the original sequence.

Nonretarded subjects performed this task efficiently by using a long exposure duration at the end of the presentation of the first three letters (for rehearsal) and then exposing the last three letters quickly. Retarded subjects however, performed the task with a brief exposure duration between all letters and showed poor recall. Butterfield et al then trained the retarded subjects to use a rehearsal strategy similar to that used by the nonretarded adults. This however, only increased their recall of the first three letter positions. The retarded subjects were then given additional training to enhance their performance on the final three letter positions. First they were informed that the test item would come from only the last three letter positions. They were instructed to point to these positions on the screen and try to remember the letters presented here by saying their names out loud. Then they were told that the probe letter could come from any of the six positions and were instructed to recall the letters in the fourth to sixth positions first and then those in positions one to three, using the rehearsal strategy previously trained for these latter items. This combined rehearsal and recency training produced superior performance to the nonretarded control subjects.

Both studies found evidence of maintenance. However, neither study found evidence of generalisation even though the training given in both studies was explicit. Thus, as Campione et al (1982) conclude, even though significantly improved performance by retarded subjects was obtained in both studies,

extensive training was required to achieve this, and this still did not produce transfer of the strategy to other similar tasks. It is not surprising in retrospect, that generalisation was not found. If the retarded subjects required such extensive training to produce task appropriate strategies, it seems logical that they should also require extensive training to transfer these learned strategies appropriately.

Brown, Campione and Murphy (1977) conducted a training experiment using retarded subjects with mental ages (MA) of six and eight years who were initially found to be "unrealistic estimators" in a memory span estimation task. Brown et al (1977) suggested that a span estimation task was an interim step between the training of specific strategies and the training of executive functions. They write "if a child is not aware of the extent of his memory limitations he/she can scarcely be expected to introduce steps to remedy his/her (metacognitive) shortcomings" (p. 193). (It has previously been mentioned that even in situations where the subject is aware of the value of a skill he/she does not always make use of it). In the first session, subjects were asked to predict their estimation span of groups of one to ten item pictures. In the second session, the actual memory span of the subjects was assessed with subjects being presented with the one to ten item pictures, and then in each, having to recall what they saw. From this session, subjects were classified as either "realistic" or "nonrealistic" estimators. Two sessions of training using the ten item picture cards followed, with half the realistic and nonrealistic subjects receiving explicit feedback as to the actual number they remembered. They were told the number of items they remembered on each list and this number was counted out by the experimenter on a toy bead counter which was visible and constantly referred to by both experimenter and subject. A no feedback group was told "Good" at the end of each recall

effort. Subjects then performed in three post-tests, one directly following training, another two weeks later and the final test one year later. No mention of the training received was mentioned in any of the post-tests. As a test of generalisation, subjects received the one to ten item picture cards used in the initial pretraining session, and twenty, ten item number cards, during these sessions.

Only 21% of the MA six and 31% of the MA eight group were initially classified as realistic estimators. During the first post-test only the MA six explict feedback group and both MA eight explicit and no feedback groups remained realistic. In the second post-test (two weeks later) only the MA eight groups remained realistic and by the final post-test one year later, only the MA 8 explicit feedback group remained realistic. No generalisation was found to the two generalisation tasks for any of the originally unrealistic subjects in both mental age groups. But realistic subjects in both age groups showed generalisation. In addition, recall levels on the tasks for all subjects remained stable, in other words, recall performance did not improve with training of a more metacognitive skill. This emphasises the importance of training on both task-specific and metacognitive skills as was provided in the study by Butterfield et al (1973). This is a point that will be returned to at the conclusion of this chapter. The studies to follow are examples of informed studies where information as to the value of the trained strategy was provided either directly or indirectly to retarded and developmentally immature subjects, in an attempt to encourage strategy generalisation.

The first, is a study by Kestner and Borkowski (1979) investigating the performance of children (aged four to five years) on a paired associate learning task. They conducted two experiments. In the first, three types of

elaborative conditions were compared, with a "labelling only" control condition. The three elaborative strategies trained were 1) sentence repetition, where the subject repeated two sentences provided by the experimenter, one involving a relationship between the paired items and the other an explanation of that relationship; 2) yes/no interrogative where the experimenter posed a question regarding the plausiblity of the relationship between the two items to which the subject had to respond; and 3) "why" interrogative where the subject had to provide a relationship or reason for the pairing of the two paired items. Kestner and Borkowski (1979) found that all three elaborative strategies improved recall significantly in comparison to the labelling condition where the subject just repeated the name of the two items presented. Kestner and Borkowski had expected the "why" interrogative strategy to produce better performance than the other two elaborative strategies. They suggested that this was not the case because of the quality of the experimenter-generated elaborations in conditions one and two. That is, differences may have been found if sentences were subject rather than experimenter generated in these conditions.

In their second experiment, Kestner and Borkowski (1979) used the elaborative format as a strategy training activity to improve recall of paired associates and also to test for maintenance and generalisation. A control group in a labelling condition was also included. Interrogative strategy training was divided into four parts: 1) physically describing the two paired items; 2) using a "why" question about the physical relationship between the two items; 3) describing what is known about the two items individually; 4) using what is known about them to make up a reason about why they go together. In addition, in an attempt to produce generalisation, Kestner and Borkowski included three other factors which they suggested might aid strategy transfer and which resembles metacognitive skills training; "1) active participation by

the subject; 2) sufficient training with the same strategy and 3) knowledge of the value of the strategy" (p. 488).

The four aspects of the strategy were gradually introduced over three successive days, with the experimenter progressively fading out prompts. Four post-training tests were also given, the first immediately following the last training sessions, the second, the next day, the third, four days later and the fourth, six days later. This last post-training test included a generalisation test where three items were presented rather than two. The value of the strategy was reinforced in both the training and the first two post-training testing sessions but not in the two final sessions.

Recall by the training group was superior in the training sessions to that of the labelling control group and this remained so for all four post-tests. However, recall performance did decline over the four posttests for the former group and in particular from the final maintenance test (post-test three) to the generalisation test (post-test four). Ten of the sixteen trained subjects were categorised as strategy users in the generalisation task and these subjects evidenced superior recall compared to those classified as non users. As Kestner and Borkowski conclude, informing children that a trained strategy can be used at a later time, in a variety of situations as a means of remembering better, does not mean that all will use this strategy on subsequent generalisation tasks.

Two points need to be made concerning this task. Firstly, maintenance post-tests took place very soon after strategy training was completed, the longest duration between training and maintenance being four days. It would be interesting to observe whether the strategy was maintained over a much longer period of time. Secondly, the generalisation task used was very similar to the task used for training (a "near" generalisation task, Brown 1978), and

even so not all trained subjects produced strategy transfer.

Kendall, Borkowski and Cavanaugh (1980) repeated the above study, using educable mentally retarded children and in addition, assessed the metamemorial skills of those subjects prior to training and after the maintenance and generalisation sessions. Metamemory was assessed by modifying and reducing the interview questionnaire developed by Kreutzer, Leonard and Flavell (1975). Subjects were divided into two groups, one trained to use the interrogative strategy previously described and the other receiving no instruction. Both groups participated in nine sessions, the first and last being assessment of metamemorial skills. Sessions two to five were training sessions (practice sessions for the uninstructed group). Sessions six and seven were both maintenance sessions, one and two weeks after training, and Session eight was a generalisation session following one week after Session seven. The same generalisation task was used as in the previous experiment. The value of using an interrogative strategy in the task situation was reinforced in Sessions two to seven for the strategy training group. In addition, half the subjects in this group were told in Sessions six and seven that the interrogative strategy was "generally useful and would aid remembering in many different situations" (p. 261).

The interrogative group produced significantly higher recall than the uninstructed group, across all sessions. However, surprisingly, no difference was found between the subjects in the interrogative group told of the value of the use of the interrogative strategy in other situations as compared to those who were not. Providing at least minimal classification on at least half of the items was taken as evidence of strategy usage during the maintenance and generalisation post-tests. Fifteen of the sixteen interrogative subjects showed

evidence of maintenance and thirteen showed evidence of generalisation. Thus, there was evidence that generalisation had occurred to a "near" task for a majority of the retarded subjects. Analysis of the metamemorial data using the modified Kreutzer et al (1975) questionnaire revealed no significant differences between both the trained and untrained groups and a control group who only participated in the metamemorial assessment Sessions one and nine. Thus, the metamemorial skills of the trained groups had not improved over those of the untrained and control groups. Kendall et al (1980) contrast this with a study by Cavanaugh and Borkowski (1979) using nonretarded third grade school children. They found a significant improvement in metamemorial skills as a result of similar strategy training, transfer and feedback regarding the strategy's value. Kendall et al suggest that this discrepancy may be due to the sort of relationship between the types of metamemorial assessments made and the tasks used. Cavanaugh and Borkowski (1979) used a highly task-specific questionnaire while those used in the study by Kendall et al (1980) were derived from the more general metamemorial assessment questionnaire developed by Kreutzer et al (1975). Kendall et al (1980) therefore, concluded that "a limited set of memory experiences will elevate only task-relevant metamemory" (p. 269). Thus, this study suggests that even if metamemorial skills can be trained in the retarded (the study by Cavanaugh and Brokowski needs to be replicated using retarded subjects) these skills themselves may be task-specific. Brown (1978) has suggested that training of control processes "taking place on only one task produced information 'truly welded' (Shif, 1969) to that specific task" (p. 125). The present study suggests that this could also be the case for metacognitive awareness skills. This has lead Campione and Brown (1977) and Belmont and Butterfield (1977) to advocate task-specific strategy training on a variety of related tasks at the same time to ascertain

whether greater generalisation can be obtained in this way. Such a study has been conducted by Belmont, Butterfield and Borkowski (1978). However, since this study also included training in metacognitive skills it will be included in the next section.

The next studies to be discussed are by Brown and Barclay (1976), Brown, Campione and Barclay (1979) and Belmont et al (1978). These studies fall into the self-control classification described by Campione et al (1982). They suggest that in this type of training study "the child is instructed not only in the use of a strategy but also explicitly in how to employ, monitor, check and evaluate that strategy" (p. 425). This is what Brown and Barclay (1976) and Brown et al (1979) attempted to do. In the experiment by Brown and Barclay (1976), subjects were presented with a list of pictures equal to one and a half times their previously estimated span for picture lists.

Pictures were presented serially, with only one picture being visible at a time, but lists could be viewed in any order and as many times as the subject wished. Subjects indicated when they felt they were ready to be tested for recall. MA six and MA eight EMR subjects were initially divided into three strategy training groups. The first two groups received either anticipation or rehearsal strategy training, both of which Brown et al suggested encouraged a "stop-check-study-recheck" self-testing routine. The anticipation strategy training group were instructed to try to remember the name of a picture before they viewed it. The rehearsal group were instructed to break the list down into manageable subsets (ie three items or pictures) and to rehearse each subset individually. They were also instructed to continue rehearsal until they were quite certain they could recall all the items. The third group acted as a control, labelling the items as they appeared. Following training, three

post-tests were given, the first a day after training when the subjects were encouraged to continue using the trained strategy. The latter two post-tests were unprompted and given one day and approximately two weeks after the first post-test.

Both the MA six and MA eight subjects in the anticipation and rehearsal groups improved their recall on the first prompted post-test. However, on the unprompted post-tests both MA six groups recall did not differ significantly from their pretraining level. The MA eight group's performance on these post-tests declined slightly in comparison with their performance on the prompted post-test but was still significantly better than their pretraining level. Brown, Campione and Barclay (1979) retested these same subjects one year later. For the MA six groups, Brown et al (1979) were interested in whether prompting would influence these subjects' performance. If so, would this be continued in two further unprompted post-tests? For the MA eight group, interest lay in whether strategy maintenance would occur and if so whether evidence of generalisation could also be found.

Four post-tests were given during the maintenance phase of this experiment (conducted one year later), the first, second and fourth sessions being unprompted. The third post-test was prompted with subjects being reminded of the training they had received a year ago, whether it be anticipation or rehearsal (or labelling) and the subject being continually encouraged to use the originally trained strategy.

The results obtained for the MA six group were as expected, given the results obtained by Brown, Campione and Murphy (1977) with no evidence of strategy usage during any of the unprompted tests. However, a significant improvement in performance resulted from the prompted post-test. For the

MA eight group, performance was high on all four post-tests, suggesting that the effects of the original strategy training program had been maintained. In addition, prompting with regard to the value of the strategy, enhanced performance on the third and fourth post-tests.

Only the MA eight group participated in the generalisation phase, as there seemed little point in including the MA six group when they had failed to provide evidence of maintenance on all but the prompted post-test. In addition, a naive MA eight group was included to act as a control, to ascertain whether there was any difference between this group and the labelling (practice) group.

While the transfer tasks used in the previously described experiments have been very similar to the training task, Brown et al (1979) were attempting to obtain transfer of more general metacognitive skills and so they chose a generalisation task very different from the original serial recall task (a "far" generalisation task). This task was one of reading prose passages and then having subjects attempt to recall the gist of each passage. Brown et al suggested however, that this task required the same general "stop-check-study-recheck" strategy as the trained task. Another reason for choosing the recall of prose passages was the prevalence of this type of task in the normal school situation. Thus, the strategy had the potential of a wider impact rather than as a purely experimentally task-specific skill. Brown et al note that while the strategies of anticipation and rehearsal would be useful on a prose recall task, they would have to be modified considerably from their form in the original training task. This is a fact true of all generalisation tasks to some degree and is probably the main cause of the observed lack of generalisation in most studies. In this case, the subject would have to change

their rehearsal or anticipation of single items to chunks of text and also monitor more subtly their readiness for recall.

Subjects were presented with two stories to recall each day, for six days. They were informed that they could do anything they liked to help them remember the text and were provided with pencils, pens, felt pens, paper, string, a stopwatch, the three key words of each story on cards and a picture of the main action of the story. However, only on days three and four did the experimenter prompt the subject to make use of these items by saying "it helps some people to underline, mark the paper, look at pictures, take notes etc to check if they are ready for a test" (Brown et al, 1979, p. 507).

Brown et al found that the rehearsal and anticipation groups (mean recall 49% and 50% respectively) recalled more than the label and naive subjects (mean recall 35% and 37% respectively) on the gist recall task. They divided the texts into three levels of importance and found that in the anticipation and rehearsal groups, recall significantly increased as the level of importance increased. For the label and naive groups, however, recall only significantly increased from levels one and two combined to the most important level, level three.

Brown et al suggested that the pattern demonstrated by the anticipation and rehearsal groups was a more mature one similar to that found for third grade and older subjects (Brown and Smiley, 1977, 1978), while the label and naive groups demonstrated a more immature pattern evidenced by poor readers of normal intelligence, EMR children, and normal children in Grades one and two (Smiley, Oakley, Worthen, Campione and Brown, 1977). Brown et al also found that the anticipation and rehearsal groups spent significantly more time (103.7 secs and 105.6 secs respectively) before attempting recall than the label

and naive groups (57.6 secs and 62.4 secs, respectively). Brown et al made some attempt to assess whether anticipation and rehearsal subjects showed greater evidence of using a stop-check-study-recheck strategy. They included such observational evidence as "looking away and self-testing, repeating chunks of material over and over, and self-admonitions to stop and check before ceasing study activity" (Brown et al, 1979, p. 509). Using this type of classification system, they report that 67% and 64% of the anticipation and rehearsal groups, respectively, showed evidence of strategy usage compared to 40% and 29% for the label and naive groups, respectively.

Finally, Brown et al found little evidence of the aids to recall provided being used, even after prompting. From these results, Brown et al concluded that strategy transfer had taken place for the anticipation and rehearsal groups and this was attributable to their change in direction from training specific strategies to training more general problem-solving routines, involving self-testing.

Both this study and the study by Kendall et al (1980) represent experiments where generalisation of trained strategies has been achieved. Kendall et al trained a task-specific strategy but stressed the value of its use in other similar tasks and obtained transfer to a "near" (very similar) generalisation task. Brown et al (1979) trained task-specific strategies that they suggested encouraged a more general "stop-check-study-recheck" self-regulatory strategy and obtained generalisation to a "far" transfer task.

It can be suggested, however, that Brown et al provided ideal conditions for obtaining evidence of generalisation. Apart from the provision of many study aids, subjects were given preliminary training at gist recalling simple stories with all the features of gist recall being fully explained to them. In addition,

subjects also received pretraining at recording their recalls on a tape recorder. Their recalls were played back to them at the end of each recall attempt and they were asked if they had anything more to add. In other words, subjects were given some training with regard to the generalisation task. The anticipation and rehearsal groups may have been better able to profit from this training due to the more extensive training they had already received. In addition, it is difficult to judge the validity and reliability of the methods used by both Kendall et al (1980) and Brown et al (1979) to identify strategy users in their generalisation tasks. In fact, this point is acknowledged by Brown et al. It is interesting to note that, even without prior training in an anticipation or rehearsal strategy, 40% of the label group in the Brown et al study evidenced some observable indications of strategy usage.

The finding of generalisation in both studies is however, important. It is of interest to ask what these two studies might have in common that produced generalisation. Brown et al would suggest that it was the training received in self-regulatory skills. However, the Kendell et al study, used a task-specific strategy for training. Both studies did use strategy training programs that encouraged self-testing and elaboration of items to be recalled and the forming of some sort of relationship between the items.

The importance of these type of variables is reinforced by the findings of Belmont, Butterfield and Borkowski (1978). This study is also important because it provided training on two rather than just one task-appropriate strategy (as was mentioned previously). In this study, subjects were divided into two groups referred to here as the experimental and control groups, respectively. Both groups received training in the use of a task-appropriate

strategy for a serial memory recall task. This task was similar to that used by Butterfield, Wambold and Belmont (1973) and consisted of presenting seven items which the subject had to recall in the order 3/4 - the last three items first then the first four items, in the correct order in which they were presented. Subjects were trained to move quickly through the last three items but slowly through the first four items, rehearsing these latter items individually. In addition, the value of the strategy and how it worked was explained on each trial, thus self-regulatory skills were also reinforced.

Subjects were then presented with the same task but in a slightly altered format, 4/3 rather than 3/4 (i.e. they had to recall the last four items first then the first three items in correct order). During this period, the experimental group received further training on a task-appropriate strategy relevant to this slightly altered task. Again, the value of the strategy was reinforced and in addition, the similarities and differences between the strategies for a 3/4 and 4/3 format were explained.

Two weeks later, both groups were retested on the above tasks and also on two new tasks, a 2/5 recall task and a Probe Recall task. In this latter task subjects were required to decide whether a probe item was a member of a previously presented seven item list. This task was, Belmont et al suggested, a "far" generalisation task while the former was a "near" generalisation task.

Belmont et al found that both groups generalised the strategy trained from the 3/4 recall task to the 4/3 recall task. When retested two weeks later, they both also performed well on these tasks indicating maintenance of the trained strategy. However, only the experimental group performed well on the "near" and "far" generalisation tasks. Belmont et al suggested this was due to these

subjects having received training on two task-appropriate strategies and most importantly, information concerning the similarities and differences between these two strategies and why they were appropriate to each task.

Thus, it appears that generalisation of task-specific strategies can be successfully obtained if training on more than one task-specific strategy is provided and the similarities and differences between these strategies are highlighted. This is an interesting approach but further experimentation replicating the results of Belmont et al is required before firm conclusion can be made.

2.4.3 MENTAL RETARDATION AND SPONTANEOUS STRATEGY USAGE

Two other studies are of interest here. They are not training studies but are nonetheless valuable contributions to understanding the nature of the strategy deficiency in the retarded population.

In the first study by Ferretti (1982) who attempted to investigate so called "passive-memory" in retarded and nonretarded individuals. Passive memory relates to the structural or architectural aspects of the memory system, that is, those that cannot be influenced by the use of strategies. Early studies (e.g. Ellis, 1963) suggested that memory differences between retarded and nonretarded groups were due to a passive-memory deficit in the retarded. While later studies (such as those just discussed) have tended to conclude that it is in the use of strategic behaviour that the retarded are deficient, the debate as to whether a passive memory deficient exists has never been convincingly resolved. The studies supporting the passive memory deficit theory have, as Ferretti (1982) points out, many methodological problems, the most damaging being the lack of control for floor and ceiling effects, and the use of strategic behaviour by nonretarded subjects to aid retention. In

addition, the acquistion levels of both groups were never controlled for so a lower retention level by retarded subjects could be purely a reflection of lower acquistion levels, due to an inadequate knowledge base or nonstrategic behaviour at acquistion.

To conduct a study of passive-memory uncontaminated by these factors, Ferretti adopted a method used by Reitman (1971, 1974) where retarded and nonretarded subjects were prevented from rehearsing recall material by the intervention of a filler task between presentation and recall. The filler task was a signal detection task requiring detection of a pure tone against a background of white noise. Ferretti suggested that while this required little burden on memory, it did require "sustained vigilance". Subjects were informed that the signal detection task was the task of greatest importance, and to avoid rehearsal of the recall items as this might interfere with signal detection. The signal to noise ratio was adjusted for each subject individually, so that an accuracy level of between 67% and 78% was maintained by all subjects. The recall task used by Ferretti involved presenting items to be recalled after a zero, nine or twenty-seven second intervention period following the signal detection task. To prevent floor and ceiling effects and differential acquisition, the number of items presented on each trial and their exposure durations were adjusted for each subject individually. During the adjustment period, nonretarded and retarded subjects were initially presented with four and three consonants respectively, to recall with an initial exposure duration of four seconds per item for all subjects. For each successive trial in which recall was perfect, the exposure duration was reduced by half a second (unless it corresponded to the time required by a subject to read the items in which case it was reduced no further. If the exposure duration was reduced below the reading rate then presumably the subject would not have time to

encode all the items and this would affect performance). Then, testing continued until five consecutive perfect recall trials were achieved, at which point the set of consonants was increased by one. For each one consonant increase, the exposure duration was increased by half a second.

In this way, it was hoped that memory loads of approximately equivalent levels would be experienced by all subjects. The mean obtained load for nonretarded and retarded subjects was 7.04 and 4.96 consonants respectively, and the mean exposure duration was 2.94 and 3.21 seconds, respectively. In addition, surreptitious rehearsers were identified by comparing each subject's performance in the signal detection task with and without the additional presence of the recall aspect of the memory task. In other words, subjects were still presented with the recall items during the task, but were not asked to recall these items at the end of each trial. Seven analyses were used to identify rehearsers (see Ferretti 1982, for further information), and from these six nonretarded and nine retarded surreptitious rehearsers were identified.

Analyses of recall data revealed that nonretarded subjects evidenced superior recall to retarded subjects. However, if the surreptitious rehearsers in both groups were removed, the differences between them became negligible, suggesting that the passive-memories of nonretarded and retarded individuals were equivalent. Obviously, however, there are problems with this study. In attempting to avoid the problems of previous studies, Ferretti has been obliged to adopt measures which like the Kendall et al (1980) and Brown et al (1979) studies are of unknown reliability and validity. He himself states that the methods of identifying rehearsers and adjusting acquisition levels were "highly inferential, indirect and probabalistic" (Ferretti, 1982, p. 83). However, support for his findings comes from the study previously described by Brown et

al (1973). They found that nonretarded subjects prevented from rehearsing in a recall task evidenced accuracy and latency patterns similar to those of untrained nonrehearsing retarded subjects.

In another study, Belmont, Ferretti and Mitchell (1982), examined the spontaneous use of a task relevant strategy by retarded and nonretarded subjects. The task used was a self-paced memory task similar to that described in the study by Butterfield, Wambold and Belmont (1973), where subjects were required to recall the last few items first, and then the first items in each list. Like Ferretti (1982), Belmont et al (1982) attempted to make the difficulty of the task equivalent for both nonretarded and retarded groups. To do this, retarded subjects were given lists of seven letters to recall, while nonretarded subjects were given lists of eight words to recall. In addition, instructions for both groups varied, the nonretarded group receiving brief instructions via a tape recorder. In contrast, retarded subjects received three introductory practice lists where the rehearsal/recency strategy was progressively introduced. Retarded subjects were also instructed to describe this strategy prior to each experimental trial by pointing to the letter positions in the order they should be recalled (i.e. 5,6,7,1,2,3,4,). Belmont et al selected the following criteria for the identification of problem solvers. Firstly, both groups had to achieve a high, approximately equivalent accuracy level, for both rehearsal and recency items and secondly, they had to perform well on both parts of each list. These criteria had to be met for at least two adjacent lists and preferably not the first and second lists, as these followed immediately after training.

Those who met these criteria in the first and second lists only, were classified as "knowers" and were excluded from further analysis. Of a total of forty retarded subjects, four subjects were classified as "knowers", seven as

"solvers" and twenty-nine as "nonsolvers". Of thirty-two nonretarded subjects, one was classified as a "knower", twelve as "solvers" and nineteen as "nonsolvers". Belmont et al (1982) found that solvers in both groups evidenced superior recall, especially for the rehearsal items, which as Belmont et al point out, are the more difficult items to be recalled because of the delay between presentation and recall. Belmont et al also found that retarded and nonretarded solvers differed in their adoption of the task appropriate strategy. Nonretarded subjects showed no separation across trials of the adoption and use of the task-appropriate strategy while retarded subjects did. Apparently the adoption of the strategy preceeded its use by several trials for the retarded subjects. Belmont et al suggested that this was due to retarded subjects "engaging in protracted tactical refinements following their initial strategic insights" (p. 208) particularly with regard to the coordination of the rehearsal and recency aspects of the strategy. Butterfield et al (1973), it should be remembered, found that retarded subjects required training on both the rehearsal and recency aspects of the task plus instruction on how to coordinate these strategies. Belmont et al (1982) suggest that given a task of equivalent difficulty, nonretarded subjects would show a similar pattern of performance. Belmont et al also suggest that "roughly equal proportions of children in both ability groups failed to generate stable, appropriate strategies and hence failed to solve the problem" (p. 207). The proportions calculated by the present author are 72% (29 out of 40) and 62% (19 out of 32) for retarded and nonretarded subjects, respectively. If however, "knowers" are included in these groups, the proportions become 82% (33/40) and 63% (20/32) respectively. Knowers were those subjects who continued with the strategy on the first two trials following instruction, but discontinued its use thereafter. It is interesting to note that knowers are drawn primarily from the retarded group. This type of finding suggests that even when retarded subjects

spontaneously develop a task-appropriate strategy, they either do not monitor its effectiveness and thus quickly discard it or they discard it because it requires to much effort to maintain.

Belmont et al also examined the IQ scores (WISC) of the retarded subjects. They divided this group into solvers (which included the knowers) and nonsolvers and compared the two group's IQ scores. They found a marginally significant six point difference between these two groups. However, they also suggest that there was much overlap between the two IQ distributions. From this result, Belmont et al (1982) concluded that "problem solving in itself is unrelated to intelligence" (p. 207). They do however, predict that if both nonretarded and retarded groups had been given the same task, problem-solving differences would have been found.

As with the study by Ferretti (1982), there are problems with Belmont et al's (1982) investigation, most importantly the problem of comparison raised by attempting to give intellectually disparate groups different tasks of equivalent levels of difficulty. But then, problems are raised when the same task is given to intellectually disparate groups. Another problem with the study is that the retarded subjects were given a more detailed introduction to the problem than the nonretarded subjects. How many retarded subjects would have developed the task-appropriate strategy without these more explicit instructions, would be worthy of further investigation. However, the important point the study does make, is that retarded subjects are not necessarily nonstrategic but that there is an interaction between task complexity and intellectual capacity in strategy production. Given a task of equivalent complexity, nonretarded subjects might also appear nonstrategic.

2.4.4 MENTAL RETARDATION, STRATEGIES AND TASK COMPLEXITY

This finding of a relationship between task complexity and strategy usage can be related to the work of Bray (1979) who used a highly complex directed-forgetting task to investigate retarded and nonretarded differences in strategy production. In this task, paired items were presented in lists. At the end of the presentation of each list one item of a paired associate acted as a probe for the subject to recall its corresponding item. During some list presentations, cues were presented which indicated to the subject that all previous pairs would not be tested and so could be forgotten. This cue was a change in the colour of the background on which the items were presented. Subjects were told that when the background colour changed the previously presented items could be forgotten. However, not all lists contained this "to-be-forgotten" cue and so all paired associates had to be remembered until an actual cue was presented. Nonretarded adult subjects have been shown to spontaneously adopt strategies which prevent the to-be-forgotten items from interfering with the subsequent to-be-remembered items (Bjork, 1972; MacLeod, 1975). Bray (1979) writes "apparently, all items are rehearsed until a forget cue is given, but following a cue the rehearsal of to-be-forgotten items is terminated and all further processing is devoted to the subsequent to-be-remembered information" (p. 706). This is indicated by comparing cued-to-forget trials with trials on which no instructions to forget are given. For example, recall of two items to remember subsequent to two items to forget (F2 R2) should not differ from recall on a list of only two items to-be-remembered with no forget cue (F0R2).

Bray (1972) predicted that retarded subjects would perform poorly on this task because it is comparatively complex and requires the selective rehearsal of

items to be recalled. However, in two studies Bray (1972, 1973) found that retarded subjects were able to perform effectively on the task, suggesting that they were using a selective rehearsal strategy. Three further experiments conducted by Bray, Justice and Simon (1978) obtained the following results: 1) given no explanation of the cue-to-forget nonretarded subjects did not use an effective selective rehearsal strategy and thus performed poorly on the directed forgetting task; 2) given minimal instructions (the significance of the forget cue was explained once) nonretarded subjects disregarded the to-be-forgotten items and performed adequately on the task, and finally; 3) given these same (minimal) instructions retarded subjects' performance showed clear evidence of interference from the to-be-forgotton items. As mentioned previously, explicit instructions regarding the forget cue resulted in adequate performance by the retarded subjects. Bray (1978) conducted a further experiment in which task complexity was reduced and found that minimal instructions were sufficient to enhance retarded performance.

Thus, there appears to be an interaction between task complexity, the complexity of the instructions given and the ability to produce strategic behaviour. However, this is further complicated by another study by Bray, Goodman and Justice (1982). In this study, retarded subjects were divided into two groups, one receiving minimal instructions and the other explicit, detailed instructions, in which the cue-to-forget was repeatedly explained during one day of pretraining.

In addition, a pause-time measure was used to monitor the adoption of a selective rehearsal strategy. This is similar to that used by Butterfield et al (1973) where the subject controlled the duration of the interval between item

presentations. Bray et al found that none of the retarded subjects spontaneously used a selective rehearsal strategy, although the retarded subjects receiving explicit instructions showed no evidence of interference from the to-be-forgotten items and performed adequately on the task, while those in the minimal instruction condition performed poorly. Like Belmont et al, they concluded that given a task of suitable complexity or level of instruction, retarded subjects are able to spontaneously develop strategies and use them effectively but that these strategies may be different from those developed by nonretarded subjects in similar situations.

A similar result was obtained by Bizanz, Bizanz and Lefevre (1984) who used figural analogies to investigate the relationship between analogical reasoning and age. They conducted two studies using "dot" analogies. These consisted of a number of dots being presented in each of the four analogy terms, A, B, C and D. The B item would represent either an increase or a decrease in the number of dots presented in the A term. To be true, the C and D terms would need to have the same pattern of changes in dots as the A and B terms. For example, if the number of dots increased by four from the A to the B term then the number of dots would also have to increase by four from the C to D term. Bizanz et al suggested this type of analogy allowed the determination of the strategy used by the subject by examination of the pattern of responding for each analogy. Bizanz et al identified four strategies ; Magnitude and Direction, which took into account the number of dots changing from the A to B term and the direction of this change (i.e. an increase or a decrease); Direction only, which took into account only the direction of the change in dots; Magnitude only, which took into account only the number of dots increasing or decreasing but not the direction of the change; and All False which did not take into account either of the relevant dimensions of magnitude or direction and was where the subject said all or most of the analogies were

false. Bizanz et al stated this last strategy was completely nonanalogical.

In their first experiment, Bizanz et al obtained an interaction between age and sophistication of strategy, using four groups of subjects aged 9, 11, 13 and 29 years respectively. The majority of the 9 year olds, (60%), Bizanz et al found to be using the nonanalogical All False strategy. This compared to 31%, 13% and 0% for the 11, 13 and 19 year old groups, respectively. Conversely, 89% of the 19 year old group were identified as using the most sophisticated strategy Magnitude and Direction compared to 57%, 45% and 0% of the 13, 11 and 9 year old groups, respectively.

In their second experiment, Bizanz et al (1984) were interested in examining whether instruction in the use of analogical rules would lead to adoption of the most sophisticated strategy, Magnitude and Direction, by the 9 and 11 year olds previously identified as using an All False nonanalogical strategy. The instructions consisted of having the subjects verbalise the magnitude and direction of the changes in the pattern of dots from the A to the B term for eight practice analogies. Subjects were also required to justify their choice of response. Training continued until the subjects could perform these two aspects of the task consistently. Bizanz et al found that both groups were able to adopt a more analogical strategy, however few were able to adopt the most sophisticated Magnitude and Direction strategy (two out of eight subjects in each age group). Most subjects were found to be using the Magnitude only strategy, (four in the 11 year old group and six in the 9 year old group). Thus, it appeared that they were only taking into account one of the two relevant dimensions. This suggests that instruction may be only partially successful in producting more sophisticated strategy usage in developmentally younger and mentally retarded subjects.

To further investigate the type of strategy adopted by the retarded subjects, Bray, Dan and Gwartney (1978) conducted a study where the number of to-be-remembered items was varied from list to list while the number of to-be-forgotten items was held constant or vice versa. When the number of to-be-remembered items was varied there was no interference from the to-be-forgotten items. However, when the number of to-be-forgotten items was varied there was clear interference from these items on those to-be-remembered. Bray et al (1978) suggested that this was due to the retarded subjects being "heavily dependant on keeping track of the spatial-temporal location of the forget cue" (p. 714). Thus, they would wait to observe whether a cue-to-forget was presented before rehearsing presented items, rather than actively rehearsing items until a cue-to-forget was presented, as nonretarded subjects did.

These studies suggest that it is not necessarily the case that retarded individuals are nonstrategic, but rather that it depends on the complexity of the task and the extensiveness of the instructions provided. In addition, it appears that studies which encourage self-testing and elaboration are more likely to produce strategy generalisation to some degree (Brown et al, 1979, Kendall et al 1980). However, an over-emphasis on metacognitive and self-regulatory skills training in the absence of training on task-appropriate strategies (Brown et al, 1977) or an inadequate knowledge base (Chi, 1981) is likely to produce limited success. As Brown and Campione (1982) concede "a great deal of learning is context bound, and broad general transfer may be a chimera" further "although we agree that it might be possible to instigate a general <u>set</u> to be strategic to trouble shoot etc, one can only expect this attitude to be fully manifested in areas where the trainee has some expertise" (p. 222, Brown and Campione's emphasis).

Finally, as evidenced in the study by Kendall et al (1980), training to enhance

metacognitive skills in awareness may (as with the lack of transfer of trained control processes where such processes are only trained for one task) be relatively task or domain specific. However, further research is required in this area before any firm conclusions can be drawn.

2.5 CONCLUSION

Some general conclusions regarding the performance of mentally retarded subjects on cognitive tasks can be drawn from the results of the preceeding studies. Retarded subjects are identifiably different from nonretarded subjects in almost all types of cognitive tasks whether they be measures of the speed of cognitive processing in general or in terms of specific areas such as memory. They can be characterised as responding more slowly and less consistently than nonretarded subjects both as a group and in terms of individual subjects (Baumeister and Kellas, 1968; Nettelbeck, 1980; Nettelbeck and Brewer, 1981). They have greater difficulty in translating a stimulus into an appropriate response (Brewer, 1978; Brewer and Nettelbeck, 1977; Jensen, 1979, 1982a,b,; Kirby, Nettelbeck and Tiggerman, 1977; Kirby, Nettelbeck and Western, 1982; McConaghy, 1980; Nettelbeck and Brewer, 1976) and appear to be more affected by attentional and motivational factors (Krupski, 1977, 1979; Nettelbeck, Robson, Walwyn, Downing and Jones, unpublished manuscript; Zigler and Balla, 1981). Some of these factors, such as speed of processing and consistency, appear to be modifiable by extensive amounts of practice although this may depend on the complexity of the task (Phillips and Nettelbeck, 1984).

They appear to have a short-term memory deficit (Belmont and Butterfield, 1969; Ellis, 1963, 1970; Detterman, 1979; Spitz, 1970, 1973; Spitz and Webreck, 1972) although whether it is structural or functional in nature,

and whether it is just the symptom of an overall less efficient cognitive system is still under debate (Ellis, 1978). Retarded subjects appear to have greater difficulty encoding and organising information in memory and may also experience difficulty maintaining this information for any length of time or while conducting further cognitive processing.

Evidence also suggests that retarded subjects are less strategic although not nonstrategic in their approach to cognitive tasks (Brown, Campione, Bray and Wilcox, 1973; Butterfield, Wambold and Belmont, 1973). The strategies they use are often less complex and less efficient (Bray, Dan and Gwartney, 1978) than those used by nonretarded subjects and may be more affected by the complexity of the task (Belmont, Ferretti and Mitchell, 1982; Bray, Goodman and Justice, 1982). They also appear to be less aware of the need to be strategic and the positive value this approach can have on their performance level (Campione, Brown and Ferrari, 1982). Retarded subjects can be trained to use both task-specific and more general strategies successfully (Brown, Campione, Bray and Wilcox, 1973; Butterfield, Wambold and Belmont, 1973; Brown, Campione and Murphy, 1977) and to maintain their use overtime (Brown and Barclay, 1976; Brown, Campione and Barclay, 1979; Kendall, Borkowski and Cavanaugh, 1980). However, they appear less able to generalise the trained strategy to other appropriate situations unless prompts are given (Brown, Campione and Barclay, 1979; Kendall, Borkowski and Cavanaugh, 1980) or training is provided on more than one task and two related strategies are trained (Belmont, Butterfield and Borkowski, 1978).

The complexity of the task and the level of instruction provided also interacts with the use of strategies by retarded subjects (Bray, 1972, 1973, 1979). Minimal instructions which are sufficient for nonretarded subjects to

understand and perform the task can be shown to be insufficient for retarded subjects (Bray, 1978; Bray, Justice and Simon, 1978) especially it appears, when the task is complex.

All these factors can be expected to have an effect on the way the retarded subjects perform the analogy task used in this series of experiments. It might be expected that they will produce longer solution times and larger standard deviations. They may also find it difficult to encode and maintain this encoded information in short-term memory. The analogical reasoning task requires that already encoded analogy terms be held in short-term memory while processing of the remaining analogy terms proceeds. Retarded subjects may also require more explicit instructions and more practice with the task, because of its greater complexity. They may also use strategies that are less efficient than those used by nonretarded subjects. Before these factors can be investigated an understanding of RJ Sternberg's componential method is required. A detailed discussion of this method will therefore, be presented in Chapter 3.

CHAPTER 3

A DESCRIPTION OF STERNBERG'S COMPONENTIAL METHOD

3.1 INTRODUCTION

This chapter provides a description and discussion of the work of R.J. Sternberg (1977a, 1976, 1980a,b, 1984)) and the influence the componential mehtod has had on the direction of research in cognitive psychology, especially in the areas of intelligence and human information processing.

3.2 THE NATURE OF A COMPONENT

The fundamental unit of componential analysis is the component, which Newell & Simon (1972) first defined as being "an elementary information process that operates on internal representations of objects or symbols" (in Sternberg, 1980a, p. 574). Sternberg is flexible in his use of the label "elementary", suggesting that it depends on the level of theorizing of interest. Thus, a component does not have to be the most basic or elementary in the system. Similar to S. Sternberg's (1969) assumption that stages may be composed of a set of processes, R.J. Sternberg (1980a) suggests that the components in his model may consist of subcomponents but that these subcomponents are of less theoretical interest and of less information value then the less elementary components they combine to form.

A component is postulated to have three quantifiable properties (1) duration, (2) difficulty (ie probability of making an error) and (3) probability of execution, all of which are, at least in principle, independent of each other. However, it is quite possible that level of difficulty

and duration are interdependent in some cases, with processes of greater difficulty being of longer duration. Also, level of difficulty and probability of execution may be interdependent on occasions with a more difficult process being less likely to be executed because of the greater effort involved. In Sternberg's methodological approach the first two quantifiable properties are the solution times and error rates obtained in given task situations. The last quantifiable property can not be obtained in the original formulation of Sternberg's methodological model.

Sternberg (1980a) proposes a hierarchial structure of components classified in terms of function and level of generality. The functional classification forms the structure of most interest with components being divided into five types (1) metacomponents, (2) performance components, (3) acquisition components, (4) retention components and (5) transfer components.

(1) Metacomponents are higher order control processes used in executive planning and decision making. These are the components that control all other components, with all control passing directly from the metacomponents to the other types of components and all information passing directly from these latter components to the metacomponents.

Therefore, the performance, acquisition, retention and transfer components can only activate and receive information from each other indirectly via the metacomponents. Metacomponents, however, are able to activate and communicate with each other and the other components directly. This relationship is represented in Fig 3.1. Sternberg views the metacomponents as central to his model and to understanding the nature of intelligence. This view

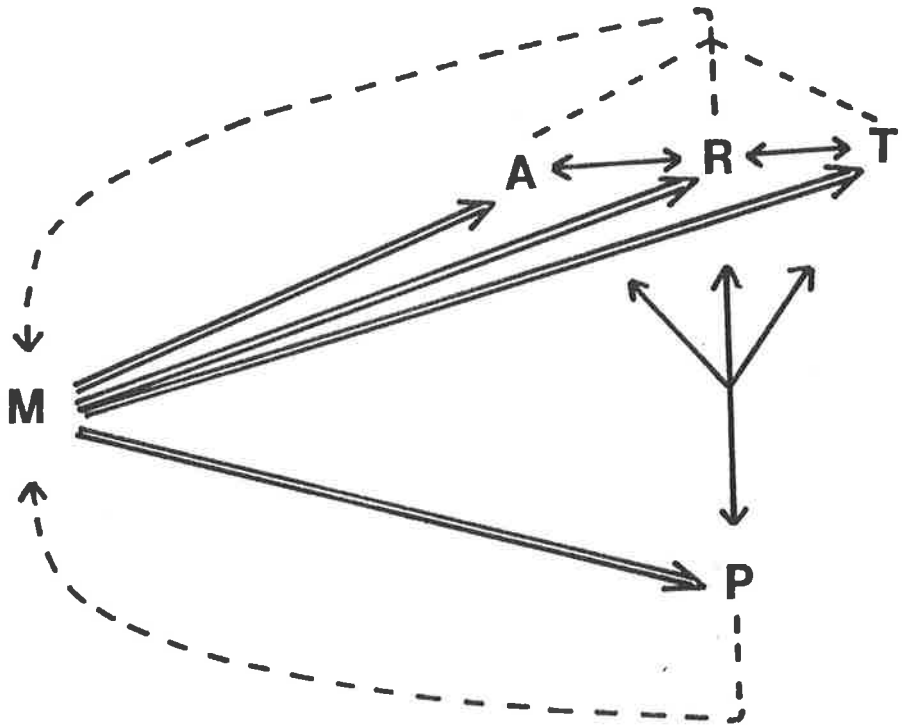


Figure 3.1 Relationship between each type of component in Sternberg's model of intelligence (Reproduced with permission from R.J. Sternberg, 1980a, Fig. 1, p. 578).

M = Metacomponents
P = Performance components
A = Acquisition components
R = Retention components
T = Transfer components

Direct activation of one type of component to another is represented by solid arrows.
Indirect activation of one type of component to another is represented by solid single arrows.
Direct feedback from one type of component to another is represented by single broken arrows.
Indirect feedback from one type of component to another is represented by solid single arrows (i.e. the same as for indirect activation).

is held by others as mentioned in Chapter 2. Little research by Sternberg, to date, however, has been concerned with the metacomponents due to the difficulty of developing tasks which make these components quantifiably identifiable.

(2) Performance components are used in the execution of a particular task and therefore are the components most easily quantifiable and on which most research has been carried out. The components encoding, inference, mapping and application identified in the People Piece Analogy experiment carried out by Sternberg (1977a) which will be discussed in greater detail subsequently are examples of performance components.

(3) Acquisition and (4) Retention components are involved respectively in the learning and retrieval of information from memory. (5) Finally, transfer components are involved in the generalisation of information from one task situation to another.

While Sternberg (1980a) states that he has some suggestions as to what these final three components might be, they are fairly recent inclusions in his model, with little research having been done on them. What these three components add to the componential subtheory of intelligence is a necessary link with memory that any model wishing to be accepted as a general and widely applicable model of intelligence or cognition must have. It would seem parsimonious to include the acquistion and retrieval components under a single category. These two components have a requirement for access to long-term memory in common and might best be referred to as memory access components. Sternberg (1984) himself has recently referred to these components under the one heading, calling them knowledge acquisition components. From recent research by Campione and Brown (1978) and Butterfield and Belmont (1977) it does appear that the transfer component

might best be subsumed under the category of metacomponents. Campione and Brown (1978) state "The results from a large number of experiments lead us to the conclusion that a hallmark of intelligence is the ability to generalise (transfer) information from one situation to another, and that this ability in turn depends on effective 'executive control'" (p. 139).

Sternberg also postulates another type of component classification, that of level of generality. He proposes three levels of generality, general, class and specific. General components are those required in all tasks. For example, the encoding component is clearly a general component; for any information to be processed it must first be encoded in some way. A class component is one which occurs in at least two tasks. For example, the mapping component is one whose occurance is confined to induction type tasks such as analogies. A specific component is one which occurs in only a single task. Sternberg (1980a) has critizised the information processing approach for producing experimental tasks which require task specific components to be executed and therefore whose results are not generalisable to other task situations. Sternberg suggested that none of the components he proposes to explain analogical reasoning are task-specific.

The above type of classification differs from that previously mentioned in that it refers to the frequency of occurance of a particular component in actual tasks rather than to the hierarchial nature of its function. Thus, the other refers to quality of function while this classification refers to quantity of occurance. On consideration, some components might prove more difficult to classify in terms of level of generality, than others. For example, in a general sense, the response component belongs to the group of general components, if both covert and overt response types are taken into account. However,

if only overt responses are accepted (as is the case in most psychological experimental research) then clearly the response component can belong to the set of class components. This type of classification problem suggests that this distinction is of limited value, and indeed, Sternberg (1980a) is vague in his explanation for its existence, except to suggest that components need to be of a general or class type to be worthy of investigation and to propose that metacomponents have a much higher proportion of general components among them, than do any of the other types of components.

Sternberg has presented a theory based around a basic unit of processing, the component. He provides a framework in which the component can be qualitatively and quantitatively identified, which is well articulated and in most cases unambiguous. In addition, he has provided interconnections between these two types so the theory can exist as a united whole. The theory now needs to be tested so that its applicability to the real nature of cognitive processing and intelligence can be ascertained. Sternberg has constructed a methodology to test the componential subtheory of intelligence and a presentation of it as it relates to this thesis follows.

3.3 THE METHODOLOGY OF COMPONENTIAL ANALYSIS

This description is drawn from Sternberg (1977a) on which the research in this thesis is based. Sternberg (1979, 1980a,b, 1984) has in more recent times expanded on the number of tasks and methods used for data collection, but the basic principles on which all these methods rest remain essentially unchanged. Sternberg (1977a) has described his method as a componential analysis of human intelligence whose overall purpose is to identify the components that underly intelligent behaviour and to discover how these components are organised in terms of their relationships with each other. The types of components to be discussed here are performance components.

The componential method gives provision for both intensive and extensive task analyses. An intensive task-analysis is one which identifies the components utilized in a particular task while an extensive task-analysis integrates the findings of a series of intensive task-analyses in a number of different experiments thus validating the identified components. An intensive task-analysis consists of two parts, internal and external validation. Internal validation separates task performance into its underlying components. External validation investigates individual differences within and across the components identified by internal validation. The analyses performed in this thesis are concerned in the main with the internal validation aspect of the intensive task-analysis.

3.3.1 FOUR MODELS OF ANALOGICAL REASONING

Sternberg (1977a) carried out research using figural, verbal and geometric analogies. However, only the work pertaining to figural analogies will be considered, as only these analogies were used in this thesis. In addition, only those components relevant to a true/false format will be discussed (for information about the components used in a forced choice format see Sternberg and Rifkin, 1979).

An analogy consists of four terms usually referred to as A, B, C, and D, where a relationship exists between the C and D terms which is isomorphic to the relationship between the A and B terms. This produces a higher order relationship relating all four terms together such that A is to B as C is to D. Sternberg (1977a) suggests that to solve an analogy of the type described above, five mandatory information processing components must be performed. The first component process is encoding. Here, the stimulus is translated into an internal representation on which further internal transformations can be

performed. The internal representation is postulated to consist of a configuration of the attributes which make up the four terms of the analogy. This component is labelled an attribute - identification component.

Three further components, are proposed by Sternberg these being inference, mapping and application, and they are labelled attribute-comparison components. Inference is the process that relates the A and B terms of the analogy. Similarly, application is the process that relates the C and D terms of the analogy, and in addition verifies the D term as true or rejects it as false. Mapping requires the discovery of the rule which interrelates the two parts of the analogy i.e. the relationship between the A and B terms and the the C and D terms. Most previous theories of analogical reasoning do not include a mapping component. However, Sternberg (1977a, 1977b) found that mapping made a statistically significant contribution to the percentage of variance accounted for by his data. The final component is preparation-response, which includes preparing to solve the analogy, translating the solution into a response and monitoring the response process.

These components are postulated to combine in an additive way. Thus, a simple linear model can be used to predict solution times. Four linear models were devised and presented as alternative explanations for the combination of components. Schematic flow charts of each model are presented in Figures 3.2. to 3.5. Model I is a completely exhaustive model (Figure 3.2). The attribute comparison components, inference, mapping and application are all exhaustive processes with each attribute in each analogy term being processed by each component, irrespective of whether the first or last attribute identifies the analogy as true or false.

For explanatory purposes, the four binary attributes used to construct the

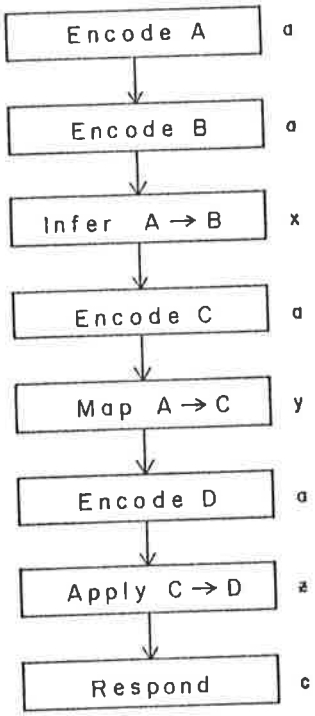


Figure 3.2 Schematic flow chart of Model I (Reproduced with permission from R.J. Sternberg, 1977a, Fig. 6.2, p. 139).

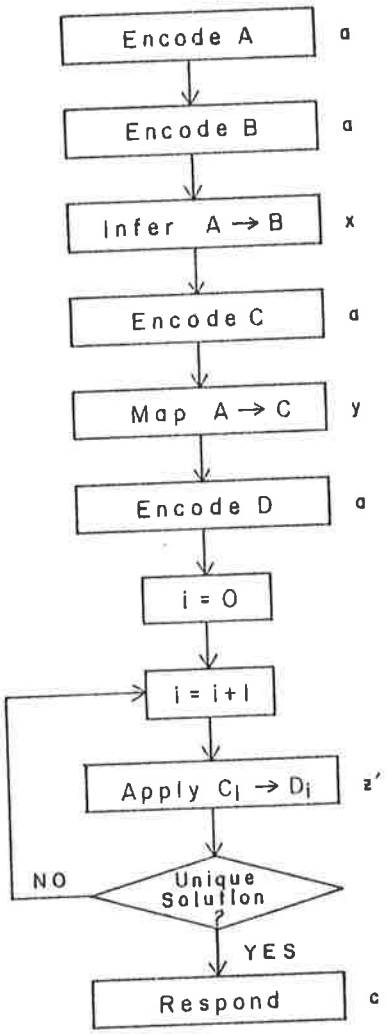


Figure 3.3 Schematic flow chart of Model II (Reproduced with permission from R.J. Sternberg, 1977a, Fig. 6.3, p. 140).

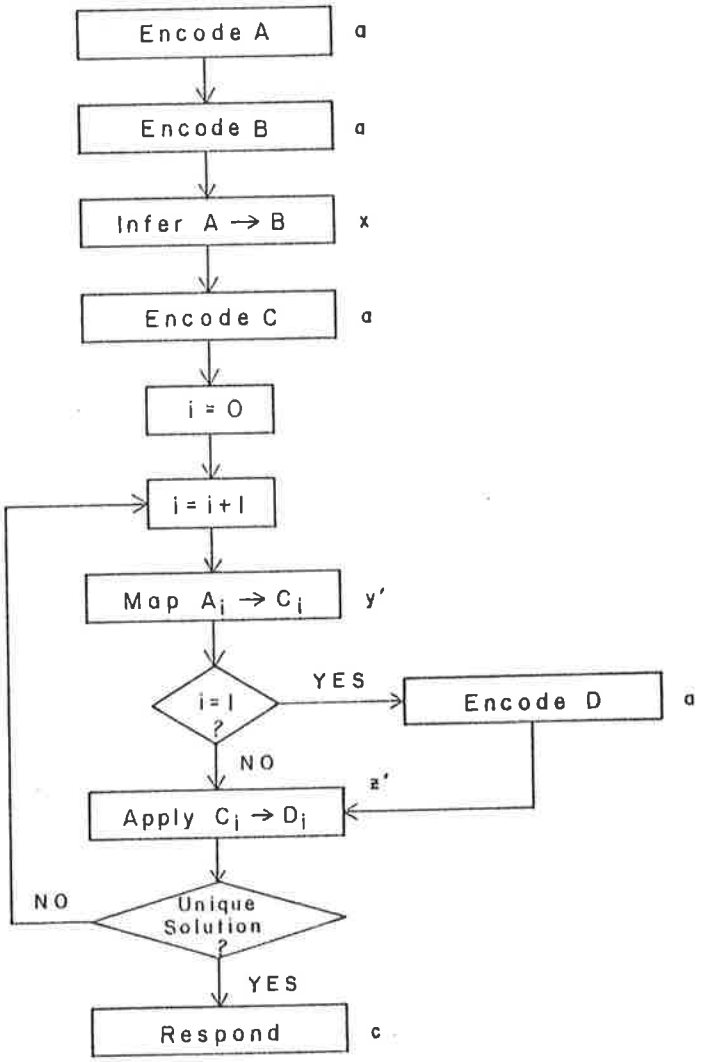


Figure 3.4 Schematic flow chart of Model III (Reproduced with permission from R.J. Sternberg, 1977a, Fig. 6.4, p. 141).

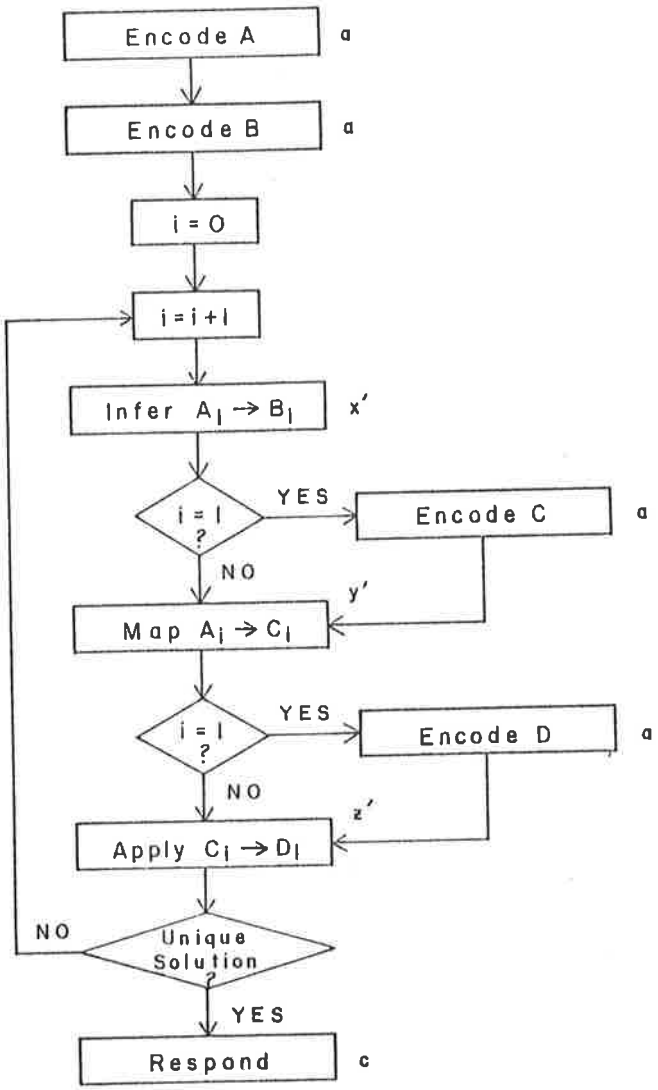


Figure 3.5 Schematic flow chart of Model IV (Reproduced with permission from R.J. Sternberg, 1977a, Fig. 6.5, p. 142).

analogies in the People Piece Analogy experiment will be described here. These were height (tall, short), weight (fat, skinny), colour (coloured in, not coloured in) and sex (male, female). Examples of these analogies are presented in Figure 3.6 (a)-(d). Figure 3.6 (c) will be used to explain the models. For example, in Model I, the subject begins analogy solution by encoding the first term of the analogy ie [height-tall]; [weight - skinny]; [colour - coloured in]; [sex - male] and then the second term [height - tall]; [weight - fat]; [colour - not coloured in]; [sex - female] and then infers the relationship between these two terms (ie both figures are tall and skinny however, one is coloured in and male while the other is not coloured in and female). The subject then encodes the third term of the analogy ie [height - short]; [weight - skinny]; [colour - coloured in]; [sex - male] and maps the relationship between the first and third terms (ie that the two figures are the same except that one is tall and one is short). Finally, the subject encodes the D term of the analogy ie [height - short]; [weight - skinny]; [colour - not coloured in]; [sex - female] and then applies the relationship previously inferred from the A and B terms to the C and D terms. If this proves isomorphic (as it does in the example described in Figure 3.6 (c)) the subject responds true. If not, the subject responds false. Thus, in this model all attributes of each figure are encoded, inferred, mapped and applied, that is they are all processed exhaustively. The three following models vary in the degree to which the attribute comparison processes, inference, mapping and application are proposed to be exhaustive or self-terminating.

In Model II, (Figure 3.3) all attributes are processed exhaustively by the inference and mapping components, but application becomes self-terminating, with only as many attributes being applied as are needed for analogy solution.

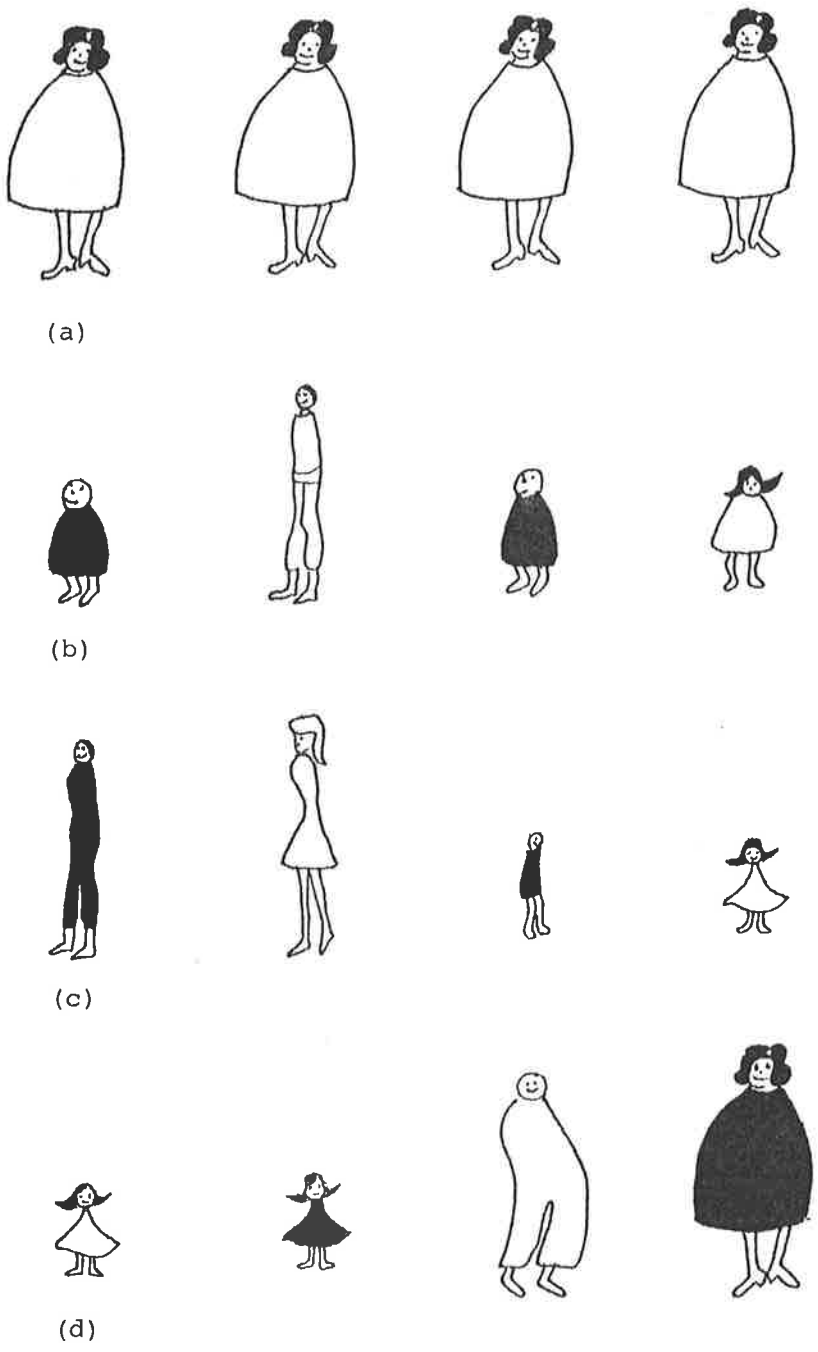


Figure 3.6 Examples of the People Piece Analogy Figures used by Sternberg (Reproduced with permission from R.J. Sternberg, 1977a, Fig. 7.2, p. 180).
(a) Degenerate
(b) Semidegenerate (A:A::B:B)
(c) Semidegenerate (A:B::A:B:)
(d) Nondegenerate

In Model III (Figure 3.4) both mapping and application become self-terminating. Thus all attributes would be encoded and inferred from the A to B terms and then the C term would be encoded. Subsequently, however, only one attribute would be mapped and after encoding of all attributes comprising the D term, it would be applied. If this attribute yielded a solution, the subject would respond true or false, if not, then another attribute would be mapped and applied and so on until a solution was reached.

In Model IV, (Figure 3.5) inference, mapping and application all become self-terminating. The subject infers, maps and then applies only as many attributes as are required to reach a solution of true or false.

Encoding is exhaustive in all four models. In the self-terminating models, Sternberg (1977a) has proposed an "attribute-counter" so that each term (with all its four attributes) is encoded only once but each attribute can be inferred, mapped and applied as many times as is required, to yield a correct solution. The attribute-counter is set at zero and is incremented by one when the first attribute is processed in a self-terminating fashion. The system then enters a processing loop with the counter being incremented by one each time an attribute passes through it. Once the attribute-counter is set at greater than one, attributes passing through the loop are not re-encoded.

In Model II, this loop is only set in motion, after the encoding of the fourth term of the analogy (Figure 3.3). In Model III, it commences after the encoding of the third term of the analogy (Figure 3.4). The subject then maps an attribute from the A to the C term and on completing this, encodes the D term and applies the mapped attribute. If a solution is reached, a response is made. If not, the subject returns to the start of the loop and maps another

attribute. However, as the attribute counter is now set at greater than one, the D term is not re-encoded. In Model IV, the loop is set in motion after the encoding of the second term with the third term being encoded only after an attribute has been inferred from the first to the second analogy term (Figure 3.5). The D term is only encoded after the inferred attribute has been mapped. Thus, the purpose of the attribute counter is to prevent terms already encoded from being re-encoded in subsequent passes through the loop.

3.3.2 THE BASIS OF COMPONENT PARAMETER ESTIMATION

The inference, mapping and application components are estimated by the number of attributes that change from the A to the B term and from the A to the C term of each analogy. For example, if height changes from tall in the A term to short in the B term for a particular analogy, but all other attributes, weight, colour and sex remained unchanged, then the inference component will equal one for that analogy. If in another analogy, height changes from tall in the A term to short in the B term and sex changes from male to female, but colour and weight remained unchanged, then inference will equal two, since there are two attribute changes between the A and B terms of that analogy.

The same process occurs for mapping except the number of attributes changing from the A to the C term of each analogy are used. Application is identical in number of attribute changes to the inference component, since for an analogy to be true, the same changes that occur between the A and B terms must occur between the C and D terms of each analogy.

An analogy may be false by one, two, three or four attributes. For example the D term might be correct in three attibutes - the correct weight, colour

and sex but be incorrect by one attribute - height. Alternatively the D term might be incorrect by all four attributes, height, weight, colour and sex. In this case it would share no attributes in common with the correct form of the D term, labelled D', if the analogy were true.

The self-terminating parameter estimates for inference and mapping are calculated by the formulae :

$$f' = \frac{(N + T)}{(N - h + 1)} \times \frac{(f)}{(N)} \quad \text{for inference}$$

and

$$g' = \frac{(N + T)}{(N - h + 1)} \times \frac{(g)}{(N)} \quad \text{for mapping}$$

Where N = the total number of attributes; T = the truth index (O = true; 1 = false); f = the number of attributes changed from the A to B terms; g = the number of attributes changed from the A to C terms and; h = the number of D attributes correctly matched to D' (the form the D term of the analogy would take if it were true). Thus each component is calculated separately for each analogy depending on the combination of attribute changes from the A to B and A to C analogy terms, and the truth or degree of falsity of that particular analogy.

Also integral to the estimation of component parameters is the precueing method. The general strategy in precueing is to give the subject progressively greater amounts of prior information in the first half of each trial, so that successively less information and therefore less processing, is required in the second half of the trial. The assumption is that while subtasks entail the

progressive removal of processes, the nature of the task as a whole is not altered. The method of precueing was first pioneered by Johnson (1960, 1962) who used it to separate the presentation of verbal analogy problems into two phases, so that difficulty could be attributed either to the inductive operation of the first phase or the deductive operation of the second phase. Sternberg (1977a) adopted this method so that an initial composite task and three subtasks, each requiring progressively less processing could be constructed.

The composite task, as in an ordinary analogy involved the presentation of all four analogy terms. The first subtask consisted of presenting the A term in a precueing situation in the first half of the trial and the full analogy in the second half of the trial. The second subtask consisted of presenting the first two analogy terms in the first half of the trial and then the full analogy in the second half of the trial, and the third subtask consisted of presenting the first three analogy terms prior to the appearance of the full analogy, in the second half of the trial. See Figure 4.2(a)-(d), Chapter 4, for examples of the precueing method.

The precueing method provides two functions (1) a means of estimating the encoding parameter and (2) a way of separating the inference and application component parameters in Models I and IV so that they are not confounded. For example, if zero terms are precued, then the encoding parameter equals four, since no terms have been presented in the first half of the trial. If the A term is precued, encoding equals three. If the A and B terms are precued, encoding equals two and if the A, B and C terms are precued, encoding equals one, the last term of the analogy. With regard to the separation of the inference and application parameters, where two and three analogy terms are precued, inference becomes equal to zero since presumably it has occurred

during the first half of the trial when the A and B terms of the analogy were encoded. Application, however, remains at the number of attribute changes between the C and D terms (i.e. equivalent to the number of attribute changes between the A and B terms if the analogy is true). In the 0 and 1 cue conditions, where zero and one terms are precued respectively, inference and application remain confounded and inseparable. This means that these parameters will in general, be more highly correlated with each other than with the other components and in comparison to any correlations between any of the other components.

Two problems might arise from the precueing method. First, the nonequivalence of composite and subtasks and secondly a memory load problem. With respect to the first problem, it is possible that the precueing procedure changes the way in which subjects process the analogies. The latter would mean that parameters did not drop out in successive subtasks. With regard to this second problem, it is assumed that when one, two or three analogy terms are precued, the attendent processing components are carried out and are not carried out again in the second half of the trial. This implies that the results of this processing must be held in memory to be retrieved when the information regarding the second half of the trial has been extracted. It is conceivable that when, for example, two terms are precued, information in memory regarding these two terms, may be lost, given the large amount of processing still required in the second half of the trial.

3.3.3 TYPES OF ANALOGIES

In addition to the parameter dropouts due to precueing, three types of analogies were constructed which corresponded to varying degrees of parameter dropouts. The three types of analogies were labelled degenerate,

semidegenerate and nondegenerate by Sternberg (1977a). Examples of each type of analogy are presented in Figure 3.6 (a)-(d).

Degenerate analogies (Fig. 3.6 (a)) were items where no attribute changes between the A and B and A and C terms occured. Thus if this type of analogy were true all four analogy terms would be identical. If it were false, the last term would have one, two, three or four attribute changes from the first three figures, depending on the degree of falsity of the item. Thus this type of analogy could be described as of the form A:A::A:A if true and A:A::A:B if false.

Semidegenerate analogies took two forms. In the first form the attribute changes between the A and B terms would equal zero and in the second form the attribute changes between the A and C terms would equal zero, thus taking the forms A:A::B:B and A:B::A:B respectively. (Sternberg provides an example of only one of these forms, the second form shown in Figure 3.6 (b)). If the analogy were true, the D term would be isomorphic to the C term in the first form and identical to the B term in the second form. If it were false, the D term would differ from the C term in the first form or the B term in the second form by one, two, three or four attributes, again depending on the degree of falsity of the item.

The degenerate and semidegenerate analogies were originally included by R.J. Sternberg (1977a) to provide a zero baseline for parameter estimation. However, they are not in any sense "real" analogies. The extraction of a higher order relationship between the two parts of the analogy is not required in the solution of these types of analogies.

Nondegenerate analogies were items where attributes changed from the A to the B term, the A to the C term and from the C to the D term. Thus they can

be considered "real" analogies, with the form A:B::C:D (Figure 3.6(d)). In true or false items, the D term would not match any of the other analogy terms so the higher order relationship would need to be extracted. If the D term were false, its constituent attributes would differ by one, two, three of four attributes from the true form (D') of the analogy.

Two factors controlled the number of combinations of attributes allowable from the A to B, A to C and D to D' terms, in each type of analogy (1) that analogies must be unidirectional and (2) that analogies must not be falsifiable until the D term had been processed. Sternberg (1977a) explains that a unidirectional analogy is one in which the direction of the attribute change matters. For example, if sex changes from male to female in the A and B terms, then sex must change from male to female in the C and D terms, to be true. It cannot change from female to male. If it did so, subjects could falsify the analogy before processing the D term. If sex didn't change from the A to B term, then it would not matter whether it changed from the C to D term if it were a false item. However, if it were a true item, sex would have to remain unchanged in the C and D terms also. Thus the total number of allowable attribute changes from the A to the B term and from the A to the C term taken together could not exceed four. This allowed 15 possible attribute change combinations between the A and B and A and C terms for all types of analogies, decomposing into one combination for degenerate analogies, eight for semidegenerate analogies and six for nondegenerate analogies. These combinations are presented in Table 3.1.

The number of attribute changes from D to D' was independent of the number of attribute changes between the AB and AC terms. D could consist of zero, one, two, three or four attribute changes from the true D' form, making a

TABLE 3.1

15 ATTRIBUTE CHANGE POSSIBILITIES

FROM THE A TO B AND A TO C ANALOGY TERMS

Number of Changes from A to B Analogy Terms	Number of changes from A to C Analogy Terms	
0	0	Degenerate Analogies
1	0	
2	0	
3	0	
4	0	
0	1	Semidegenerate
0	2	Analogies
0	3	
0	4	
1	1	
1	2	
1	3	Nondegenerate
2	1	Analogies
2	2	
3	1	

total of five DD' attribute change possibilities. Half the analogies constructed by Sternberg (1977a) were true and half were false, with equal numbers of one, two three and four attribute changes in the false items.

Thus the 15 attribute change possibilities combined with the 5 D to D' attribute change possibilities made a total of 75 different analogy types, with 15 of these types being true and 60 being false (15 at each of the zero, one, two, three or four attribute change possibilities between D and D'). Therefore, parameter estimation and multiple regression were based on 300 data points, each data point representing a different type of analogy (15 change possibilities between AB and AC analogy terms x five attribute change possibilities between D and D' x four precue conditions).

3.4 A DESCRIPTION OF THE PEOPLE PIECE ANALOGY EXPERIMENT

The methodology just described was first used by Sternberg (1977a, 1977b) in the People Piece Analogy experiment and was subsequently used with verbal and geometric analogies, with slight modifications required by the change in stimuli (Sternberg 1977a).

3.4.1 EXPERIMENTAL DESIGN

The experimental stimuli in the People Piece Analogy experiment were Elementary Science Study (ESS) People Pieces, drawings of figures varying in four binary attributes : height (tall, short); weight [1] (fat, skinny); colour (red, blue) and sex (male, female) See Figure 3.6 for examples of these figures. The analogies were presented using a three-field tachistoscope and in a true/false format. Internal validation was accomplished by predicting solution times and error rates and by testing their correspondence to the four models of analogical reasoning previously described. 16 subjects were selected

from an initial testing session which covered three main areas, reasoning, perceptual speed and vocabulary. The ability tests were especially constructed by Sternberg for use in the experiment but he states they were similar to the items found on Thurstone's (1938) Primary Mental Abilities Test. Four subjects had high perceptual speed and reasoning scores, four subjects had high reasoning and low perceptual speed scores, four subjects had high perceptual speed and low reasoning scores and four subjects had low reasoning and perceptual speed scores.

The same 288 analogies were presented to each subject in each session, there being four sessions so that each analogy could be presented in each of the four precueing conditions. These analogies consisted of 16 degenerate analogies, 128 semidegenerate analogies, (64 in each form) and, 144 nondegenerate analogies. The 288 analogies combined with the four cue conditions made a total of 1152 analogies. Presentation of the 288 analogies was divided into four blocks per session, each block consisting of a different cue condition so that each cue condition was presented during each session. The order was balanced both within and between sessions in a Latin Square arrangement. Analogy form was balanced across but not within subjects, thus form order remained the same for a given subject throughout the four sessions. Errors were repeated at the end of each block until correctly solved. This was necessary for the mathematical modelling procedure, so that for the 300 data points to be plotted there were no empty cells.

---

1 Note. Sternberg (19771) refers to this attribute as girth. I found it simpler to describe this attribute as weight, especially with retarded subjects. In more recent experiments (Sternberg and Rifkin, 1979) Sternberg also refers to this attribute as weight.

3.4.2 RESULTS

The results were divided into those for interval scores, component scores, and error rates. Interval scores were mean response times for subjects in the individual cue conditions, and consisted of two types, cue times and solution times. Cue times and solution times were the mean response times for the first and second parts of each trial, respectively. The calculation of the interval scores formed the basis for the test of additivity. Sternberg (1977a) suggested that the additivity assumption held "if the cue conditions truly captured successive intervals of processing" (p. 183). If the cue conditions changed the nature of the task in some way then the additivity assumption would break down.

The assumption made constrasting predictions for the cue and solution times. For the cue scores it was assumed that when one term was precued the corresponding cue score (C1) would contain all the processes found in the composite task where no terms were precued (CO), plus additional processes ; when two terms were precued the corresponding cue score (C2) would contain all the processes contained in C1 (and therefore the composite task cue score, CO) plus additional processes and that; when three terms were precued the corresponding cue score (C3) would contain all the processes in C2 (and therefore C1 and CO) plus additional processes. In contrast, it was assumed that S2 (the solution scores to the two precued terms condition) contained all the processes included in S3 (where three precued terms were presented) plus additional processes. That S1 contained S2 (and therefore S3) plus additional processes and that SO (solution scores to the composite task) contained S1 (and therefore S2 and S3) plus additional processes. Sternberg found that cue scores increased and solution scores decreased as the number of precued figures increased, thus providing support for the assumption of additivity.

Sternberg used the simplex model to statistically test whether the additivity assumption held for his data. The simplex model consisted of constructing a correlation matrix using the solution times obtained from each cue condition. If the assumption of additivity was met, then the correlations near the principle diagonal of the correlation matrix would be highest and would reduce monotonically as they moved away from the principle diagonal. Sternberg found that the correlations for solution times all showed simplical structure, with no breakdowns and thus he considered that the assumption of additivity had been met.

The component scores were derived using linear multiple regression. The method of deviation has been described in detail previously. Solution times for the 300 data points formed the criteria to be predicted, with each point representing a different analogy type. There were at least two (and as many as twelve) analogy items for each analogy type.

Table 3.2 presents the basic equations for Models I, II, III and IV. All parameters enter into the equation in the 0 cue condition in each model. The subject must encode all four analogy terms, plus perform the inference, mapping, application and preparation-response processes in the second half of the trial. In the 1 cue condition, only one change is made, encoding becomes equal to three as it is assumed that the A term has been encoded during precueing. In the 2 cue condition, the encoding parameter reduces to the two as it is assumed that the first two analogy terms, A and B, have been encoded during precueing and the inference parameter also drops out. In the 3 cue condition, there is only one term left to encode as the first three analogy terms have been encoded during precueing and both the inference and mapping parameters also drop out.

In Model I, all parameters are exhaustive. In Models II, III and IV application,

TABLE 3.2

MATHEMATICAL EQUATIONS FOR EACH OF THE FOUR PROPOSED MODELS OF ANALOGICAL REASONING

Model I

0 cues	ST_0	=	4a	+	fx	+	gy	+	fz	+ c
1 cue	ST_1	=	3a	+	fx	+	gy	+	fz	+ c
2 cues	ST_2	=	2a	+		+	gy	+	fz	+ c
3 cues	ST_3	=	a	+		+		+	fz	+ c

Model II

0 cues	ST_0	=	4a	+	fx	+	gy	+	f'z'	+ c
1 cue	ST_1	=	3a	+	fx	+	gy	+	f'z'	+ c
2 cues	ST_2	=	2a	+		+	gy	+	f'z'	+ c
3 cues	ST_3	=	a	+		+		+	f'z'	+ c

Model III

0 cues	ST_0	=	4a	+	fx	+	g'y'	+	f'z'	+ c
1 cue	ST_1	=	3a	+	fx	+	g'y'	+	f'z'	+ c
2 cues	ST_2	=	2a	+		+	g'y'	+	f'z'	+ c
3 cues	ST_3	=	a	+		+		+	f'z'	+ c

Model IV

0 cues	ST_0	=	4a	+	f'x'	+	g'y'	+	f'z'	+ c
1 cue	ST_1	=	3a	+	f'x'	+	g'y'	+	f'z'	+ c
2 cues	ST_2	=	2a	+		+	g'y'	+	f'z'	+ c
3 cues	ST_3	=	a	+		+		+	f'z'	+ c

Symbol Defintions

ST_i	=	solution time i
a	=	exhaustive figure scanning and encoding time
x	=	exhaustive inference time
y	=	exhaustive mapping time
z	=	exhaustive application time
x'	=	self-terminating inference time
y'	=	self-terminating mapping time
z'	=	self-terminating application time
c	=	constant preparation and response time
N	=	total number of features
T	=	truth index (0 = true; 1 = false)
f	=	number of features changes from A to B
g	=	number of features changed from A to C
h	=	number of D features correctly matched to D'
f'	=	$[(N + T)/(N - h + 1)] \times (f)/(N)$
g'	=	$[(N + T)/(N - h + 1)] \times (g)/(N)$

mapping and inference, respectively, are presented as self-terminating.

Figure 3.7 presents the solution times obtained by Sternberg (1977a) for true degenerate, semidegenerate and nondegenerate analogies in each cue condition, in relation to the 15 attribute change possibilities between the A and B and A and C terms. Figure 3.8 presents the mean solution times for true and false degenerate, semidegenerate and nondegenerate analogies collapsed over cue conditions.

Refering to these figures, Sternberg suggests that the solution times for nondegenerate analogies conform to four major qualitative predictions of self-terminating models; that slopes across attribute changes decrease with higher numbers of precued terms, since fewer processes per attribute change are involved as attribute-comparison operations drop out (Figure 3.7); curves are displaced downwards with higher numbers of precued terms, since less encoding is required as analogy terms drop out (Figure 3.7); true solution times are solved more slowly than false solution times, since in self-terminating models, true items require more attribute comparisons, than false items (Figure 3.8); mean solution times decrease with increasing degree of falsity (Figure 3.8).

Sternberg found that solution times for degenerate and semidegenerate analogies showed a different pattern. True items were solved more quickly than false items (Figure 3.8) and semidegenerate analogies showed no slope across attribute changes (Figure 3.7). Thus, if zero attribute changes occured from the A to B term, it didn't appear to matter how many changes occured from the A to C term. I would suggest that these findings are consistent with the construction of these types of analogies, even though Sternberg expresses

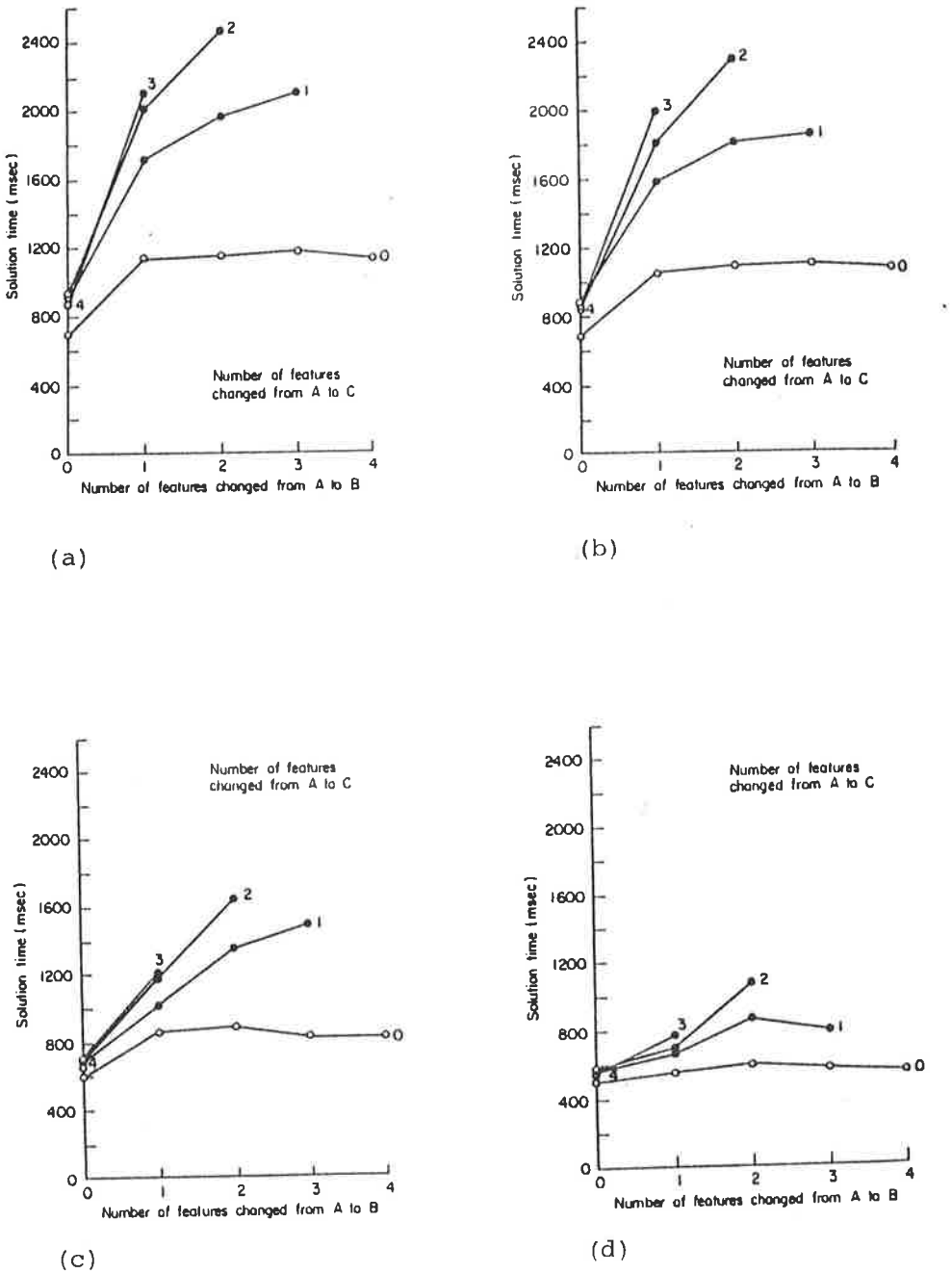


Figure 3.7 Mean solution times for 15 AB/AC attribute change combinations for true degenerate, semidegenerate and nondegenerate analogies in each cue condition, obtained by Sternberg (Reproduced with permission from R.J. Sternbe 1977a, Fig. 7.3, p. 188)
(a) 0 cue condition
(b) 1 cue condition
(c) 2 cue condition
(d) 3 cue condition.

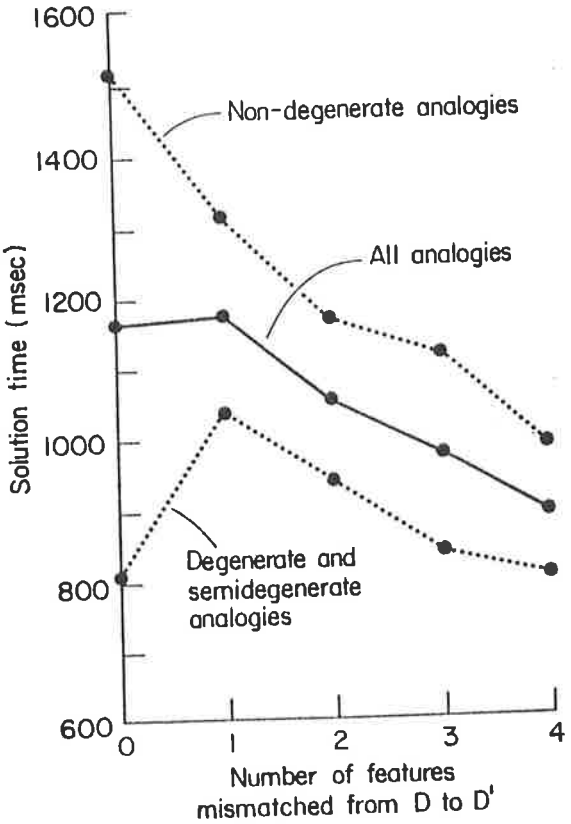


Figure 3.8 Mean solution times for true and false analogies, obtained by Sternberg (Reproduced with permission from R.J. Sternberg, 1977a, Fig. 7.4, p. 189).

surprise at these results. These analogies, as mentioned previously, can not really be classified as real analogies as they do not require the extraction of a higher order relationship and are more consistent with the items one might expect to find in a same-different type task. That is, the subject attempts to match the last term of the analogy with one of the preceeding terms.

The results concerning these latter types of analogies led Sternberg (1977a) to propose a modification to his original models of analogical reasoning. He suggested that subjects solved all the analogies in two stages. In the first stage, which he called holistic scanning, subjects performed a brief scan of the analogy terms to ascertain whether two or more terms were identical. In the second stage, which he called attribute-comparison processing, processing proceeded as described previously, via extraction of the number of attribute changes form the A and B, A and C and D and D' terms. Sternberg assumed that holistic and attribute-comparison processing started simultaneously. Thus, if holistic processing was successful, an answer would be chosen and attribute-comparison processing would be terminated. If holistic processing was unsuccessful, attribute-comparison processing would continue until a solution was reached. The two types of processing were believed by Sternberg (1977a,b) to occur in parallel because the use of holistic processing did not appear to add to the time taken to solve the analogies via attribute-comparison processing. In effect, degenerate and semidegenerate analogies would be solved using holistic processing while nondegenerate analogies would have to be solved using attribute-comparison processing. Sternberg called this new conceptualisation dual-processing and incorporated it into his component models by introducing two new assumptions. Firstly, that in degenerate and semidegenerate analogies, all attribute comparison processes would be same-different; and secondly, that for these analogies

"different" transformations would take longer than "same" ones. Changes to the mathematical equations for the four models of analogical reasoning as a result of these assumptions affected the degenerate and semidegenerate analogies only. A decision of "sameness" was treated identically to zero attribute changes and a decision of "difference" was treated as identical to one attribute change. Thus the number of attribute changes was either zero (same) or one (different) for these types of analogies. The inclusion of dual-processing significantly increased the percentage of variance accounted for by the models. Table 3.3 presents the percentage of variance accounted for by each model, with and without dual-processing using Sternberg's data.

TABLE 3.3

THE PERCENTAGE OF VARIANCE ACCOUNTED FOR BY EACH MODEL

STERNBERG'S SUBJECTS

MODELS	DUAL PROCESSING	NO DUAL PROCESSING
I	75.5	55.5
II	84.7	59.7
III	91.8*	62.1*
IV	90.8	61.9

* Best Fitting Model

From these results Sternberg concluded that Model I could be discounted as providing a much poorer fit to the data than the other three models. Also Model II could be discarded as providing a poorer fit compared to the two

remaining models. Models III and IV both provided extremely good fits to the data, with Model III being marginally better than Model IV. On the basis of this, Sternberg (1977a) suggested that the preferred model for the People Piece Analogy Experiment was Model III, with the incorporation of dual processing.

Error rates were very low, ranging from .5% to 2.6% across sessions, with a mean of 1.4%. Sternberg suggested that these low error rates were in part attributable to the easiness of the items and in part to the instructions which encouraged very low error rates. Indeed, a monetary reward was given for a low error rate. Error rates decreased with increased precueing information and decreased across sessions.

Four conclusions can be drawing from the results of the People Piece Analogy experiment with regard to analogical reasoning. Firstly, that five components are used in solving the analogies, these being encoding, inference, mapping, application and preparation-response. Secondly, that the combination rule for the components is additive. Thirdly, that the inclusion of dual processing is required because of the different manner in which degenerate and semidegenerate analogies are processed, in comparison to nondegenerate analogies. Finally, that Model III is the preferred model with exhaustive encoding and inference components and self-terminating mapping and application components; however, that Movel IV can not be convincingly rejected.

The difference between Models III and IV is that Model III postulates an exhaustive inference process while in Model IV this process is postulated to be self-terminating. It is difficult to explain why these two models account for similar amounts of the variance - Sternberg makes no comment on this matter. However, it may be due either to subjects switching from exhaustive

to self-terminating inference processing depending on the analogy they are attempting to solve or it may be due to some subjects using exhaustive and some using self-terminating inference processing. An answer to this latter possibility would require individual model fitting, in addition to the group model fitting used by Sternberg.

Some conclusions regarding the actual methodology can also be made. From the interval scores it appears that the precueing manipulation is experimentally sound. The decomposition of the composite task into progressively smaller subtasks, which allows the extraction of individual processes, appears to leave the remaining processes unchanged. It also appears that the mathematical modelling in this experiment is adequate to explain analogical reasoning. Sternberg (1977a) cautions however, that the ability of mathematical modelling to account for the data declines as the modelled task becomes more complex. The People Piece Analogy task is a relatively simple one, but, verbal and geometric analogies are in general more complex. Indeed, Sternberg (1977a) found that less of the variance was accounted for in experiments using verbal and geometric analogies analysed via the componential method. In addition, it is likely that the use of mentally retarded subjects may act in a similar fashion to increasing the complexity of the task. It is likely that for these subjects, the People Piece Analogy task will be more difficult and therefore more complex than for nonretarded subjects. Thus, it is probable that less of the variance will be accounted for using retarded as opposed to nonretarded subjects.

3.5 THE COMPONENTIAL METHOD, AGE AND ABILITY LEVEL

Two studies which are related to these points will be discussed here. One is by Sternberg and Rifkin (1979) who were interested in examining differences in

analogical reasoning and age. The other is by Smith (1981) who included intellectual retarded subjects. Both studies made use of the componential method (developed by RJ Sternberg). Integral and schematic analogies were used in these studies. However, only the results pertinent to the integral analogies will be discussed here as these are the analogies used in the experiments in this thesis. The integral analogies were People Piece Analogies composed of four two-dimensional elements, height (tall - short), weight (fat - skinny) sex (male - female) and colour (blue - red).

In the study by Sternberg and Rifkin (1979) subjects received 24 booklets, each booklet containing the People Piece Analogies. A time limit of 64 seconds was set for each booklet. This allowed the calculation of three independent variables (1) solution times for analogies correctly answered, computed by dividing the set amount of time per booklet by the number of items correctly answered in each booket. This provided an index of both quantity and quality of performance; (2) solution times for all analogies attempted whether correctly or incorrectly solved, computed by dividing the set amount of time per booklet by the number of items completed in each booklet. This provided an index of the quantity of performance; and (3) error rates for the analogies, computer by dividing the number of items incorrectly answered by the total number of items completed. This provided an index of the quality of performance. Subjects were drawn from four age groups, those of 8, 10, 12 and 19 years, corresponding to Grades 2, 4, 6 and college students, respectively. Mean solution times for People Piece Analogies correctly answered were 8.42, 6.40, 5.52 and 4.82 seconds for Grades 2, 4, 6 and college students, respectively, showing a decline across age level. Mean solution times for all analogies attempted also showed a decrease over ages, being 7.04, 5.74, 5.14 and 4.71 seconds, respectively. Finally, error rates also decreased with increasing age being 15%, 10%, 6% and 2% for Grades 2, 4, 6

and college students, respectively. Thus, Grades 2 (in particular) and 4 produced higher error rates than the two older groups. Their mean solution times for both correctly answered and all attempted analogies were also longer.

With regard to model fitting and parameter estimation, Sternberg and Rifkin (1979) obtained the following results. The Grade 6 and college student groups were found to be using Model III, the partially self-terminating model which accounted for 86% and 89% of the variance respectively for these two groups. The Grade 4 subjects were found to be using Model IV, which accounted for 80% of the variance, while Grade 2 subjects were found to be using a modification of the original Model IV which Sternberg called IVM and from which it differed in two key respects. Firstly, mapping (the extraction of the higher order relationship) was removed from the data analysis, subjects presumably proceeding directly from inference to application. Secondly, encoding was assumed to become self-terminating, immediately preceeding the first self-terminating attribute-comparison process. These subjects therefore, encoded only as many attributes of an analogy term as were required for analogy solution thus placing less load on memory. In Model IVM (where 82% of the variance was accounted for by this group) self-terminating encoding began immediately with the processing of the first analogy term, as all attribute-comparison processes (i.e. inference, mapping and application) are self-terminating.

Thus, three conclusions can be drawn from this study. Firstly, that with increasingly age, increasing exhaustive processing occurs and secondly, that mapping (the extraction of a higher order relationship) is integrated into the processing system only after a certain level of maturity is reached. Finally, there is a trend for the percentage of variance accounted for to increase with age. For example, more of the variance is accounted for by the Grade 6 and

college students than the Grade 4 and 2 subjects. This may be due to the greater consistency in performance evidenced by the older subjects. They produced lower error rates and faster solution times. While standard deviations are not provided it might be expected that the older subjects also produced lower standard deviations.

The study by Smith (1981) involved two groups of subjects. One group consisted of twenty educable (IQ range 55-70) mentally retarded subjects and the other twenty Grade 11 high school students of the same age. The results of this study should be viewed with caution as only 12 of the 24 booklets used by Sternberg and Rifkin (1979) were used. In consequence not all possible AB, AC and DD' combinations were tested. While it is not explicitly stated, it appears that the more difficult booklets, with a greater number of attribute changes between AB, AC and DD', and the simplest booklets with zero attribute changes were not used. This may have produced ceiling effects for the Grade 11 subjects and floor effects for the retarded group. In addition, Model III was the only model tested by Smith (1981) and he did not examine how much of the variance was accounted for by this model, thus no conclusions about the type of model used by retarded subjects can be made. The purpose of presenting the results of this study here, therefore, are to give some indication of the performance level likely to be obtained with retarded subjects.

Mean solution times for the People Piece Analogies correctly solved were 9.30 seconds and 4.79 seconds for the retarded and Grade 11 subjects, respectively. Mean solution times for all analogies attempted were 6.57 secs and 4.54 respectively for the retarded and Grade 11 groups and mean error rates of 22.25% and 4.50% were obtained form the retarded and Grade 11 groups, respectively. These results are consistent with those obtained by Sternberg

and Rifkin (1979) using chronological age as the distinguishing factor as opposed to intellectual ability. Both studies suggest that retarded subjects in this type of experiment will produce longer solution times, higher standard deviations and more errors than nonretarded subjects. In addition, retarded subjects may use more self-terminating processes i.e. Model IV rather than the more exhaustive models, Models I, II and III.

3.6 CONCLUSION

Sternberg's contributions to the areas of theoretical and methodological research have been stimulating and far reaching but the criticism has been made that his approach is overambitious (see Sternberg, 1980a). In response to this criticism Sternberg (1980a) suggests firstly, that his theory is actually a subtheory and not a comprehensive theory of intelligence and secondly, that some proposals have solid experimental backing while others have only meager or no backing at all and are only intended as stimulation for further research.

It has too often been the case in psychology that a new methodology or theoretical approach has been hailed as "the approach" and been used extensively by investigators from many different fields prior to its verification as a robust and reliable method, or with little thought to its applicability to the paricular field of interest to the investiagator.

A great deal of research is then eventually found to be of questionable value or of little relevance to its area of application. What usually follows is rejection of the theory or methodology (e.g. introspection or factor analysis) when a little prior consideration and investigative research may have improved the theory or method to enable it to be of real value. The same can be said of

the componential approach. It is an approach of potentially great value, but with only the small number of investigations as yet carried out, firm conclusions as to the approach's theoretical postulations or empirical findings can not be made. This thesis seeks to examine the validity of Sternberg's theoretical and methodological contributions in terms of his original experiment using performance components. It is also an attempt to assess the general applicability of the componential method in terms of being able to be used reliably with mentally retarded subjects and in identifying process differences between groups of differing intellectual ability.

CHAPTER 4

TWO ATTEMPTS TO REPLICATE THE ORIGINAL RESULTS OF THE PEOPLE PIECE ANALOGY EXPERIMENT

4.1 INTRODUCTION TO EXPERIMENT 1

Experiment 1 had two aims; firstly to attempt to replicate the results of the People Piece Analogy experiment by Sternberg (1977a) using similar (above average) subjects and secondly, to ascertain whether the People Piece analogies were within the capabilities of a group of subjects of below average intelligence. Previous experiments carried out by Sternberg and Rifkin (1979) and Smith (1981) have found that children and retarded subjects can solve the People Piece Analogies. However, these studies presented the analogies in booklet form and in a forced-choice format where errors were taken into account, whereas in Sternberg's original experiment the analogies were presented tachistoscopically and in a true/false format with errors being repeated until they were correctly solved. In a forced-choice format, two (or more) answer options are provided with one being the correct answer. These two studies, therefore, avoided two aspects of the original experiment by Sternberg (1977a) that may have proved problematic when using children and mildly retarded individuals as subjects; the precueing method and error free data. As mentioned in Chapter 3 the precueing method might require the use of memory which, while not affecting nonretarded adults performance, may adversely affect the performance of children and retarded subjects. As mentioned in Chapter 2 it is generally acknowledged that retarded subjects have poorer memories than nonretarded subjects. With regard to the need for error free data, it is likely that retarded subjects and children will make more errors and require more repetitions of errors to achieve error free data, than the nonretarded subjects in Sternberg's (1977a) original experiment.

This in turn may affect the validity of repeating errors as each repetition will increase the likelihood of the analogy being solved correctly by chance. The method used is that used by Sternberg in the original People Piece analogy experiment, where error data were repeated at the end of each block, so mathematical modelling could be based on error free data. An error rate of 1.4% as obtained by Sternberg (1977a) may not affect the data analysis. However, an error rate of 22.25% as obtained by Smith using retarded subjects may affect the stability of the data.

From the results of these two studies and some of the studies discussed in Chapter 2 (Baumeister and Kellas, 1968; Nettelbeck and Brewer, 1981), some predictions regarding the expected results of Experiment 1 can be made: (1) mean solution times for the below average intelligence group will be greater than those for the above average intelligence group; (2) error rates for the below average group will be larger than those for the above average group and /or more practice on the task will be required by the below average group to reduce their error rate to an acceptable level; (3) standard deviations will be longer for the below average compared with the above average group; (4) all these factors may affect the reliability of the data obtained from below average subjects which in turn will reduce the effectiveness of the mathematical modelling procedure. Thus, less of the variance may be accounted for by the models for these subjects; (5) finally, the below average group will use a more self-terminating model than the above average group, in order to avoid a load on memory which is greater than its capacity. For example, in a more exhaustive model, such as Model II, the subject must hold in memory the attributes of the A, B, C and D terms, the inferred relationship between the A and B terms and the mapped relationship between the A and C terms. If a more self-terminating model is not used, some attributes in some analogy terms might need to be re-encoded or their relationship re-inferred or re-mapped.

4.2 METHOD

4.2.1 SUBJECTS

Twenty-four subjects particpated in this experiment. Twelve subjects were Psychology I subjects from the University of Adelaide. Their mean age was 18.5 years (range 17-23). No form of intelligence test measure was obtained from these subjects, but as a group, they were presumed to be of above average intelligence. Twelve further subjects were employees of Bedford Industries Rehabilition Centre. Their mean age was 21.4 years (range 18-27). Exact IQ scores were not available for all subjects because of the practice in some Australian Goverment agencies of only making IQ ranges available. However using the classification system developed by the AAMD, five subjects were classified as in the dull-normal range (IQ range 85-100) five subjects were classified as falling into the borderline range (IQ range 70-85) and two subjects were classified as mildly retarded (IQ range 55-70). A large range of ability levels was included in the below average group to ascertain whether there was an ability level below which the People Piece Analogies could no longer be solved. The group is labelled below average rather than retarded due to almost half the subjects being classified as dull normal and a further five being classified as borderline retarded. The below average subjects had no known organic cause of intellectual impairment, were taking no prescribed drugs, and had no physical disabilities that would hinder their performance of the task. All experimental subjects remained naive to the experimental aims.

4.2.2 APPARATUS

The apparatus consisted of a Northstar Advantage Microcomputer which included a Graphics package. Attached to this was a response box which

consisted of three keys, a central home key, and two response keys an equal distance to the left and right of the home key.

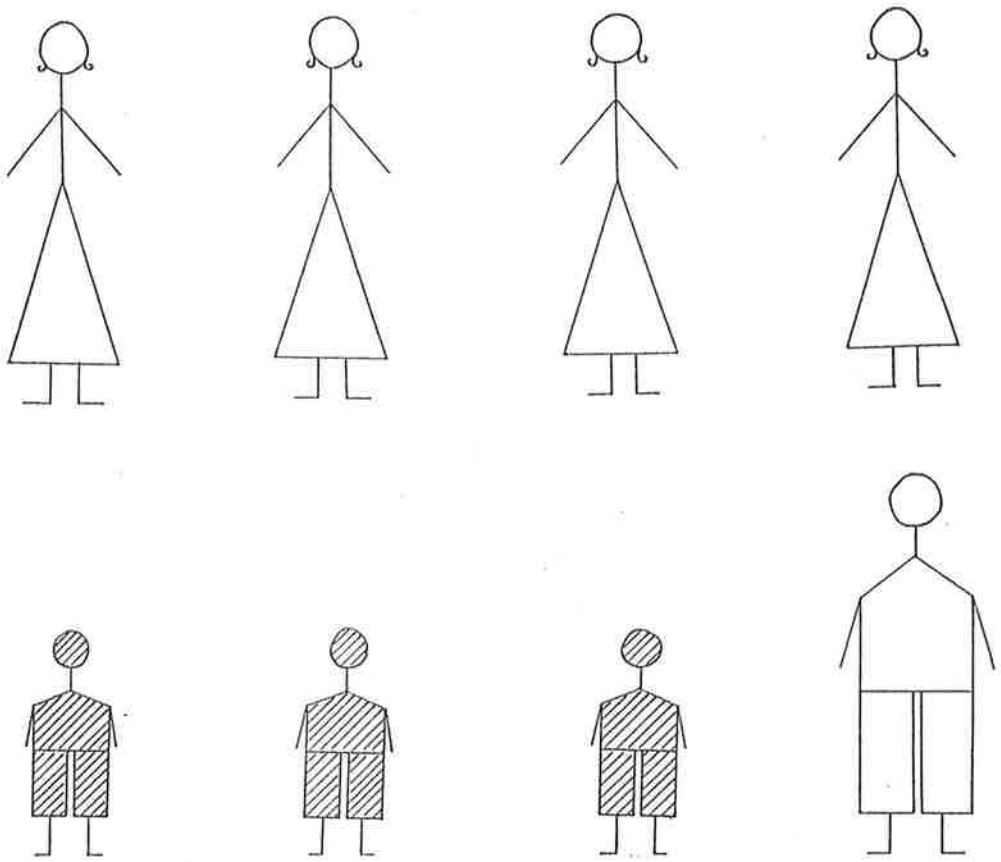
Two sets of cards, 10 x 15 centimetres on which were drawn the figures to be presented via the computer, were used in the first session to describe the nature of the task. One set consisted of the 16 possible figures that could appear in the analogies. The second set consisted of 16 cards arranged into groups of four, corresponding to the four forms the analogies could take. Examples of the design of the figures drawn on the cards are presented in Figure 4.1(a)-(d).

4.2.3 DESIGN

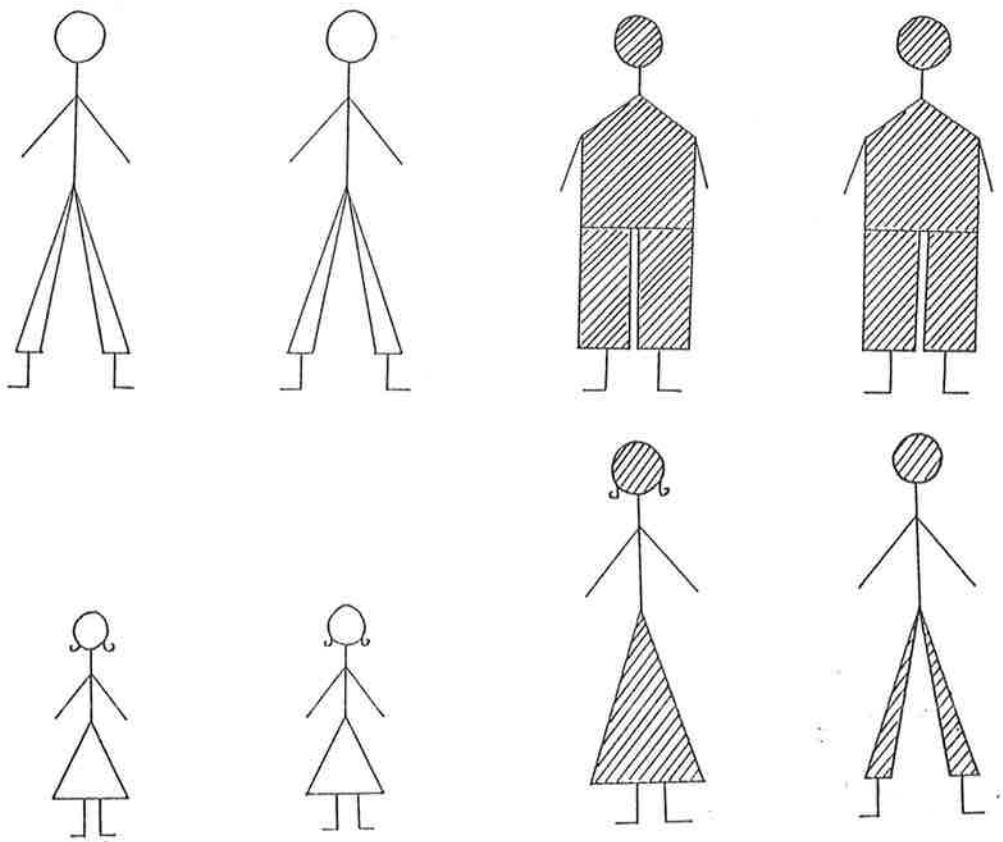
The design was intended to replicate as closely as possible that described by Sternberg (1977a). Degenerate, semidegenerate and nondegenerate analogies were presented in each of four precueing conditions. Examples of each analogy form are presented in Figure 4.1 (a)-(d), Figure 4.1 (a) is an example of a degenerate analogy. Figures 4.1 (b) and (c) are examples of semidegenerate analogies and Figure 4.1 (d) is an example of a nondegenerate analogy. The degenerate analogies were of the form A:A::A:A:, thus there were zero attribute changes between the A and B and A and C analogy terms. The semidegenerate analogies were of two forms, A:A::B:B and A:B::A:B, with zero attribute changes between the A and B terms in the first form and zero attribute changes between the A and C terms in the latter from. Finally, the nondegenerate analogies took the form A:B::C:D; with all analogy terms being different. In this form of analogy, the subject must therefore extract the higher order relationship between the two parts of the analogy. All analogies were presented in a true/false format.

As in Sternberg's (1977a,b) original experiment differences between analogies

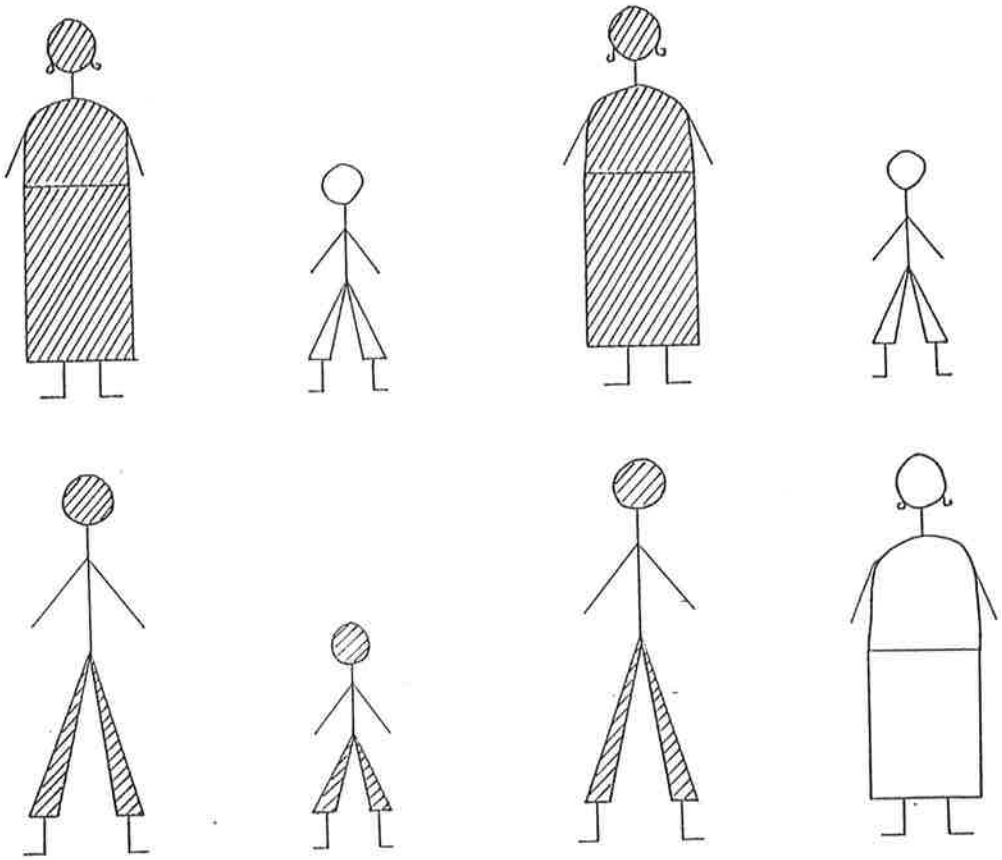
Figure 4.1 Examples of the People Piece Analogy Figures used in this series of experiments.
(a) Degenerate
(b) Semidegenerate (A:A::B:B:)
(c) Semidegenerate (A:B::A:B:)
(d) Nondegenerate



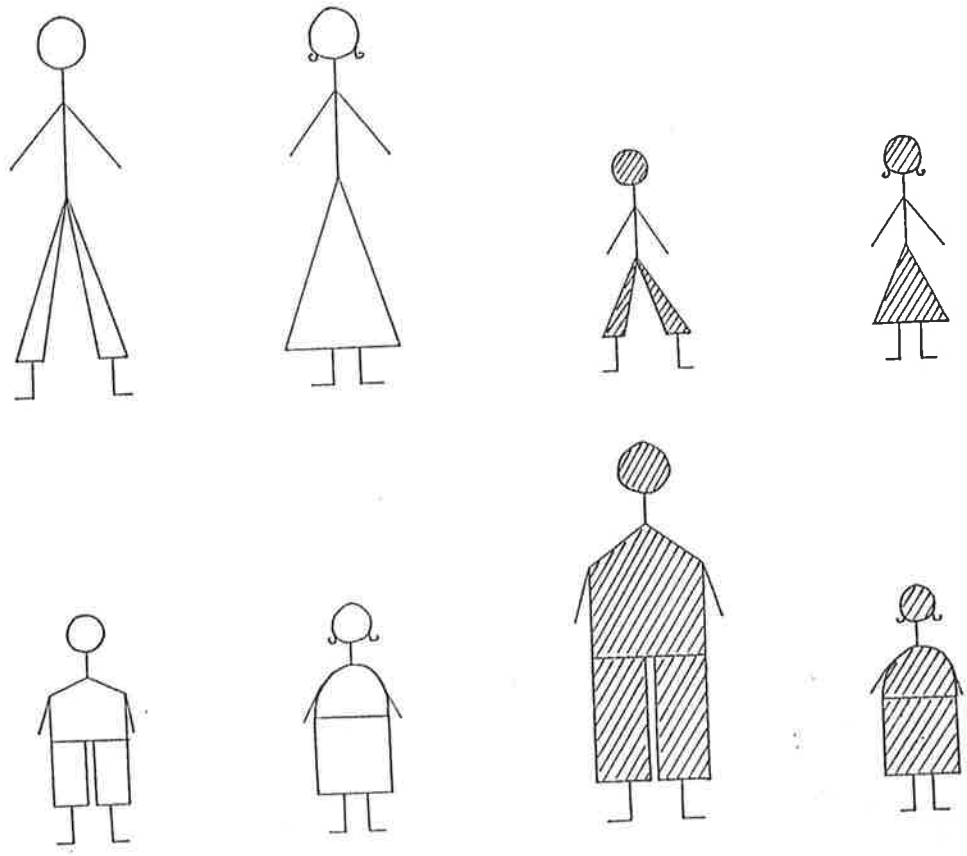
(a)



(b)



(c)



(d)

centered around three factors: (1) the number of attributes changed from the first (A) to the second (B) analogy term; (2) the number of attribute changes between the first (A) and third (C) analogy terms and; (3) the number of attributes changed from the correct form of the D term (D') to the incorrect form (D) if the analogy was false. The number of attributes changed from the A to B and A to C terms of each analogy were not independent, but were constrained in the two ways described by Sternberg and discussed in Chapter 3, that is: (1) only unidirectional analogies were used, and, (2) analogies could only be falsified after the processing of the D term. Therefore, the number of attribute change possibilities between both the A and B and A and C terms was no greater than four, thus allowing 15 possible AB and AC attribute change combinations as in Chapter 3, Table 3.1. The number of attribute changes between D and D' was independent of the number of attribute changes between A and B and A and C. There were 5 possible attribute changes between D and D'. The first was 0, which meant the analogy was true. The second, third fourth and fifth corresponded to 1,2,3, and 4 attribute changes respectively and were all associated with false analogies. Half the analogies were true and half were false, with equal numbers of analogies being false by 1,2,3, or 4 attributes.

In addition, the number of attribute changes between all three types of combinations (i.e. AB, AC and DD') were balanced across the four attributes, so that there were equal numbers of changes due to height, weight, colour and sex, and the combinations of these attributes.

Thus the total of 15 AB, AC attribute change possibilities multiplied by the 5 DD' change possibilities made a total of 75 different analogy types of which 15 types were true and 60 types were false (15 for each false analogy type i.e.

1,2,3 or 4 attribute changes from the true form, D'). The four cue conditions consisted of 0, 1, 2, or 3 precued terms for each analogy. This multiplied by the 75 different analogy types made a total of 300 different analogy types.

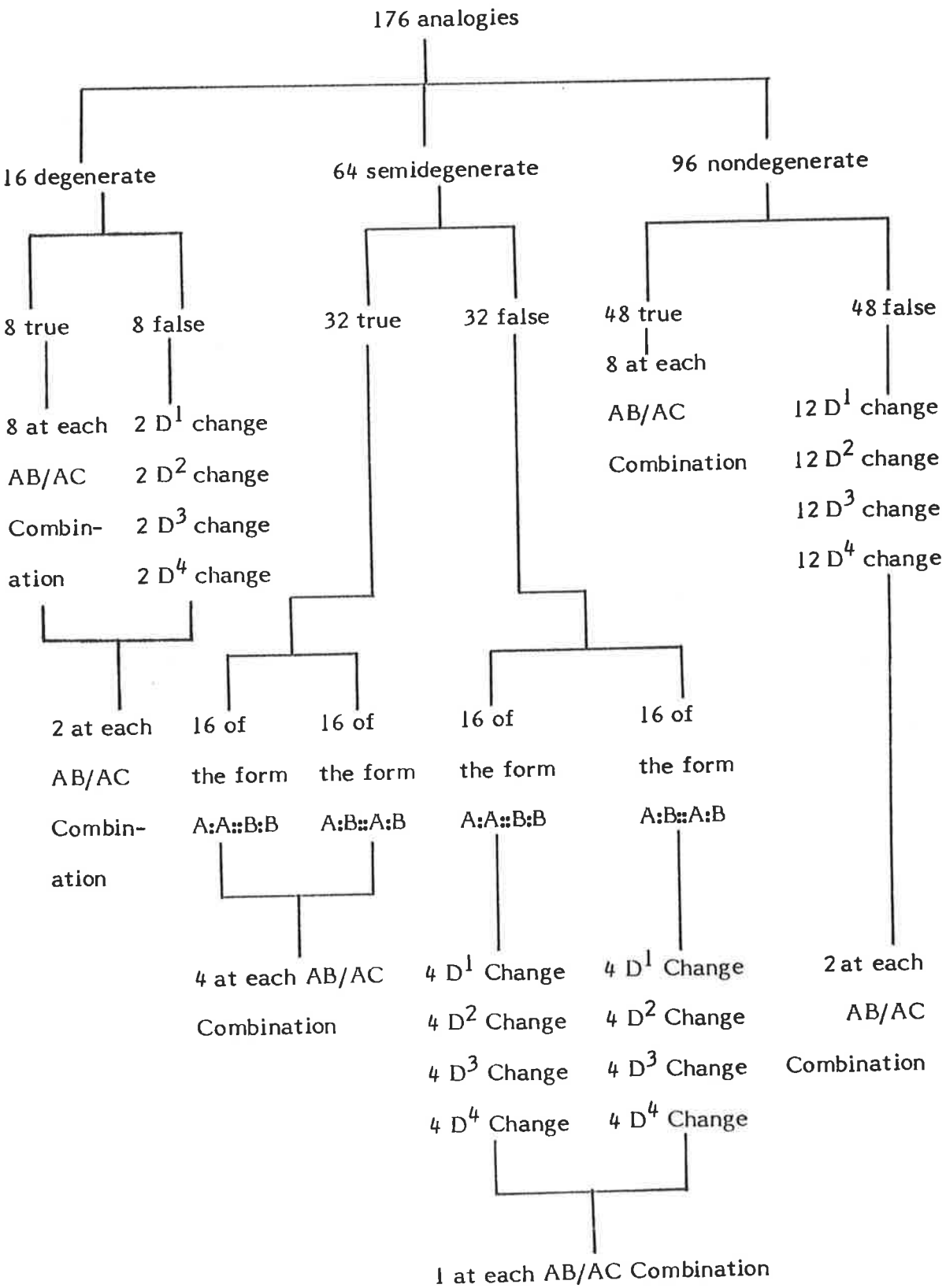
4.2.4 PROCEDURE

Subjects particpated in four experimental sessions. All four sessions consisted of the presentation of the same set of 176 analogies. These analogies consisted of some of the 300 different analogy types described above, so that over the four experimental sessions all different analogy types would be presented. Table 4.1 presents a breakdown of the number of analogies used in each analogy type.

The number of analogies used here is smaller than that used by Sternberg (1977a) who, as previously mentioned, used 288 analogies. The reduction was necessary due to the fact that each session using the 288 analogies lasted approximately one hour and 15 minutes using above average subjects. It was therefore assumed that the below average subjects would take longer to perform the task and thus have considerably longer sessions. In such cases, the performance of the below average subjects might be adversely affected by factors such as fatigue and loss of attention. Evidence reviewed in Chapter 2 has suggested that these factors are more likely to affect the mentally retarded. By reducing the number of analogies used, the length of each session was significantly reduced. Session durations declined across sessions, for both groups. For the above average group, a session lasted approximately 25 minutes while for the below average group, sessions lasted approximately 35 minutes.

The analogies were presented in four blocks per session, each block corresponding to a different precueing condition. A block consisted of 44

TABLE 4.1


176 analogies
16 degenerate
64 semidegenerate
96 nondegenerate
8 true
8 false
32 true
32 false
48 true
48 false
8 at each AB/AC Combination
2 D1 change
2 D2 change
2 D3 change
2 D4 change
8 at each AB/AC Combination
12 D1 change
12 D2 change
12 D3 change
12 D4 change
2 at each AB/AC Combination
16 of the form A:A::B:B
16 of the form A:B::A:B
16 of the form A:A::B:B
16 of the form A:B::A:B
4 at each AB/AC Combination
4 D1 Change
4 D2 Change
4 D3 Change
4 D4 Change
4 D1 Change
4 D2 Change
4 D3 Change
4 D4 Change
1 at each AB/AC Combination

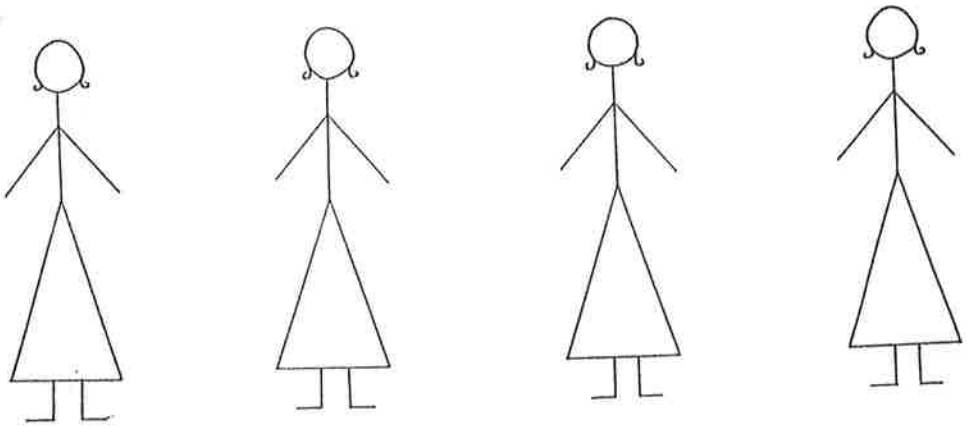
analogies of which 4 were degenerate, 16 were semidegenerate, (8 of each form) and 24 were nondegenerate, with equal numbers of true and false types of each form in each block. Thus a total of 16 degenerate, 64 semidegenerate and 96 nondegenerate analogies were presented in each session making a total of 176 analogies.

Cue conditions were ordered in a Latin Square arrangement both between and within sessions. Thus one quarter of the subjects in each group began each session with a different cue condition. Form order (ie whether the subjects began with the degenerate, semidegenerate or nondegenerate analogies) was also organised in a Latin Square arrangement across but not within subjects. Full counterbalancing of cue and form order was not possible because there were 16 possible cue-form sequences, but only 12 subjects. Thus three subjects received the same form order in each session, while form order varied for each subject across sessions. In Sternberg's original experiment 16 subjects were used, thus allowing for full counterbalancing of cue and form order.

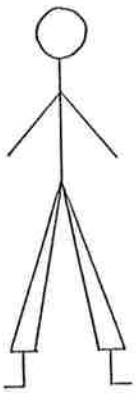
Each analogy or trial was presented in two parts. The first part consisted of the presentation of the precued terms plus a fixation dot which appeared above the area where the first noncued term would appear. The second part of each trial consisted of the presentation of the full analogy i.e. the precued and nonprecued terms of the analogy. Figure 4.2 (a)-(d) presents examples of this for the 0, 1, 2 and 3 cue conditions respectively. The fixtation dot also remained present after the full analogy had appeared, as it was intended to guide the subjects' eyes to the first nonprecued term and to discourage looking back to the precued terms previously presented. The subjects pressed a central key on the response box using the index finger of the preferred hand when they had viewed the precued figures for as long as they considered necessary, terminating the first part ot the trial. This differed slightly from

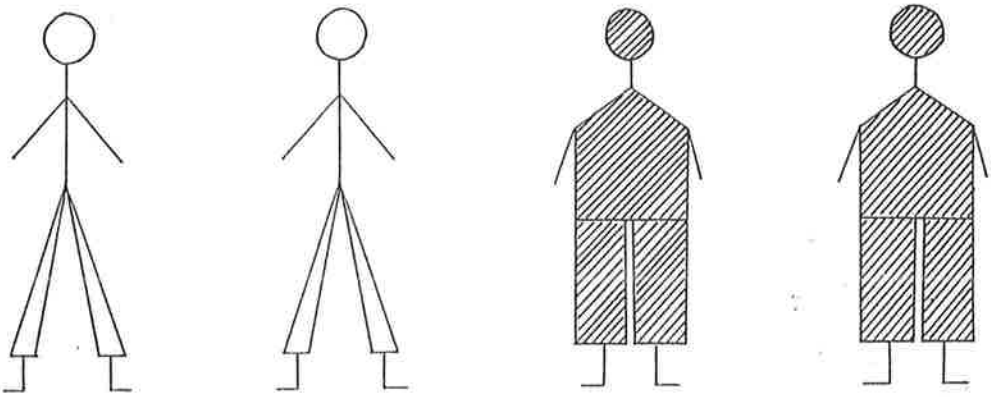
Figure 4.2 The method of precuing used by Sternberg and in this experiment.
(a) 0 cue condition
(b) 1 cue condition
(c) 2 cue condition
(d) 3 cue condition



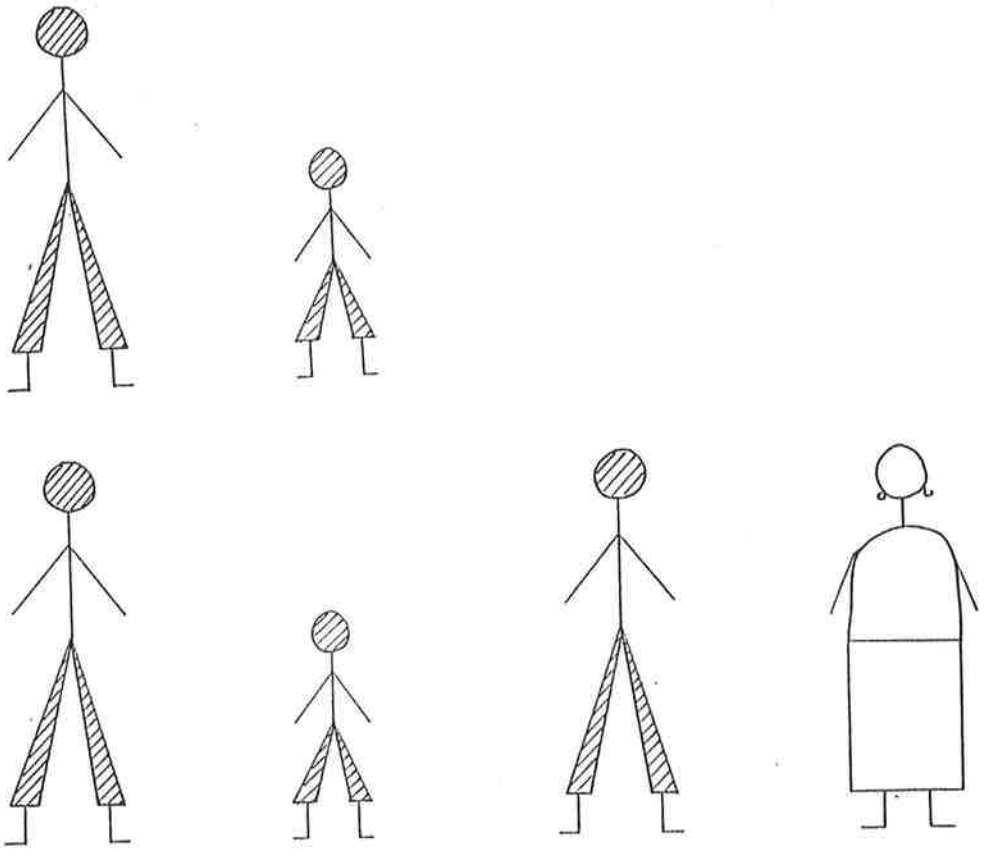


(a)

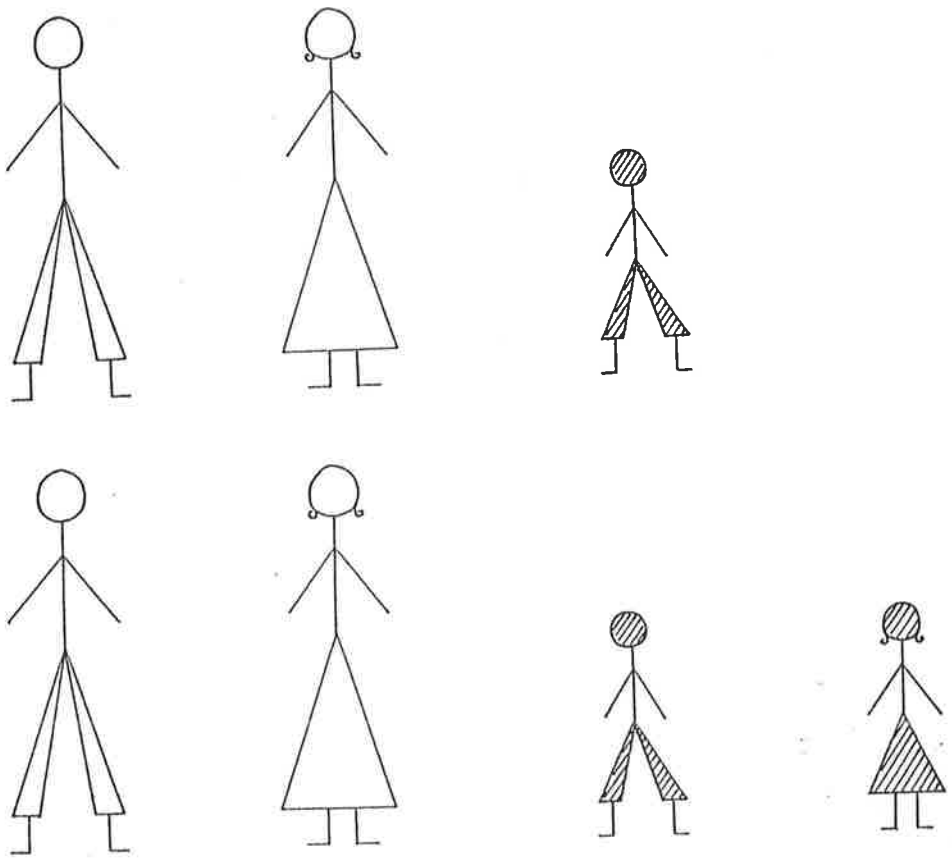




(b)



(c)



(d)

Sternberg's experiment, his subjects pressing a central button which signalled to the experimenter thatthe subject was ready to continue. The experimenter then initiated the second part of the trial. In the present experiment, the second part of the trial was then immediately presented and was terminated by the subject when he /she made a response of true or false, again using the index finger of the prefered hand. Subjects were informed that they were being timed for both parts of the trial and that they should therefore spend only as much time on each part as they needed to respond correctly.

Subjects were instructed to try and make use of the precued terms, but they were not explicitly told how this should be done. A search of the relevant available literature (Sternberg, 1975, 1977a, 1977b) provided no information as to the instructions Sternberg gave his subjects with regard to the use of the precued terms and therefore it was assumed that no specific instructions were necessary.

Initially, in the first session, a set of 16 cards was used to acquaint each subject, in both the above and below average intelligence groups, with the figures that would shortly appear on the computer screen. It was explained that each figure consisted of four attributes - height [tall-short] weight [fat-skinny], colour [coloured in- not coloured in] and sex [male-female]. Subjects were then asked to sort the cards on the basis of each of the four attributes, first sorting for height, then sex, then weight, then colour. A second set of cards was then used to explain the different forms the analogies could take ie. degenerate, A:A::A:A; semidegenerate A:A::B:B; and A:B::A:B; and nondegenerate A:B::C:D.

Both true and false examples of each form were provided. 48 practice trials were then presented via the computer. These consisted of degenerate

analogies, semidegenerate analogies in each form and nondegenerate analogies. True and false examples of each form of analogy were provided as were examples of each analogy form in each cue condition.

Subjects were told that in the case of the degenerate analogies, if the last figure (the D term) matched the first three figures then the analogy was true. If not, the analogy was false. In the case of the semidegenerate analogies of the form A:A::B:B, subjects were told that if the last figure matched the second to last figure (the C term) the analogy was true. If not the analogy was false. For the semidegenerate analogies of the form A:B::A:B, the subjects were told that the last figure must match the second figure (the B term) for the analogy to be true, otherwise it was false. Finally, for the nondegenerate analogies, the subjects were told that as all figures were different from each other they would have to find the relationship between the first two figures (the A and B terms) and then see if the last two figures (the C and D terms) had the same relationship. They were instructed to find the relationships between the two sets of figures by comparing which attributes changed and which attributes didn't change from the A to B and C to D terms. If those same attributes which changed between the A and B terms also changed between the C and D terms and those same attributes which didn't change between the A and B terms also didn't change between the C and D terms then the analogy was true. If the C and D terms did not have the same pattern of changes and nonchanges as the A and B terms then the analogy was false.

Some below average subjects found the nature of the nondegenerate analogies difficult to grasp and so it was decided to extend the practice trials for all of the first session for this group. During this session the subjects received the set of the experimental trials that would be used in the experimental sessions to follow. During this practice session, examples of each of the analogy forms

(degenerate, semidegenerate, and nondegenerate) were presented in each of the four cue conditions. On completion of this additional practice session, the below average group proceeded onto the first of the four experimental sessions, usually after a time lapse of one day.

For both above and below average subjects during their practice trials, errors were immediately corrected and explained. This was done by having the subjects state verbally whether they thought the analogy true or false before pressing the appropriate response key. Also for both groups each experimental session began with the presentation of the 48 practice computer trials. Then the subjects proceeded onto the experimental trials. Errors were replayed at the end of each block until correctly solved. Subjects were instructed to go as fast as possible but without making too many mistakes. They were told "It is more important not to make errors. Go more slowly rather than go faster and make more errors".

4.3 RESULTS AND DISCUSSION

This section is divided into three subsections: Interval Scores, Component Scores, and Error Rates.

The derivation of the interval scores and component scores are taken from Sternberg's (1977a) analysis described in his book "Intelligence, Information Processing and Analogical Reasoning: A componential Model of Human Intelligence".

4.3.1 INTERVAL SCORES

Sternberg (1977a) describes the interval scores as the mean response times for all subjects in each of the cue conditions. They are divided into two times, the

mean response times for the first half of the trial i.e. the time spent processing the precued figures the "cue times", and the mean for the second half of the trial, i.e. the time spent processing the nonprecued figures and solving the analogy, the "solution times". Tables 4.2 to 4.4 present the mean cue and solution times for each cue condition, over all sessions and in the first and fourth (last) sessions separately, for both groups. Unlike Sternberg's data, the analogies are also divided into two types. Type I refers to both the degenerate and semidegenerate analogies combined. Type II refers to the nondegenerate analogies. This was done so that the data for above average and below average subjects could be examined for both the simpler degenerate and semidegenerate and more difficult nondegenerate analogies, separately. It was thought that differences between the groups might be more pronounced for the Type II than for the Type I analogies.

Also presented in these tables and not used by Sternberg (1977a) are Underflow and Overflow trials. Again these were extracted for comparison purposes. It was noticed by the author that below average subjects sometimes produced extremely long solution times, and also extremely short cue times. Short cue times suggested that the subjects were not processing the precued figures. Extremely long solutions times may have been due to fatigue or loss of attention (Baumeister and Kellas, 1968; Krupski, 1977, 1979; Nettelbeck and Brewer, 1981). These factors would be likely to reduce the amount of variance accounted for by the mathematical models. Examination of the data for both groups revealed that most response times were within the range of 200 msecs - 15000 msecs. However, to avoid the possibility of above average subjects in future experiments producing cue times of less than 200 msecs or retarded subjects producing solution times of greater than 1500 msecs the limits were set to 50 m secs for Underflow trials and 30,000 msecs for Overflow trials.

TABLE 4.2

INTERVAL SCORES FOR ABOVE AND BELOW AVERAGE SUBJECTS AND STERNBERG'S SUBJECTS

Overal Means (for both Analogy Types)

Cue Condition

	0	1	2	3
Above Average Subjects				
Cue Time	649	711	1023	1551
SD	444	482	788	1250
No of Observations	2112	2112	2112	2112
Underflow Trials	2	1	0	1
Solution Time	2506	2418	2081	1732
SD	1494	1568	1357	1197
No of Observations	2112	2112	2112	2112
Overflow Trials	1	0	0	0
Below Average Subjects				
Cue Time	894	839	875	1040
SD	586	576	568	911
No of Observations	2112	2112	2112	2112
Underflow Trials	4	12	9	10
Solution Time	3720	3624	3498	3412
SD	2702	2612	2640	2713
No of Observations	2112	2112	2112	2112
Overflow Trials	8	5	1	4
Sternbergs Data				
Cue Time	530	755	952	1147
SD	131	187	261	363
No of Observations	4608	4608	4608	4608
Solution Time	1423	1328	947	681
SD	235	222	193	170
No of Observations	4608	4608	4608	4608
Session 1	0	1	2	3
Cue Times	635	990	1352	1540
SD	200	417	554	844
No of Observations	1152	1152	1152	1152
Solution Times	1646	1587	1173	820
SD	319	288	251	205
No of Observations	1152	1152	1152	1152
Session 4				
Cue Times	460	574	731	917
SD	129	154	235	303
No of Observations	1152	1152	1152	1152
Solution Times	1277	1153	820	618
SD	245	195	187	181
No of Observations	1152	1152	1152	1152

TABLE 4.3

INTERVAL SCORES FOR TYPE I AND TYPE II

ANALOGIES ABOVE AVERAGE GROUP

	Cue Condition			
Type I Analogies				
All Sessions	0	1	2	3
Cue Time	645	667	858	1095
SD	402	406	693	951
No of Observations	960	960	960	960
Underflow Trials	1	1	0	1
Solution Time	1775	1683	1516	1219
SD	945	981	952	658
No of Observations	960	960	960	960
Overflow Trials	1	0	0	0
Session 1				
Cue Time	798	839	972	1318
SD	446	547	940	1414
No of Observations	240	240	240	240
Underflow Trials	0	0	0	0
Solution Time	2048	1984	1700	1403
SD	1156	1338	975	660
No of Observations	240	240	240	240
Overflow Trials	0	0	0	0
Session 4				
Cue Time	560	538	643	799
SD	462	278	340	347
No of Observations	240	240	240	240
Underflow Trials	0	1	0	0
Solution Time	1559	1475	1289	976
SD	747	739	707	552
No of Observations	240	240	240	240
Overflow Trials	0	0	0	0

TABLE 4.3 (Continued)

Type II Analogies

All Sessions	0	1	2	3
Cue Time	653	755	1187	2007
SD	483	547	873	1490
No of Observations	1152	1152	1152	1152
Underflow Trials	1	0	0	0
Solution Times	3236	3152	2646	2245
SD	1890	1988	1666	1559
No of Observations	1152	1152	1152	1152
Overflow Trials	0	0	0	0
Session 1				
Cue Times	800	917	1258	2087
SD	645	582	905	1722
No of Observations	288	288	288	288
Underflow Trials	0	0	0	0
Solution Times	3753	3679	2842	2747
SD	2248	2267	1720	1808
No of Observations	288	288	288	288
Overflow Trials	0	0	0	0
Session 4				
Cue Time	555	624	1021	1925
SD	400	484	753	1454
No of Observations	288	288	288	288
Underflow Trials	0	0	0	0
Solution Time	2656	2613	2387	1990
SD	1535	1187	1415	1385
No of Observations	288	288	288	288
Overflow Trials	0	0	0	0

TABLE 4.4

INTERVAL SCORES FOR TYPE I AND TYPE II ANALOGIES BELOW AVERAGE GROUP

	Cue Condition			
Type I Analogies All Sessions	0	1	2	3
Cue Time	897	828	852	956
SD	583	593	546	863
No of Observations	960	960	960	960
Underflow Trials	3	6	6	6
Solution Time	2870	2763	2621	2414
SD	2207	2096	2006	1820
No of Observations	960	960	960	960
Overflow Trials	0	1	0	0
Session 1				
Cue Times	985	865	984	1013
SD	658	516	584	582
No of Observations	240	240	24	240
Underflow Trials	1	4	1	0
Solution Times	3204	3249	3081	2732
SD	1767	2602	2127	2114
No of Observations	240	240	240	240
Overflow Trials	0	1	0	0
Session 4				
Cue Times	856	801	746	856
SD	625	633	530	1266
No of Observations	240	240	240	240
Underflow Trials	0	1	1	3
Solution Times	2450	2386	2152	2085
SD	1860	1346	1459	1423
No of Observations	240	240	240	240
Overflow Trials	0	0	0	0

TABLE 4.4 (Continued)

Type II Analogies All Sessions	0	1	2	3
Cue Times	891	849	898	1123
SD	589	559	589	957
No of Observations	1152	1152	1152	1152
Underflow Trials	1	6	3	4
Solution Times	4570	4484	4375	4409
SD	3120	3042	3149	3377
No of Observations	1152	1152	1152	1152
Overflow Trials	8	4	1	4
Session 1				
Cue Times	978	891	1003	1122
SD	588	496	646	697
No of Observations	288	288	288	288
Underflow Trials	0	0	0	1
Solution Times	4868	4688	4657	4984
SD	2922	2608	3100	3499
No of Observations	288	288	288	288
Overflow Trials	0	0	0	0
Session 4				
Cue Times	849	810	839	1047
SD	588	600	568	931
No of Observations	288	288	288	288
Underflow Trials	1	2	1	0
Solution Times	4357	4107	4083	3952
SD	3236	3124	3136	3102
No of Observations	288	288	288	288
Overflow Trials	3	2	0	3

For reference purposes, Sternberg's data are also presented in Table 4.2 for the overall data and for Sessions 1 and 4.

Referring to Table 4.2 it can be seen that for the above average group, cue times increase and solution times decrease from the 0 to the 3 cue condition. These changes are similar too but not as marked as the changes obtained by Sternberg (1977a) shown in the bottom section of the table. In addition, cue and solution times especially, are much longer for these subjects in comparison to those obtained by Sternberg. Standard deviations are also much greater. The below average subjects show even less change across cue conditions with no increase in cue time from the 0 to the 2 cue condition and only a slight increase in the 3 cue condition.

In addition, cue and solution times are much longer for these subjects in comparison to both the above average group and Sternberg's subjects. Standard deviations also are significantly greater. These results suggest that the below average subjects in this experiment are not making full use of the precued figures.

Interval scores also show a decline from Session 1 to Session 4 for both groups (Tables 4.3 and 4.4 respectively) and this decline is similar to that found by Sternberg (Table 4.2). For the above average group this decline is most marked in the case of the Type II (nondegenerate) analogies. However, the reverse is true of the below average group. The decline in their interval scores is more marked for the Type I than the Type II analogies. This difference may be due to the fact that the below average group were not able to improve their performance on the Type II analogies because they experienced a greater degree of difficulty on these analogies. Conversely, the fact that the above average group did not improve as much on the Type I analogies may be due to the simplicity of these analogies for this group. They

were closer to optimum performance on these analogies after the initial practice trials than the more difficult Type II analogies.

A three way analysis (Cue x Type x Group) of variance using the solution time data revealed significant main effects for cue condition ($F(3, 176) = 2.96$, $p < .05$), type of analogy ($F(1,176) = 120,72$ $p < .01$) and Group ($F(1, 176) = 97.55$, $p < .01$) see Appendix 1.1 for the analysis of variance tables. The fact that the main effect for cue condition was significant only at the .05 level indicates that use of the cues was not as great as might have been expected for both groups.

The significant difference between Type I and Type II analogies indicates that for both groups, solution times to Type I analogies are much shorter than those for the Type II analogies (See Tables 4.3-4.4 for the above and below average groups). The significant group effect is due to the expected finding that solution times for below average subjects are significantly longer than those produced by above average subjects (see Table 4.2). In addition, the interaction between type and group was almost significant ($F(1,176) = 3.27$ $p > .05$). It indicates that the below average group tended to take disproportionately longer to solve the Type II than the Type I analogies when compared to the above average subjects. One might expect that this would have reached significance if a mildly retarded group rather than a below average group had been used.

A four way analysis of variance (Group x Session x Type x Cue with repeated measures for Session) was conducted to examine whether there was a significant improvement in performance from Session 1 to Session 4 for both groups of subjects (See Appendix 1.2). The factors Group, Type and Cue were included to examine whether performance improved to a greater extent for a

particular group, type of analogy or cue condition. Significant main effects were obtained for Session ($F(1,22) = 29.63$, $p<.01$), Group ($F(1,22) = 15.16$, $p < .01$), Type ($F(1,22) = 161.61$, $p < .01$) and Cue ($F(3,666) = 15.65$, $p < .01$) the last three mirroring the results obtained for the previous analysis of variance using the data for all sessions. The main effect for Session suggests that performance improved from Session 1 to Session 4. None of the interactions between Session and the other three factors were significant suggesting that improvement in performance was equivalent for both groups, both Type I and Type II analogies and in each cue condition.

An assumption made by Sternberg (1977a) is that interval scores are additive, and thus the composite task represented by the 0 cue condition can be broken down into three subtasks represented by the 1, 2 and 3 cue conditions with each of these subtasks requiring fewer of the processes required in the composite task but not altering the nature of the task or the processes used. To investigate whether this assumption was met in this experiment, analysis for a significant linear trend for cue condition was conducted, the expectation being that if solution times are to some degree additive they will produce a linear trend from the 0 to 3 cue conditions. A significant linear trend was obtained ($F(1,176) = 8.72$, $p < .01$) which suggests that the assumption of additivity was met for both groups. However, the finding that there was little change in solution times across cue conditions for the below average group, suggests that the assumption has not been met for these subjects.

As mentioned in Chapter 3, Sternberg used the simplex method to test whether the assumption of additivity had been met. Using this method, the solution times for each cue condition are intercorrelated, forming a correlation matrix. If the correlations for these scores are highest near the diagonal of the matrix and fall away monotonically from the diagonal, then a simplex is formed, suggesting that the assumption of additivity has been met. In other words, higher correlations between the solution times for the 0 and 1 cue condition should be obtained than for the 0

and 2 cue condition and this latter correlation should be higher than that obtained for the 0 and 3 cue conditions. Furthermore, the correlation between the 1 and 2 cue conditions should be greater than that between the 1 and 3 cue condition and so on.

Table 4.5 presents the results of this analysis for both the above and below average groups.

TABLE 4.5

SIMPLEX ANALYSIS, MEAN SOLUTION TIMES FOR THE 0, 1, 2 and 3 CUE CONDITIONS, ABOVE AND BELOW AVERAGE SUBJECTS

Above Average Subjects

		Predictor Variable Cue Condition			
		0	1	2	3
Predicted Variable	0	1.0000	.9162	.9108	.7795
	1		1.0000	.9162	.8168
	2			1.0000	.8843
	3				1.0000

Below Average Subjects

		Predictor Variable Cue Condition			
		0	1	2	3
Predicted Variable	0	1.000	.6257	.3554	.6619
	1		1.000	.4384	.6595
	2			1.0000	.5232
	3				1.0000

As can be seen, the above average subjects solution times form a simplex with no breakdowns, suggesting that the assumption of additivity has been met. The below average subjects, however, show a number of breakdowns in simplical structure. It appears that the 2 cue condition is the cause of the breakdowns since, it has very low correlations with the 0,1 and 3 cue conditions. In fact, the correlations between the solution times for each of the cue conditions are much lower overall than those

obtained for the above average group. The fact that the correlations between the solution times for each cue condition for these subjects are lower than for the above average subjects is probably due partly to the greater variability evident in their large standard deviations for cue and solution interval scores. However, it may also be due to their not treating the cue conditions as variants of the same task but as different tasks and thus using different processes in each of the cue conditions.

Analysis of the interval scores, therefore, suggests that for the above average subjects the assumption of additivity has been met. However, for the below average subjects, the assumption of additivity is not really met. Their solution times across cue conditions show some decline but there are a number of breakdowns in simplical structure. These results suggest that the model fitting procedure will have reduced reliability when applied to the data for the below average group.

4.3.2 COMPONENT SCORES

The component scores were predicted using linear multiple regression for each of the four models of analogical reasoning. The independent or predictor variables were the number of terms (figures) to be encoded (dependent upon the cue conditions) and the number of attribute changes from the A to B, A to C and D to D' terms of each analogy. This made a total of 300 data points to be predicted - 15 AB/AC change possibilities x 5 DD' value change possibilities x 4 cue conditions. Each data point was the mean of at least 1 and as many as 8 solution times (see Table 4.1). The encoding, inference, mapping and application parameters were the estimated unstandardised regression coefficients and the preparation - response parameter was represented by the regression constant.

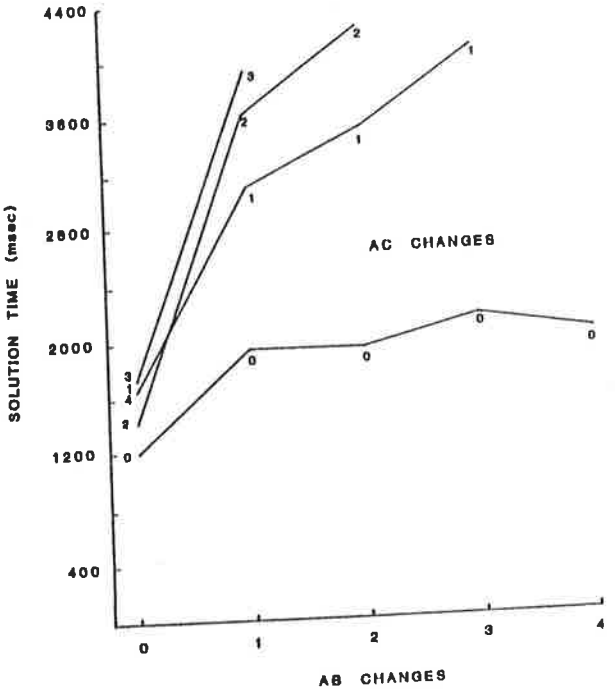
Table 3.2 (in Chapter 3) presented the models to be tested. Each model includes the encoding, inference, mapping and application processes but the models vary according to whether each process is postulated to be exhaustive or self-terminating. In addition, there are parameter dropouts due to the cue conditions. For example, all parameters, encoding, inference, mapping and application enter into the equation for each model in the 0 cue condition. Subjects must encode all four analogy terms plus perform the attribute-comparison processes (inference, mapping and application) and the preparation - response process. The 1,2 and 3 cue conditions are defined by progressively more parameter droupouts. For example, the encoding of the A term drops out in the 1 cue condition, it presumably having been encoded in the first half of the trial. Therefore in this case encoding equals 3. In the 2 cue condition the encoding of the A and B terms drops out together with the inference process, all these processes presumably having occurred in the first half of the trial when the A and B terms were precued. In the 3 cue condition, the encoding process is reduced to 1, the A,B and C terms presumably having been encoded in the first half of the trial. The inference and mapping processes also drop out because they have been carried out when the precued figures were encoded. This process theoretically allows for the estimation of unconfounded parameters and for multiple estimates to be made of each process. Table 3.2 indicates the introduction of the self-terminating forms of each of the attribute-comparison processes, inference, mapping and application, except for encoding which is exhaustive in all four models. In Model I, no self-terminating processes occur. In Model II, application becomes self-terminating, in Model III, mapping and application both become self-terminating and in Model IV, all three attribute-comparison processes, inference, mapping and application become self-terminating.

Figures 4.3 (a)-(d) and 4.5 (a)-(d) present the solution times for the 15 AB/AC

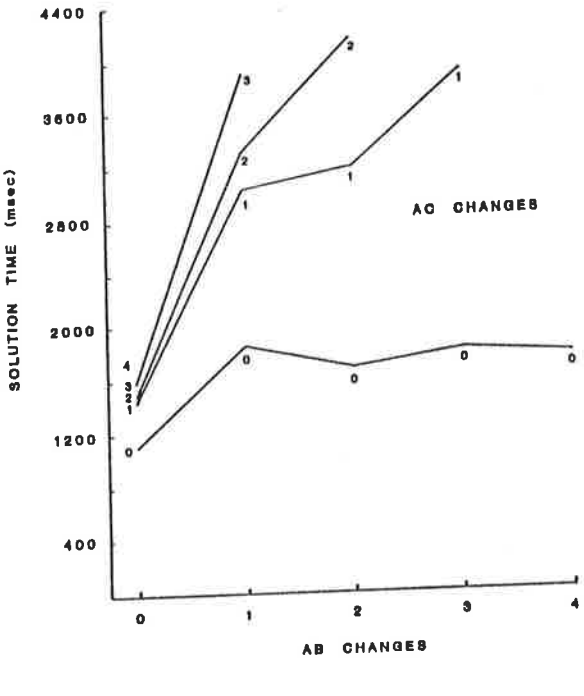
attribute change combinations for the true analogies in each cue condition, for above and below average groups, respectively. Figures 4.4 and 4.6 present the solution times for true and false Type I and Type II analogies, for above and below average groups respectively. As has been discussed previously, Sternberg (1977a) has suggested that there are four points indicative of self terminating processes being used. These are (1) that slopes across attribute value changes decline as the number of precued figures presented increases because of the drop out of the attribute-comparison processes; (2) that curves are displaced downwards (i.e. the intercept values for each slope are lowered) as the number of cues increases because of the dropout of the encoding process; (3) that true Type II solution times are slower than all false Type II analogies because the former require on average, more attribute comparisons than false analogies; and finally (4) that solution times for false Type II analogies decrease as the degree of falsity increases (ie from 1 to 4 DD' value changes).

It can be seen in Figures 4.3 and 4.4 that these points are, in the main, met for the above average group. Slopes decline across attribute value changes from the 0 and 1 cue conditions to the 2 cue condition and from the 2 to 3 cue condition (Figure 4.3 (a) to (d)). Also the intercepts for each slope are reduced, most markedly from the 0 and 1 cue conditions to the 3 cue condition (Figures 4.3 (a) to (d)). With regard to points 3) and 4), Figure 4.4 indicates that these predictions are also met for the above average group. True Type II analogies are solved more slowly than false Type II analogies and false Type II analogies show a decline in solution time with increasing degree of falsity.

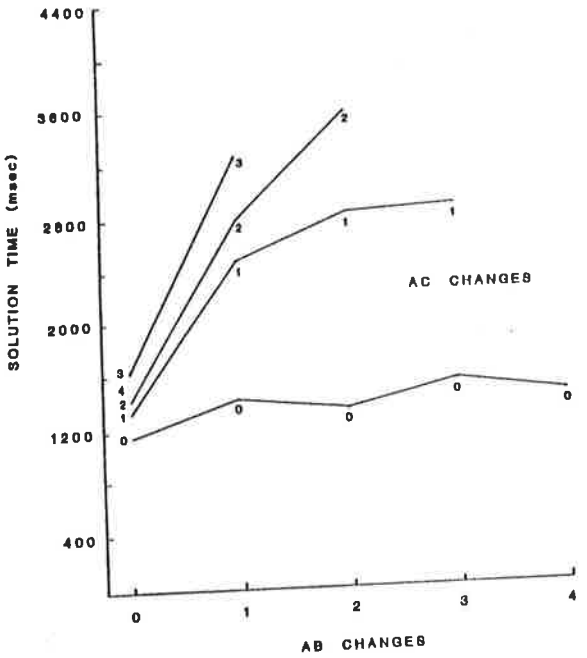
These latter two predictions are also met for the below average subjects as shown in Figure 4.6. With regard to the first two points however, slopes show



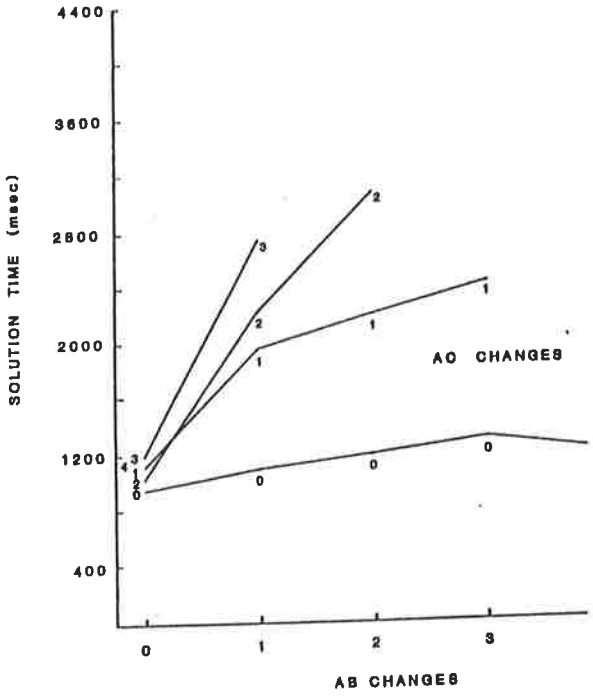
(a)



(b)



(c)



(d)

Figure 4.3 Mean solution times for 15 AB/AC attribute change combinations for true Type I and II analogies in each cue condition, above average subjects.
(a) 0 cue condition
(b) 1 cue condition
(c) 2 cue condition
(d) 3 cue condition

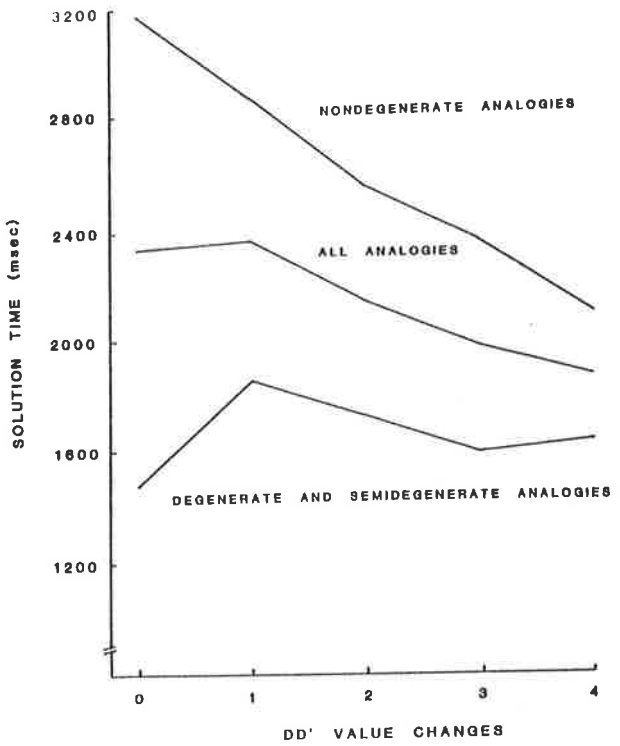


Figure 4.4 Mean solution times for true and false Type I and II analogies, above average subjects.

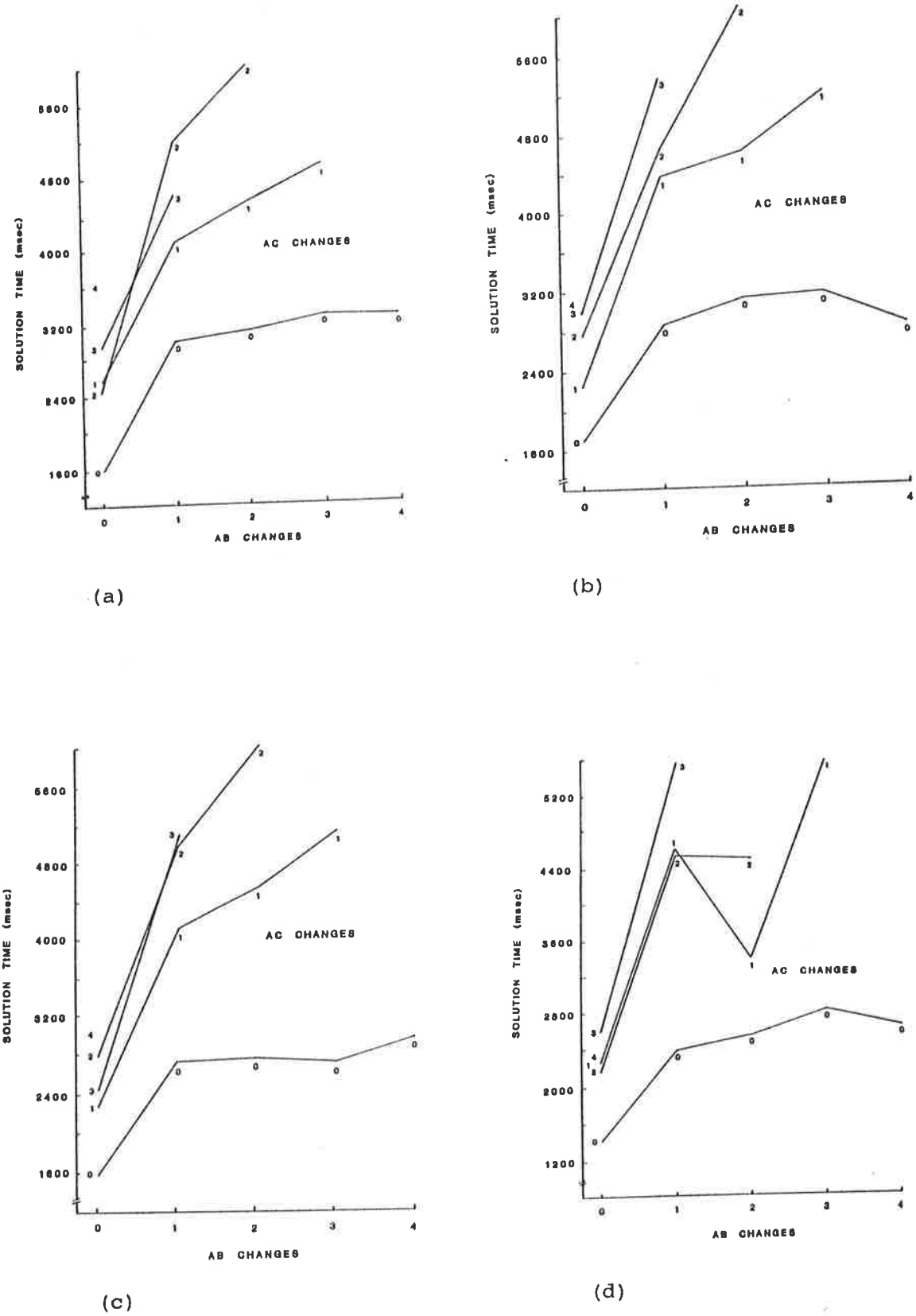


Figure 4.5 Mean solution times for 15 AB/AC attribute change conditions for true Type I and II analogies in each cue condition, below average subjects.
(a) 0 cue condition
(b) 1 cue condition
(c) 2 cue condition
(d) 3 cue condition

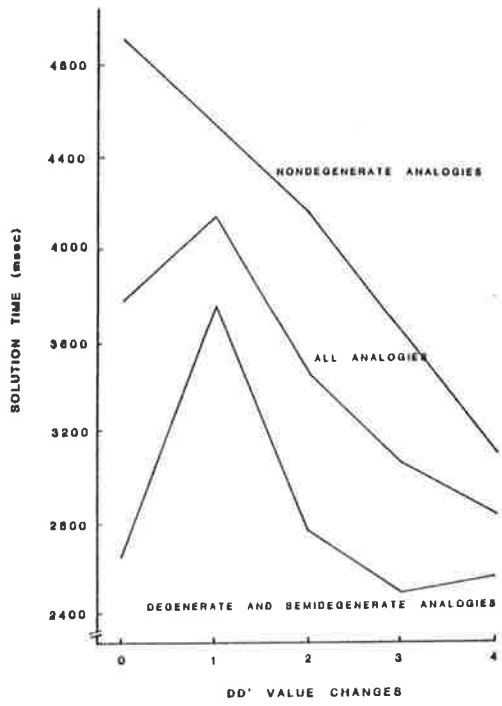


Figure 4.6 Mean solution times for true and false Type I and II analogies, below average subjects.

very little decline over cue conditions and the intercepts for these slopes are not lowered as the number of precues increases, Figures 4.5 (a) to (d). Thus, there appears to be some support for the use of self-terminating processes by the below average subjects, but it is not as strong as for the above average subjects. Alternatively, the finding that the first two points are not met for these subjects, may be due to their not using the precued figures in the first half of the trial. If the precued figures are not being processed in the first half of the trial, then solution times will reflect those processes thought to have occurred in this part of the trial plus the processes being used in the second half of the trial. In other words, with regard to the equations for the models presented in Table 3.2, Chapter 3, parameter dropouts for encoding, inference, mapping and application will not occur. This may also be true to a lesser extent for the above average group, who show less decline in slope and intercept across cue conditions than did the subjects used by Sternberg (1977a).

The results obtained for the Type I analogies (the degenerate and semidegenerate analogies) correspond to the results obtained by Sternberg (1977a). These analogies show no slope across attribute value changes in any of the cue conditions and no reduction in intercept, for both above and below average groups. (Figures 4 (a)-(d) and 4.5 (a)-(d) for above and below average groups respectively where at least one term has zero attribute changes). There is a difference between the degenerate analogies (with zero AB/AC attribute changes) and the semidegenerate analogies (with either 0 changes between the A and B terms or the A and C terms, especially for the below average subjects, but these results are consistent with those obtained by Sternberg (1977a). (See Figure 3.7, Chapter 3).

As Sternberg found, these analogies are solved much more quickly than the

Type II analogies and true analogies are solved more quickly than false analogies for the above average group (Figure 4.4). For the below average group, true Type I analogies are solved at about the same rate as the 2, 3 and 4 DD' value change false Type I analogies, all of which are solved much more quickly than the false Type I analogies with only 1 DD' value change (Figure 4.6). This suggests that the below average subjects have difficulty solving those analogies where the presented D term is incorrect by just one attribute, compared with the true form (D').

Taken as a whole, however, the results for these types of analogies suggest adoption of dual processing as described by Sternberg and discussed in Chapter 3. Sternberg suggested that subjects solved the analogies in two ways, using either holistic or attribute-comparison processing. These two methods of processing Sternberg postulated, occured in parallel so that if holistic processing was unsuccessful attribute-comparison processing would continue but no additional time would be added to the actual solution time by the initial holistic scan. It is postulated that Type I analogies are processed by a holistic scan while Type II analogies require the use of attribute-comparison processing. Sternberg incorporated this postulation into his models by proposing that the number of changes between the A and B and A and C terms were irrelevant to the solution of the Type I analogies. Rather the subject made a holistic scan by matching the D term to either the B or C term of the analogy. If this scan resulted in a match then the subject responded true, if not then the subject responded false. Sternberg incorporated this into the mathematical equations for each of the four models by proposing that a match be equal to zero value changes (as he found that these analogies were solved more quickly than most false Type I analogies) and that a mismatch be treated as equal to one value change.

Table 4.6 presents the results of the model fitting procedure, incorporating dual processing, for the above average group, together with the parameter estimates for each process in each model. Model III was the best fitting model for the above average group accounting for 65.5% of the variance. This was followed by Model IV which accounted for 65.3% of the variance. Then followed Model II which accounted for 60.7% of the variance and finally, Model I, which accounted for 56.1% of the variance. These fits compare with 35.7%, 39.5%, 40.3% and 39.0% for Models I to IV respectively when dual processing was excluded. Thus, inclusion of dual processing appears to make a significant difference to the amount of variance accounted for, a similar result to that found by Sternberg.

Models III and Model IV appear to produce the best fits while Models II and I are not so successful. This ordering of models and improvement in fit using dual processing is consistent with that obtained by Sternberg using comparable subjects. However, far less of the variance is accounted for in this experiment. Sternberg obtained fits of 75.5%, 84.7%, 91.8% and 90.8% for Models I to IV respectively (55.5%, 59.7%, 62.1% and 61.9% without dual processing).

The percentage of variance accounted for by the models incorporating dual processing, using the below average group's data was even more disappointing. Model IV was the best fitting model, accounting for 38.1% of the variance. Model III followed, accounting for 37.9% of the variance, with Model II accounting for 32.1% of the variance and Model I for 26.0% of the variance. (Table 4.7 presents these results for the below average group). Without dual processing these fits corresponded to 21.8%, 31.7%, 35.3% and 35.2% for Models I to IV respectively. Thus, the improvement in the fit provided by dual processing is not as great for these subjects. In addition, it can be seen in Table 4.7 that Models II, III and IV produce a negative estimate for the

TABLE 4.6

MODEL FITS AND PARAMETER ESTIMATES, MODELS I TO IV

ABOVE AVERAGE SUBJECTS

Parameter Dropouts Dual Processing

					Parameter Estimates			
	% variance	Freg	df	a	x x'	y y'	z z'	c
Model I	56.1%	94	4,295	131	87	369	287	1169
Model II	60.7%	114	4,295	102	157	429	453	1144
*Model III	65.5%	140	4,295	95	210	744	276	1310
Model IV	65.3%	139	4,295	101	377	709	215	1357

TABLE 4.7

MODEL FITS AND PARAMETER ESTIMATES, MODELS I TO IV
BELOW AVERAGE SUBJECTS

Parameter Dropouts Dual Processing

					Parameter Estimates			
	% variance	Freg	df	a	x x'	y y'	z z'	c
Model I	26.0%	26	4,295	40	-11	422	536	2465
Model II	32.1%	35	4295	-17	117	536	867	2405
Model III	37.9%	45	4,295	-27	153	1029	635	2609
*Model IV	38.1%	45	4,295	-27	330	982.6	574	2666

* Best Fitting Model

encoding parameter and in Model I, a negative parameter estimate is produced for inference. Part of this poorness of fit can probably be attributed to these subjects high random variability (Baumeister and Kellas, 1968).

To investigate whether an improvement in the percentage of variance accounted for could be obtained by taking into account the finding that the subjects and particularly below average subjects were not making as much use of the precued figures as the subjects in Sternberg's experiment, an alternative to the models used previously was tested. The mathematical equations for this alternative procedure are presented in Table 4.8. As the above and below average groups appeared to be making some use of the precued figures (i.e. there was some decline in solution times across cue conditions), in the alternative model fits, encoding still dropped out from the 0 to the 3 cue condition. However, it was assumed that all attribute-comparison processes occurred in the second half of the trial. Thus, it was assumed that subjects encoded the precued figures in the first half of the trial and did not re-encode these precued figures in the second half of the trial but that all the required attribute-comparison processes were taking place in the second half of the trial.

Inference and application were not confounded in the mathematical equations of Models I and IV because of the inclusion of dual processing and the Type I analogies. Thus, for Type I analogies, inference equaled 0 while application equalled either 0 or 1 depending on whether the analogy was true or false. For the Type II analogies , inference and application were confounded.

The percentage of variance accounted for using this alternative procedure was significantly improved for both groups. Model III remained the best fitting model for the above average subjects accounting for 74.4% of the variance and

TABLE 4.8

NEW MATHEMATICAL EQUATIONS FOR MODELS I TO IV

ALTERNATIVE PROCEDURE

MODEL I

0 cues	=	4a	+	fx	+	gy	+	fz	+	c
1 cue	=	3a	+	fx	+	gy	+	fz	+	c
2 cues	=	2a	+	fx	+	gy	+	fz	+	c
3 cues	=	a	+	fx	+	gy	+	fz	+	c

MODEL II

0 cues	=	4a	+	fx	+	gy	+	f'z'	+	c
1 cue	=	3a	+	fx	+	gy	+	f'z'	+	c
2 cues	=	2a	+	fx	+	gy	+	f'z'	+	c
3 cues	=	3a	+	fx	+	gy	+	f'z'	+	c

MODEL III

0 cue	=	4a	+	fx	+	g'y'	+	f'z'	+	c
1 cue	=	3a	+	fx	+	g'y'	+	f'z'	+	c
2 cues	=	2a	+	fx	+	g'y'	+	f'z'	+	c
3 cues	=	a	+	fx	+	g'y'	+	f'z'	+	c

MODEL IV

0 cue	=	4a	+	f'x'	+	g'y'	+	f'z'	+	c
1 cue	=	3a	+	f'x'	+	g'y'	+	f'z'	+	c
2 cues	=	2a	+	f'x'	+	g'y'	+	f'z'	+	c
3 cues	=	a	+	f'x'	+	g'y'	+	f'z'	+	c

again was closely followed by Model IV which accounted for 73.6% of the variance. Model II accounted for 69.5% of the variance and Model I, for 61.6% of the variance. These results are presented in Table 4.9 together with the parameter estimates for each process in each model. Model IV remained the best fitting model for the below average group, accounting for 51.3% of the variance, followed closely by Model III which accounted for 50.4% of the variance. Model II accounted for 42.6% of the variance and Model I for 32.6% of the variance. These results are presented in Table 4.10. In addition, the estimates for the encoding parameter are no longer negative in Models II, III and IV, nor is the estimate for the inference parameter in Model I. The regression constant (c) is also greatly reduced in comparison to that previously obtained. Thus, this alternative model fitting procedure appears to approximate more closely the performance of both groups. However, it is still not as close as the original model fits obtained by Sternberg (1977a).

Table 4.11 presents the F regression tables for the best fitting alternative model, Model III incorporating dual processing, for the above average group. It can be seen that parameter estimates are quite reliable and all regression F values are significant. As can be seen in the step wise multiple regression table shown in the lower half of Table 4.11, variables were entered into the regression equation in the order of y' (self-terminating mapping) followed by x (exhaustive inference) followed by a (exhaustive encoding) and finally z' (self-terminating application). Each parameter made a statistically significant contribution to the amount of variance accounted for and all but the application parameter appear to have made a worthwhile contribution to the amount of variance accounted for. (These F Regression tables are presented in Appendices 1.3 and 1.4 using both model fitting procedures and for both groups for the remaining models).

TABLE 4.9

MODEL FITS AND PARAMETER ESTIMATES, MODELS I TO IV, ALTERNATIVE PROCEDURE ABOVE AVERAGE SUBJECTS

No Parameter Dropouts Dual Processing

					Parameter Estimates			
	% Variance	Freg	df	a	x x'	y y'	z z'	c
Model I	61.6%	118	4,295	227	100	364	184	949
Model II	69.5%	168	4,295	229	107	423	452	740
*Model III	74.4%	213	4,295	227	194	671	205	938
Model IV	73.6%	205	4,295	226	401	596	62	1074

TABLE 4.10

MODEL FITS AND PARAMTER ESTIMATES, MODELS I TO IV, ALTERNATIVE PROCEDURE BELOW AVERAGE SUBJECTS

No Parameter Dropouts Dual Processing

					Parameter Estimates			
	% variance	Freg	df	a	x x'	y y'	z z'	c
Model I	32.6%	36	4,295	121	203	430	244	2381
Model II	42.6%	55	4,295	121	142	562	840	1920
Model III	50.4%	75	4,295	121	212	1031	501	2170
*Model IV	51.3%	78	4,295	121	582	867	263	2363

* Best Fitting Model

TABLE 4.11

F REGRESSION TABLE ALTERNATIVE MODEL III

Above Average Group

Parameter	Time (msecs)	Standard Error	B	Freq	df
a	227	18	.36	152	1,295
x	194	27	.26	53	1,295
y'	671	42	.56	258	1,295
z'	205	43	.15	23	1,295
c	938				

Stepwise Multiple Regression

Parameter	Cumulative R^2	r	Cumalative Freg	Cumulative df
y'	.53	.73	332	1,298
x	.59	.60	217	2,297
a	.72	.36	258	3,296
z'	.74	.35	214	4,295

TABLE 4.12

F REGRESSION TABLE ALTERNATIVE MODEL IV

Below Average Group

Parameter	Time (msecs)	Standard Error	B	Freg	df
a	121	43	.11	8	1,295
x'	582	140	.29	17	1,295
y'	867	115	.43	57	1,295
z'	263	122	.11	5	1,295
c	2363				

Stepwise Multiple Regression

Parameter	Cumalative R^2	r	Cumulative Freg	Cumalative df
y'	.41	.64	208	1,298
x'	.49	.64	144	2,297
a	.51	.11	101	3,296
z'	.51	.37	78	4,295

Table 4.12 presents the F regression tables for the below average subjects for alternative Model IV, incorporating dual processing. Both self-terminating mapping and inference are well predicted, while encoding and self-terminating application are less well predicted. The beta weights for these two parameters are quite low and the standard error of the estimate for application is very high. Referring to the lower table, it can be seen that each parameter makes a statistically significant contribution to the analysis. However, the contributions of the encoding and application parameters overall are not as great as those made by inference and mapping. This suggests that these two parameters are not being as reliably predicted as the latter two parameters for these subjects. As mentioned previously, the poor predictive power of encoding is probably due to these subjects having not made use of the precued figures. The poor predictive power of application suggests that the subjects are not always using self-terminating application. It may be that they are sometimes using exhaustive application processing.

A number of conclusions can be drawn from the results of these analyses. Firstly, that the two groups of above and below average subjects differ in the type of model that best fits the data, the best fitting model for the former group being Model III and for the latter group, Model IV. This tends to confirm the results obtained by Sternberg and Rifkin (1979) who found that data obtained from young children was best fit by Model IV, while for older subjects, the best fitting model was Model III. In addition, estimates of the time spent on each process indicate that the above average group is spending more time on encoding and consequently, much less time on inference, mapping and application than the below average subjects. As mentioned previously, both Sternberg (1977a) and Sternberg and Rifkin (1979) have obtained results which suggest that older and better reasoners spend more time on encoding than younger and poorer reasoners and that this results

in faster subsequent processing and a faster overall solution time. This finding also appears to be confirmed here. Parameter estimates for encoding are relatively longer for the above average group when compared to the below average group while the attribute-comparison processes are relatively shorter (Tables 4.9 and 4.10 respectively). The fact that poorer reasoners spend less time on encoding may be due to the load on memory that more time spent on encoding is likely to produce. More will be said on this matter in later chapters.

However, the point must also be made that the model fits for both groups and especially the below average group are much lower than those obtained by Sternberg, and that the overall reliability of the data is not as high for the best fitting models, again especially for the below average group. Thus the conclusions drawn here can only be tentative.

The lower percentage of variance accounted for may be due to a number of factors. For the above average group, consideration must be given to the fact that these subjects received less trials and therefore, less practice on the task than Sternberg's subjects. This probably contributed to the findings that these subjects were making less use of the precued figures and were producing longer overall solution times than Sternberg's subjects. For the below average subjects, a more complex explanation is required. A partial explanation can be obtained by taking into consideration the finding that they were making even less use of the precued figures than the above average group. However, it may also be due to their using different processes to solve the analogies or their having less understanding of the task. The greater random variability produced by these subjects must also be a contributor here. A number of experiments using mildly retarded young adults and reaction time as a dependent variable (Baumeister and Kellas, 1968; Nettelbeck and Brewer,

1981) have found that the standard deviations produced by these subjects are much greater than those produced by nonretarded subjects. The large standard deviations produced by the below average subjects in this experiment, indicate a high random variability for these subjects. The model fitting procedure developed by Sternberg requires consistent, accurate performance for effective use. High random variability due to lapses in concentration or loss of attention will tend to distort the results obtained from the model fitting procedure, and reduce its reliability.

Finally, although Model III appears as the best fitting model for the above average group and Model IV for the below average group, there is very little to distinguish between these two models for both groups. Since this may be due to some subjects using one model and some subjects another it was decided to examine the fits provided by all models for each subject individually. As discussed in Chapter 1, a number of recent investigators (Bethall-Fox et al, 1984; Cooper, 1980a; Cooper and Regan, 1982; MacLeod et al, 1978) have found evidence suggesting that there are significant individual differences in the strategies used to solve cognitive tasks. The same alternative model fitting procedure was used as for the full data analysis, which took into account the possibility that the subjects were not making use of the precued figures.

Separate model fits for each individual in each group: Table 4.13 presents the results of these analyses for both above and below average groups. One very noticeable result is that the percentage of variance accounted for by each subject individually is reduced compared to the group data. This varies across subjects and is especially noticeable for the below average group. This reduction in the percentage of variance accounted for is most probably due to the greater variability one would expect to find in individual as opposed to

TABLE 4.13

MODEL FITS FOR EACH INDIVIDUAL SEPARATELY ABOVE AND BELOW AVERAGE GROUPS

SUBJECT NO	MODEL I	MODEL II	MODEL III	MODEL IV
ABOVE AVERAGE GROUP				
S_1	17.6%	19.4%	22.3%*	21.9%
S_2	17.7%	24.9%	27.1%	27.4%*
S_3	29.8%	33.0%	34.1%*	34.0%
S_4	33.6%	36.2%	36.6%*	36.3%
S_5	33.8%	36.6%	38.6%*	38.3%
S_6	50.1%	54.7%	62.6%	63.3%*
S_7	39.3%	45.8%	47.2%	47.3%*
S_8	52.1%*	51.5%	49.2%	40.2%
S_9	28.5%	33.7%	37.9%*	37.5%
S_{10}	50.6%	53.2%*	50.5%	49.2%
S_{11}	18.3%	26.6%	34.8%	35.5%*
S_{12}	19.1%	21.5%	22.9%	23.2%*
BELOW AVERAGE GROUP				
S_1	37.9%	39.1%	41.0%*	38.5%
S_2	14.7%	24.7%	30.8%	31.8%*
S_3	7.2%	15.2%	20.2%	22.1%*
S_4	4.7%	10.4%	14.5%	14.6%*
S_5	7.6%	10.0%	10.7%*	10.3%
S_6	22.5%	25.2%*	24.3%	23.3%
S_7	15.4%	16.3%	18.5%*	18.5%
S_8	30.1%	33.1%	37.6%	38.4%*
S_9	21.4%	21.4%	22.7%*	17.9%
S_{10}	8.6%	12.3%	16.6%	16.9%*
S_{11}	10.5%	12.1%	14.2%	15.0%*
S_{12}	11.8%	13.7%*	13.6%	12.9%

* Best fitting model

group data. One would also expect this to be exaggerated for the below average group because of their greater level of variability in responding. The reduced fits may also be due to some individuals making some attempt to use the precued figures ie sometimes they use the precues and sometimes they don't - a point also relevant to the model fits for group data. Finally, the reduction in fit may be due to some subjects using processes different from those included in the models tested.

This type of analysis also reveals the cause of the lack of difference between Models III and IV. For the above average group, the data of five subjects are best fit by Model III and a further five subjects data are best fit by Model IV. One subject's data are best explained by Model II, while another subject's data are best explained by Model I. However, there is still little to distinguish between Models III and IV when considering the results of each of the ten subjects whose solution times are best explained by one of these two models. For all subjects whose data are best explained by Model III, Model IV follows closely as the next best fitting model. A similar situation exists for those subjects whose solution times are best explained by Model IV. Thus, the models are still essentially indistinguishable.

For the below average subjects, a similar pattern is revealed. Model IV provides the best explanation of the data for six subjects, while Model III is best for four subjects. Model II provides the best fit for the remaining subjects. For two of the subjects best fitted by Model III, Model IV follows as the next best fitting model. For the remaining two subjects best fit by Model III, Model II provides the next best fit. For the six subjects whose data were best explained by Model IV, Model III follows as the next best fitting model in all cases. Thus, for both groups, a majority of subjects are using either Model

III or IV and there is little to choose between the fits of both these models.

In Sternberg's results it is also difficult to distinguish between Models III and IV. (Sternberg did not carry out individual model fits for each subject separately). In addition, in the study by Sternberg and Rifkin (1979), very little separated the models for all four groups, college students and the children in Grades 6, 4 and 2. While Sternberg and Rifkin found Model III to be the best fitting model, accounting for 89% for the adult subjects, Model II also accounted for 89% of the data for these subjects. Sternberg and Rifkin chose Model III over Model II because it had a larger regression F and a lower standard error of the estimate. For the Grade 6 subjects, Model III, the best fitting model, accounted for 86% of the variance and the next best fitting model, Model II accounted for 83% of the variance. For the Grade 4 subjects, Sternberg and Rifkin suggested Model IV was the best fitting model even though it accounted for 1% less of the variance than Model III (80% compared to 81%). Their decision was based on the fact that Model IV had a higher regression F. For the Grade 2 subjects, Sternberg and Rifkin suggested that Model IVM was the best fitting model (this model differed from Model IV in that it included self-terminating encoding and no mapping component). It accounted for 82% of the variance while Models II and III actually accounted for more of the variance (both 85%). Sternberg and Rifkin rejected Models II and III because they had lower regression Fs than Model IVM, lower standard errors of the estimate and gave a negative parameter estimate for the inference process. These results clearly show that very little separates the best fitting models (and often the remaining models) from each other using the componential method.

This may be due to the mathematical equations for each of the models being

too similar, especially in terms of separating self-terminating and exhaustive forms of the same process. However, another explanation is that subjects are flexible in their use of the exhaustive and self-terminating forms of each process. Mathews et al (1980), Sternberg and Ketron (1982) and Sternberg and Weil (1980) all provide evidence that subjects are to some extent flexible in their use of certain processes by instructing subjects to use strategies and processes they would not normally use. Bethall-Fox et al (1984) have also suggested that subjects alter the type of process they use, depending on the difficulty level of the particular item. It is quite possible in this experiment that subjects are altering the processes they use depending on item difficulty.

With regard to the below average subjects this may be less the case, as some of the researchers previously mentioned found flexibility in strategy or process usage reduced with ability (Bethall-Fox et al, 1984; Mathews et al, 1980; Sternberg and Weil, 1980). In the case of these subjects it may be that they take longer to decide on the most appropriate strategy as Belmont, Ferretti and Mitchell, (1982) found in a self-paced memory task where they attempted to equate task difficulty for nonretarded and retarded subjects.

Separate model fits were also obtained for the 0 cue condition, for Type II (nondegenerate analogies) only and for Sessions 1 and 4 separately. Sternberg conducted these analyses to check the reliability of the model fitting procedure he had developed. If the procedure was reliable then the same model, Model III should remain the best fitting model in each of the three instances above. Table 4.14 presents the results of these analyses for both above and below average groups. Because of this only the model providing the best fit will be presented in the text (F regression tables for these analyses are presented in Appendices 1.5 to 1.15).

TABLE 4.14

MODEL FITS FOR ALL ADDITIONAL ANALYSES
ABOVE AND BELOW AVERAGE SUBJECTS

	MODELS			
	MODEL I	MODEL II	MODEL III	MODEL IV
Above Average Subjects				
Analysis of each cue condition separately				
0 cue	50.7%	62.1%	70.3%	72.6%*
1 cue	61.9%	71.5%	78.0%*	77.1%
2 cue	50.3%	59.2%	65.8%*	64.0%
3 cue	70.0%	75.8%*	75.4%	71.2%
Analysis of Type II (nondegenerate analogies) only	32.9%	66.1%	71.4%*	71.4%*
Analysis of Session 1 separately	48.4%	49.1%	50.4%*	47.0%
Analysis of Session 4 separately	47.8%	51.8%	59.8%	60.4%*
Dual Processing in Application Only	47.7%	46.4%	48.3%*	45.8%
Self-terminating encoding	61.5%	69.5%	71.4%*	65.4%
No mapping	49.7%	51.8%		61.0%*
Dual Processing in 1 DD' Change only	62.1%	66.2%	74.2%*	74.0%
Below Average Subjects				
Analysis of each cue condition separately				
0 Cue	35.1%	47.6%	57.9%	59.0%*
1 Cue	21.2%	31.8%	38.4%	39.5%*
2 Cue	30.8%	40.8%	49.2%	50.0%*
3 Cue	44.3%	52.3%	59.0%	59.1%*
Analysis of Type II nondegenerate analogies only	7%	58.7%	68.0%*	67.9%
Analysis of Session 1 separately	16.0%	19.1%	21.2%*	20.4%
Analysis of Session 4 separately	27.6%	33.8%	41.2%	43.8%*
Dual Processing in Application only	33.8%	38.2%	46.1%	47.9%*
Self-Terminating Encoding	32.6%	42.6%	50.4%	50.8%*
No Mapping	26.8%	31.7%		42.0%*
Dual Processing in 1 DD'value change only	33.0%	42.8%	52.5%	53.7%*

* Best fitting Model

Model fits for the 0 cue condition only: The 0 cue condition is equivalent to the composite task where no figures are presented in the first half of the trial. Sternberg found that the same model, Model III, remained the best fitting model in the 0 cue condition (89%) accounting for a similar amount of the variance as the analysis when all four cue conditions were used (92%). As the subjects in both groups in this experiment do not appear to have used the precued figures to the same extent as Sternberg's subjects in the 1,2 and 3 cue conditions it is of interest to examine the results for this cue condition only. One might expect an improvement in the amount of variance accounted for by the 0 cue condition alone. Due to there being only one cue condition, encoding becomes a constant and thus, can not be separately estimated. Model IV became the best fitting model using this method for the above average group, accounting for 72.6% of the variance. (See Table 4.14 for the amount of variance accounted for by Models I, II and III.) Thus there is a change in the best fitting model from the full analysis (Model III) to the analysis using the data from the 0 cue condition only but a similar amount of the variance is accounted for.

The fact that Model IV becomes the best fitting model in the 0 cue condition for the above average group suggests that other models might provide better fits in the remaining cue conditions. To examine whether this was the case, separate model fits for the 1, 2, and 3 cue conditions were carried out. This change in the best fitting model across cue conditions was indeed found to be the case. Model III provided the best fit to the data in the 1 cue condition, accounting for 78.0% of the variance. In the 2 cue condition, Model III was again the best fitting model, accounting for 65.8% of the variance. In the 3 cue condition, however, Model II became the best fitting model accounting for 75.8% of the variance. As in the previous analysis, all three analyses here

are based on three paramters only, inference, mapping and application, encoding being a constant. It appears that processing becomes more exhaustive from the 0 to 3 cue conditions. This may be explained by suggesting that while the subjects were making some attempt to use the precued figures they were referring back to the precued figures in the second half of the trial in the latter cue conditions and thus, were being more exhaustive in their processing.

For the below average group, Model IV remained the best fitting model in the 0 cue condition, accounting for 59.0% of the data. Although the same model provided the best fit here as in the analysis using all four cue conditions, separate model fits were conducted for each of the remaining three cue conditions. In the 1 cue condition, Model IV remained the best fitting model but much less of the variance was accounted for, only 39.5%. In the 2 cue condition, Model IV remained the model providing the best fit to the data, accounting for 50.0% of the variance. Finally, for the 3 cue condition, Model IV provided the best fit to the data, accounting for 59.1% of the variance, but was almost indistinguishable from Model III, which accounted for 59.0% of the variance.

Thus, for the below average subjects a different pattern is evident. In all four cue conditions analysed separately, Model IV, the fully self-terminating model, provides the best fit to the data. This result is surprising since it seems likely these subjects are referring back to the precued figures in the second half of the trial as suggested for the above average subjects, in the 1,2 and 3 cue conditions. It is possible that even though they are referring back to the precued figures they are doing this by one attribute at a time. This would then produce support for the most self-terminating model, Model IV.

In addition, the solution times to the 1 cue condition , although best explained

by Model IV are very poorly predicted by all four models in comparison to the other cue conditions. This is also surprising as neither the graphs for the cue conditions (Figures 4.4 (a)-(d)) nor the interval scores presented in Tables 4.2 and 4.4 for these subjects, gave any indication that these solution times were being poorly predicted. The finding suggests that the below average group may be using a different method of analogy solution for this cue condition, although what method is difficult to determine. Further experimentation may help to explain this result.

Model fits for Type II (nondegenerate) analogies only: Since the Type II analogies are the only "real" analogies in the task ("real" being defined as requiring the extraction of two lower order relationships and then the forming of a higher order relationship concerning these relationships) they might produce the use of a different type of model to the full set of data. Sternberg found using only Type II analogies that Models III and IV were indistinguishable as the model providing the best fit to the data, both accounting for 93% of the variance.

Inference and application are now confounded in Models I and IV because the Type I analogies which previously separated these two parameters via dual processing are no longer included. Separate parameter estimates can be made for the inference - application, mapping, encoding and preparation - response parameters. For the above average group, Models III and IV both accounted for 71.4% of the variance an identical result to that of Sternberg. For the below average group, the best fit was obtained by Model III which accounted for 68.0% of the variance. This was closely followed by Model IV which accounted for 67.9% of the variance. Thus, for these subjects, Model III rather than Model IV becomes the model providing the best fit. These results are the reverse of those obtained by Sternberg and Rifkin (1979) using

only nondegenerate analogies. They found that the data obtained from young adults were best explained by Model III, while Model IV provided the best fit to the data obtained from the young children, but as mentioned previously very little separated these models in Sternberg and Rifkin's data. This suggests that the below average group are more similar to the above average group when solving the more difficult analogies, in that they are slightly more exhaustive in their processsing.

In addition, these two models account for a far greater percentage of the variance than the model fits using both types of analogies. This suggests that the Type II analagies are being better predicted by the models than the Type I anolagies. It may be the case that dual processing is not the best explanation of how the Type I analogies are solved. It does appear from reference to Figures 4.3 and 4.5 that the degree of falsity has some effect on the solution time, with Type I analogies false by one attribute being solved more slowly than the other Type I analogies. This analysis was carried out and is disussed later.

Model fits for Sessions 1 and 4 separately: It was observed that interval scores declined over sessions due to practice with the task. What effect might this have on the models used by the subjects? Does the type of model used change from the first to the last session or does it remain constant? In addition, is more of the variance accounted for in the last session compared with the first because of practice with the task? Sternberg in a similar analysis found that Model IV closely followed by Model III provided the best fits to the data in both sessions and similar amounts of the variance were accounted for (77.6% and 77.0% for Models IV and III respectively, in the first session and 78.5% and 77.1% for the same models in Session 4).

For the above average group, Model III remained the best fitting model accounting for 50.4% of the variance in Session 1. In Session 4, however, Model IV became the best fitting model accounting for 60.4% of the variance, followed closely by Model III which accounted for 59.8% of the variance. Thus, unlike the results obtained by Sternberg, there is a change in the amount of variance accounted for by the best fitting model and in the ordering of the models. In Session 1, the more exhaustive models, Models III and II, best explain the data, while in Session 4, the trend is towards more self-terminating processing, with Models IV and then III providing the best explanation of the data. In addition, more of the variance is explained by the data obtained in Session 4. This suggests that compared with Sternberg's subjects there is a strong practice effect for the above average subjects in this experiment.

For the below average group, in Session 1, Model III was also the best fitting model although it accounted for only 21.2% of the variance. In Session 4, as was found with the above average group, Model IV became the best fitting model, accounting for 43.8% of the variance. Thus, there is an even greater improvement in the amount of variance accounted for from Session 1 to Session 4 and hence a greater practice effect for this group when compared to the above average group. This may be similar to the findings of Phillips and Nettelbeck, (1984) who found a significant improvement in performance for retarded subjects after seven sessions of practice. Also, these subjects have become more self-terminating in their processing from the first to the last session, although this is not as great as the change found for the above average group.

Further additional model fits were also conducted. These included the alternative model fits that Sternberg (1977a) originally carried out; dual processing in application only, self-terminating encoding and no mapping. One

additional model fitting procedure was also included, this being dual processing in 1 DD' value change only. This alternative procedure was suggested by the poor predictive power of the application parameter for the below average subjects.

Dual Processing in Application only: As can be seen in Table 4.14, much poorer fits to the data were obtained for the above average group, using this model fitting procedure. Model III remained the model providing the best fit to the data, accounting for 48.3% of the variance compared to 74.4% with dual processing. For the below average group, model fits using this method were not as dramatically different from the original model fits as they were for the above average group. Model IV remained the best fitting model accounting for 47.9% of the variance (compared with 51.3% of the variance with dual processing). This is a finding that occurs throughout many of the experiments to follow using retarded subjects. Less of the variance is accounted for and alternative model fits can not always be as easily rejected as for nonretarded subjects. This may be due to the greater random variability of the retarded subjects data and because they are less consistent in the use of one particular model or strategy as suggested previously. However, the fits were still poorer than the results obtained using the original models with dual processing in all three attribute-comparison processes. Thus both groups and as Sternberg found, this alternative model fitting procedure was discounted as providing a poorer fit to the data.

Self-Terminating Encoding: In all the model fitting procedures so far performed, encoding has been assumed to be exhaustive, subjects encoding all four attributes of each analogy term in each analogy. However, it is possible that like the attribute-comparison processes, inference, mapping and application, self-terminating encoding of some analogy terms may occur. In this case, only as many attributes of each analogy term would be encoded as

were required to reach a solution. It appears likely that it is the C and D terms of the analogy in which self-terminating encoding is most likely to occur. For the relationship between the A and B terms to be extracted, it is likely that in most cases (at least for Type II analogies) all four attributes in these two figures will need to be encoded. However, once inference has occurred (the extraction of the relationship between the A and B terms) it might only be necessary to encode one or two of the attributes in the C and D terms for the analogy to be solved. This is especially likely to be the case if the analogy is false.

Sternberg (1977a) when applying self-terminating encoding to his models, assumed that exhaustive encoding occurred when an exhaustive attribute-comparison process was postulated to be used while self-terminating encoding occurred just prior to when a self-terminating attribute-comparison process was postulated. Thus, self-terminating encoding would never occur before an exhaustive attribute-comparison process but could occur after such a process. This was translated into the models thus: Model I remained unchanged as all attribute-comparison processes are postulated to be exhaustive; in Model II, encoding became self-terminating just prior to self-terminating application; in Model III, self-terminating encoding occurred just prior to self-terminating mapping; and in Model IV, self-terminating encoding occurred just prior to self-terminating inference. Prior to these points in all models, encoding was assumed to be exhaustive.

Using this analysis, Model III remained the best fitting model for the above average group, accounting for 71.4% of the variance. For the below average group, Model IV remained the best fitting model accounting for 50.8% of the variance, followed very closely by Model III which accounted for 50.4% of the variance. Thus, while the fits using this method are slightly below those

obtained using exhaustive encoding they can not be discounted as providing a much poorer fit. Sternberg obtained a reduction in the percentage accounted for using self-terminating encoding of between 1% (in Model III) and 10% (in Model IV) He concluded that there was no evidence to support an assumption of self-terminating encoding. Further experimentation is required, however, before any firm conclusions of this kind can be drawn.

No Mapping: The mapping parameter is one introduced by Sternberg (1977a) and not previously included in earlier research on analogical reasoning. He found that when this parameter was excluded much less of the variance was accounted for. Using this procedure, modelling is based on three parameters only, inference, application and encoding, mapping being no longer included. Due to the absence of a mapping parameter, Models II and III become indistinguishable, Model II originally incorporating exhaustive mapping, and Model III self-terminating mapping.

For the above average group, Model IV became the best fitting model, accounting for 61% of the variance. For the below average group, Model IV remained the best fitting model accounting for 42.0% of the variance. Thus, for both groups, while Model IV stands up quite well with no mapping the other models all provide poorer fits. Therefore, this alternative model fitting procedure can be discounted as providing a poorer fit to the data at least for Models I and II-III.

Dual Processing in 1 DD' Value Change Only: This alternative procedure was carried out because of the unreliability of the application parameter estimate for the below average subjects. As mentioned previously, it was found that for these subjects, model fitting using the Type II analogies accounted for much more of the variance than the model fits using both analogy types

(68.0% compared to 51.3%). This suggested that the Type I analogies were being poorly predicted. It was also found that for these subjects, Type I analogies false by 1DD' value change were solved much more slowly than the true Type I analogies and Type I analogies false by 2, 3 and 4 DD' value changes. (See Figure 4.6). It is possible that this was the cause of the Type I analogies being less well predicted. To examine this possibility, dual processing in the Type I analogies was altered from all false analogies being equal to one attribute change to only false analogies false by 1 attribute change equalling one with 2, 3 and 4 attribute changes being equal to zero.

Using the below average group data, this alternative procedure did improve the amount of variance accounted for although not substantially but application time was more reliably predicated. Model IV remained the best fitting model accounting for 53.7% of the variance (See Appendix 1.15). This model fitting procedure was also carried out for the nonretarded subjects to examine whether it would change the amount of variance accounted for, for these subjects. Model III remained the best fitting model and a similar although slightly reduced amount of variance was accounted for (74.2% compared to 74.4% for the previous analysis).

These additional model fits shed some light on the validity and reliability of the componential method, and the models it tests. While no mapping and dual processing in application only can be discounted as providing poorer fits to the data for both groups, the same can not be said for self-terminating encoding or dual processing in 1 DD' value change only. This suggests that the componential method is sensitive to changes in the type of processes used and ordering of models. However, it appears to be less sensitive to individual difference data and changes from self-terminating to exhaustive forms of the

attribute-comparison processes inference, mapping and application. Further experimentation is required before firm conclusions can be drawn.

4.3.3 ERROR RATES

Error rates for above average subjects were very low, with a mean rate of 1.57%. This corresponds well to the mean rate produced by Sternberg's (1977a) subjects, which was 1.4%. Mean rates declined from Session 1 to Session 4 as would be expected as the subjects' experience with the task increased, the biggest drop being from Session 1 to Session 2. Mean rates were 2.74%, 1.32%, 1.14% and 1.09% for Sessions 1 to 4, respectively. Sternberg gives mean error rates for Sessions 1 and 4 only. These were 2.6% and .5% respectively. This corresponds quite well with the decline obtained in this experiment although his subjects appear to have improved over sessions more than the above average subjects in this experiment.

Error rates for below average subjects will be presented in greater detail than for the above average group as their pattern of errors was somewhat different. The above average group required only one repetition, in general, to solve an error. Sternberg doesn't say how many repetitions his subjects required to correct errors. However, the below average group often required more than one repetition at the end of a block. This was especially the case in the first and second sessions. Thus, errors are divided into three sections for this group 1) percentage of errors made prior to any repetitions. This error rate is equivalent to the error rates presented for the above average group; 2) percentage of errors remaining after one repetition but subsequently corrected after two or three repetitions; and 3) the total percentage of errors (i.e. 1) and 2)).

Table 4.15 presents these results for the below average group. Error rates were still quite low but they were significantly greater than the error rates produced by the above average group. The total percentage of errors was 7.24, this being made up of 5.39% errors present prior to any repetitions and 1.85% of errors remaining after one repetition. Thus, as was anticipated repetitions after the initial error made up a proportion of the below average group's error rate. While this is not a large percentage of the total, it must be acknowledged that repetitions of errors are likely to increase the possibility of the subject solving the analogy by chance. This would appear to be a weakness of the componential method especially when retarded individuals are used as subjects. Error rates declined from 9.57% to 5.40% from Sessions 1 to 4 for these subjects. This was due to a drop in both types of errors. The decline in errors from Sessions 1 to 2 is not as great as that observed for the above average group and is probably due to this group having received an initial session of practice. However, there is still a greater reduction in errors from the first to the second session than all remaining sessions.

TABLE 4.15

MEAN ERROR RATES
BELOW AVERAGE GROUP

Errors	Session 1	Session 2	Session 3	Session 4	All Sessions
% of errors produced at the end of a block	6.63	5.40	5.02	4.50	5.39
% of errors remaining after 1 repetition	2.94	2.37	1.18	.90	1.85
Total % of errors	9.57	7.77	6.20	5.40	7.24

4.4 CONCLUSION

A number of conclusions can be drawn from the results of this experiment. Firstly, it appears that both groups, but especially the below average group were not making use of the precued figures to the same extent as Sternberg's subjects. While it was not known what instructions Sternberg used to obtain use of the precued figures it seems that such instructions were provided. It might be mentioned here that Bethell-Fox et al in their analysis of eye movements, found that subjects referred back to the precued figures in the second half of the trial, and that this was greater for more difficult items and lower ability subjects. This did not, like Sternberg found, appear to affect the percentage of variance accounted for although it would seem to violate the assumption of pure insertion. Quite a good fit to the data was obtained for the above average group (65.5%, Model III) and this was improved by altering the model fitting procedure to take into account the fact that subjects were not using the precued figures as much as Sternberg's subjects (74.1%, Model III). However, the amount of variance accounted for is still not as high as that obtained by Sternberg (1977a, 91.8%, Model III). For the below average subjects, there was even less evidence that they were making use of the precued figures. The below average groups' data appeared to be generally less reliable than that obtained for the above average group and encoding and application were not reliably predicted. Even when the alternative model fitting procedure was used, only 51.4% of the variance was accounted for (Model IV). Also, alternative models which were generally much worse for the above average subjects were only slightly worse for these subjects (i.e. the dual processing in application only and no mapping model fits). The 1 cue condition accounted for very little of the variance when analysed separately from the other three cue conditions. The Type I analogies

also appeared to be poorly predicted, with the analysis including Type II analogies only, accounting for a much higher amount of the variance than when the two types were analysed together.

Sternberg and Rifkin's (1979) finding that older and better reasoners spend more time on encoding than younger and poorer reasoners is confirmed here. Above average subjects' data produced longer estimates for encoding and shorter inference, mapping and application processes than the below average group's data. (See Tables 4.11 and 4.12 respectively) The regression constant for this group, representing the preparation and response processes is also less, indicating than they were taking less time to execute these processes.

In addition, while both groups showed evidence of a practice effect (tending to become more self-terminating in their processing across sessions), the below average subjects showed a much more dramatic improvement in the amount of variance accounted for than did the above average group across sessions, even though they had received an initial session of practice with the task, which the above average group did not. This suggests that they may have taken longer to reach asymptotic performance, a finding consistent with that of Phillips and Nettelbeck (1984) who found that retarded subjects' performance level had not reached asymptotic even after seven practice sessions using S. Sternberg's (1969b) memory scanning task. Finally, they produced larger standard deviations and higher error rates than the above average subjects and the simplical structure of the mean solution times for each cue condition broke down because of the 2 cue condition. The below average group did, however, tend to be more consistant in the use of one particular model, namely Model IV in comparison to the above average group who showed a tendency to use more

self-terminating processes across sessions and across cue conditions. The only instance in which the below average groups' data appeared to favour more exhaustive processing was in the analysis using the Type II analogies only. This suggests that for these more difficult analogies they became more exhaustive in their processing. The difference between Models III and IV is that while in the former, inference is exhaustive, in the latter, inference is self-terminating. While the actual difference between the percentage of variance accounted for by these two models is minimal, it may be suggested that for the more difficult Type II analogies the below average group are using more exhaustive inference processes. More exhaustive processing will produce more thorough processing which may have reflected a goal on the part of the below average subjects to solve the analogies accurately. Whether this actually lead to more accurate performance is unknown but this type of processing would place a greater load on memory. The use of Model III by the below average subjects tends not to support Sternberg and Rifkin (1979) who found that young children tend to use the most self-terminating model, Model IV, to solve Type II analogies. It appears that at least for the Type II analogies the below average group are more similar to nonretarded young adults than children. Different results may have been obtained using a retarded group. However, as mentioned before the difference between Models III and IV for these analogies is marginal making it difficult to draw meaningful conclusions.

Individual analyses for each subject in each group separately confirmed the lack of difference between Models III and IV. This suggests that the process that separates Models III and IV, namely, the inference parameter may be involved here. Either the subjects' data favour both exhaustive and self-terminating processing for inference, this depending on the particular analogy or memory capacity of the individual. Alternatively,

the actual mathematical equations used to distinguish exhaustive from self-terminating inference are not effective. Some studies reviewed in Chapter 1 would seem to support the former conclusion, especially for above average subjects. For below average subjects, the closeness of all model fits may suggest more trial and error in the use of alternative forms of the same process as found by Belmont et al, 1982.

Further experimentation is required to determine whether a greater percentage of the variance can be accounted for if subjects can be made to use the precues in a way similar to that obtained by Sternberg. If so, then the validity and reliability of the models fitted here can be better evaluated. In addition, two questions remain to be answered concerning retarded subjects. As the below average subjects have been able to perform the task, although at a less efficient and therefore less reliable level than the above average subjects, can subjects of greater intellectual handicap also perform the task? If so, can the percentage of variance accounted for by these latter subjects be improved by increasing their use of the precues?

4.5 INTRODUCTION TO EXPERIMENT 2

One result of Experiment 1 which required further investigation was the lack of use of the precued analogy terms by both groups of subjects but especially the below average group. This failure to use the precued terms could be due to three factors 1) the lack of specific instructions to do so or 2) the inadequacy of the method of precuing to produce use of the precues in the way Sternberg describes 3) a combination of both factors. Support for the first alternative comes from the results of Sternberg's experiment and Experiment 1. Sternberg obtained results that suggested that his subjects were using the precued figures and this implies that the method of precueing was adequate. In Experiment 1, no specific instructions were given to use the precued terms and the method of precueing alone proved inadequate. While nowhere does Sternberg state that he gave specific instructions regarding the precued terms, personal correspondence following the completion of Experiment 1 revealed that he did. Sternberg always instructed subjects to make as much use of the precued terms as possible, informing them that the purpose of the method was to enable them to do extra processing in the first part of the trial, so that they would not have to do so much in the second part of the trial. Experiment 2 was designed to investigate if, with more specific instructions, the method of precueing would prove sufficient to produce use of the precues.

In addition, Experiment 2 included a mentally retarded group of subjects. In Experiment 1, it was found that, given sufficient practice, the below average group could perform the task adequately. They were found to use more self-terminating processes than the above average group at least when the full set of data was used. In addition their solution times, standard deviations and error rates were significantly greater than those obtained for the above

average group. Therefore, it might be expected that a retarded group will use even more self-terminating processes when solving the analogies and that their solution times, standard deviations and error rates will be significantly greater than the below average group used in Experiment 1. In addition, it is probable that their data will account for less of the variance than the below average group.

4.6 METHOD

4.6.1 SUBJECTS

Twenty-four subjects participated in this experiment. The nonretarded group was made up of 12 Psychology I students, from the University of Adelaide. Their mean age was 20.9 years (range (17 to 43). Their IQ scores were unknown, however, as a group they were presumed to be of above average intelligence. The retarded subjects were all employees of Bedford Industries Rehabilitation Centre. Their mean age was 19.3 years (range 16-24). Again, exact IQ scores were unavailable for most subjects, but they had been classified according to the system developed by the AAMD. Using this system, four subjects were classified as borderline retarded (IQ range 70-85) and eight subjects were classified as mildly retarded (IQ range 55-70). The subjects were not known to have any organic cause of mental deficiency or to be taking prescribed drugs. All subjects remained naive as to the aims of the experiment.

4.6.2 APPARATUS

The apparatus used in this experiment was identical to that used in Experiment 1.

4.6.2 DESIGN

The design of this experiment was the same as that described in Experiment 1. That is, there were three types of analogies, degenerate, semidegenerate and nondegenerate. There were also 15 possible attribute change combinations from the A to B and A to C analogy terms and 5 possible attribute changes between the correct (D') and incorrect (D) D term of each analogy (0,1,2,3,4) and four cue conditions (0,1,2,3,).

4.6.4 PROCEDURE

While the procedure used in this experiment closely resembled that used in Experiment 1, some aspects were changed. These changes included a session of practice for both nonretarded and retarded groups and specific instructions (described below) to use the precued terms during this practice session. Thus all subjects participated in five sessions, the initial session being concerned entirely with practice, after which four experimental sessions followed. Each session was similarly divided into four blocks corresponding to the four cue conditions, with a total of 176 analogies being presented in each session, as in Experiment 1. The 176 analogies were comprised of 16 degenerate, 64 semidegenerate (32 in each form), and 96 nondegenerate analogies. Cue order and form order were identical to that used in Experiment 1.

During the initial practice session, subjects were first presented with a set of 16 cards corresponding to the 16 possible figures, varying on four binary attributes - height (tall - short), weight (fat - skinny), colour (coloured in - not coloured in) and sex (male - female). They sorted the cards on the basis of each attribute. A second set of cards and the 48 computer practice trials used in Experiment 1 were then used, in combination, to explain the nature and

forms of each of the different types of analogies and the cue conditions. Thus an analogy of the degenerate type would be presented using the cards, giving both a true and false example. Progressive numbers of cards were then removed to indicate the precued terms which would be presented in the first half of each trial in each of the cue conditions, starting with the three cue condition. The response apparatus was then explained to the subject and the computer practice trials corresponding to the degenerate analogies were presented. These computer trials included examples of the analogies in all four cue conditions. On completion of these trials, the subject was presented with the two forms of semidegenerate type analogies using the cards. Again true and false examples were provided and cards were progressively removed to indicate the dropout of precued terms in each of the four cue conditions. Subjects then solved the semidegenerate analogies presented via the computer. Finally, the cards were used to explain the nondegenerate types of analogies in the same way as above, with subjects then solving these analogies via the computer.

For each analogy (of all three types) subjects were asked to indicate verbally, whether they thought the analogy true or false before making a key press. In this way, errors could be immediately corrected and also the importance of a low error rate could be impressed on the subjects. All subjects then received the set of 176 experimental analogies, divided into four blocks commencing with the 0 cue condition. This was the same as for the below average subjects in Experiment 1. With regard to the precued terms, subjects were instructed to process these figures before pressing the central key, so that when the complete analogy appeared they could concentrate their attention on the nonprecued terms. In addition, subjects were instructed that speed when processing the precued terms presented in the first half of the trial was not as important as actually processing these figures. Subjects were told, "it is

better to go slowly and look for the relationship between these figures in the first half of the trial rather than press the central key and try to do this in the second half of the trial". In addition, they were instructed to spend only as much time as was really necessary to solve the analogy on the second part of the trial. In this way it was hoped that subjects would be discouraged from referring back to the precued terms of each analogy, after initiation of the second part of the trial. These instructions were repeated at the start of each experimental session. During these sessions, subjects were also instructed to go as fast as they could but without making too many mistakes. They were told "it is more important to get the analogies right rather than go fast and make errors". One additional feature used in this experiment was immediate positive feedback. It was hoped that this would outway any feelings of failure the retarded subjects might experience (Zigler, 1973; Zigler and Balla, 1981) given that they were participating in a complex cognitive task. Waters, (1979) found that contingent feedback significantly improved the performance of retarded subjects on an industrial sewing task. Immediate positive feedback was therefore introduced in this experiment for the retarded subjects. They received positive verbal feedback (the verbal response "good") after every correct response during their initial practice session (incorrect responses were immediately corrected and explained) and during their four experimental sessions.

4.7 RESULTS AND DISCUSSION

As in Experiment 1, this section is divided into three subsections, Interval Scores, Component Scores and Error Rates.

4.7.1. INTERVAL SCORES

As mentioned previously, interval scores were divided into two types, cue

scores and solution scores. Cue scores refer to the amount of time spent processing the information in the first half of the trial while solution times represent the time spent processing the information in the second half of the trial. Tables 4.16 to 4.18 present the mean cue and solution times for each cue condition over all sessions and for Sessions 1 and 4 separately, for nonretarded and retarded subjects respectively. The interval scores are also divided into Type I (degenerate and semidegenerate) and Type II (nondegenerate) analogies, as in Experiment 1.

As in Experiment 1, cue times increased and solution times decreased from the 0 to 3 cue condition for the nonretarded subjects (See Table 4.17). Their times are slightly shorter overall than those obtained for the comparable group in Experiment 1, but are still much longer than those obtained by Sternberg (1977a). In addition, the cue times show a similar rate of increase and the solution times a similar rate of decrease to the same subjects in Experiment 1. The faster overall response rate for the nonretarded group in this experiment is probably due to this group having received an initial session of practice. One might have expected results similar to those obtained by Sternberg given that these subjects also received instructions to use the precued figures but this was not the case. Cue and solution times were more similar to those obtained by the above average group in Experiment 1.

The retarded subjects show even less change over cue conditions than the nonretarded subjects here and the below average subjects in Experiment 1. As can be seen in Table 4.16, cue times actually decrease from the 0 to the 1 cue condition and then increase marginally in the 2 and 3 cue conditions. The solution times decrease from the 0 to the 1 cue condition and from these two cue conditions to the 3 cue condition. However, the longest mean solution time is for the 2 cue condition. As can be seen in Table 4.18, this is due to the

TABLE 4.16

INTERVAL SCORES FOR NONRETARDED AND RETARDED SUBJECTS AND STERNBERG'S SUBJECTS

Overall Means (for both Analogy Types)

	Cue Conditions			
Nonretarded Subjects	0	1	2	3
Cue Time	611	676	1171	1748
SD	451	457	908	1267
No of Observations	2112	2112	2112	2112
Underflow Trials	5	2	1	1
Solution Time	2366	2212	1807	1581
SD	1520	1406	1439	1212
No of Observations	2112	2112	2112	2112
Overflow Trials	1	0	0	0
Retarded Subjects				
Cue Time	894	852	893	968
SD	675	630	730	877
No of Observations	2112	2112	2112	2112
Underflow Trials	9	4	9	12
Solution Time	3812	3760	3841	3678
SD	2621	2792	3200	2851
No of Observations	2112	2112	2112	2112
Overflow Trials	5	4	1	3
Sternberg's Data				
Cue Time	530	755	952	1147
SD	131	187	261	363
No of Observations	4608	4608	4608	4608
Solution Time	1423	1328	947	681
SD	235	222	193	170
No of Observations	4608	4608	4608	4608

TABLE 4.17

INTERVAL SCORES FOR TYPE II ANALOGIES NONRETARDED SUBJECTS

EXPERIMENT 2

Cue Conditions

Type I Analogies All Sessions	0	1	2	3
Cue Time	606	660	936	1121
SD	481	501	763	716
No of Observations	960	960	960	960
Underflow Trials	5	2	1	0
Solution Time	1654	1524	1347	1059
SD	829	811	1102	505
No of Observations	960	960	960	960
Overflow Trials	1	0	0	0
Session 1				
Cue Time	626	776	993	1241
SD	426	686	641	773
No of Observations	240	240	240	240
Underflow Trials	2	2	1	0
Solution Time	1936	1777	1517	1199
SD	1071	817	895	510
No of Observations	240	240	240	240
Overflow Trials	0	0	0	0
Session 4				
Cue Time	594	630	901	1036
SD	403	393	618	650
No of Observations	240	240	240	240
Underflow Trials	1	0	0	0
Solution Times	1431	1330	1167	917
SD	558	526	439	359
No of Observations	240	240	240	240
Overflow Trials	0	0	0	0

TABLE 4.17 (Continued)

	Cue Conditions			
Type II Analogies				
All Sessions	0	1	2	3
Cue Time	615	691	1405	2374
SD	418	410	1033	1643
No of Observations	1152	1152	1152	1152
Underflow Trials	0	0	0	1
Solution Time	3077	2900	2266	2102
SD	1984	1815	1712	1638
No of Observations	1152	1152	1152	1152
Overflow Trials	0	0	0	0
Session 1				
Cue Time	623	867	1411	2351
SD	372	517	772	1322
No of Observations	288	288	288	288
Underflow Trials	0	0	0	1
Solution Time	3521	3535	2801	2687
SD	2301	2324	2453	1962
No of Observations	288	288	288	288
Overflow Trials	0	0	0	0
Session 4				
Cue Time	596	623	1571	2566
SD	402	362	1200	1785
No of Observations	288	288	288	288
Underflow Trials	0	0	0	0
Solution Time	2624	2456	1835	1511
SD	1471	1330	1061	952
No of Observations	288	288	288	288
Overflow Trials	0	0	0	0

TABLE 4.18

INTERVAL SCORES FOR TYPE I AND TYPE II ANALOGIES RETARDED SUBJECTS

EXPERIMENT 2

Cue Conditions

Type I Analogies All Sessions	0	1	2	3
Cue Time	881	830	862	972
SD	641	609	747	966
No of Observations	960	960	960	960
Underflow Trials	4	2	3	7
Solution Time	2909	2775	2754	2562
SD	2027	1968	2165	2125
No of Observations	960	960	960	960
Overflow Trials	0	0	0	0
Session 1				
Cue Time	916	829	858	1132
SD	589	528	480	1059
No of Observations	240	240	240	240
Underflow Trials	2	1	0	2
Solution Time	3245	2900	2925	2925
SD	1960	1676	1924	2501
No of Observations	240	240	240	240
Overflow Trials	0	0	0	0
Session 4				
Cue Time	776	784	775	832
SD	459	537	703	676
No of Observations	240	240	240	240
Underflow Trials	2	0	3	0
Solution Times	2512	2528	2434	2250
SD	1893	1866	1777	1781
No of Observations	240	240	240	240
Overflow Trials	0	0	0	0

TABLE 4.18 (Continued)

	Cue Condition			
Type II Analogies				
All Sessions	0	1	2	3
Cue Time	907	873	923	964
SD	707	650	713	779
No of Observations	1152	1152	1152	1152
Underflow Trials	5	2	6	5
Solution Time	4715	4744	4927	4793
SD	3104	3423	3974	3426
No of Observations	1152	1152	1152	1152
Overflow Trials	5	4	1	3
Session 1				
Cue Time	918	894	958	1051
SD	707	580	714	870
No of Observations	288	288	288	288
Underflow Trials	2	2	1	3
Solution Time	5149	4675	5186	5656
SD	3076	2636	4098	4080
No of Observations	288	288	288	288
Overflow Trials	2	0	0	2
Session 4				
Cue Time	838	849	849	846
SD	619	700	664	601
No of Observations	288	288	288	288
Underflow Trials	2	0	1	2
Solution Time	4028	4128	4514	4250
SD	2645	2551	3861	2959
No of Observations	288	288	288	288
Overflow Trials	0	0	0	0

Type II analogies and not to the simpler Type I analogies, which show a steady if slight decrease from the 0 to the 3 cue condition. This suggests that the retarded subjects experienced greatest difficulty with the Type II analogies in the 2 cue condition. This difficulty did not decline with time as both Sessions 1 and 4 (Table 4.18) indicate this same increase in solution time for Type II analogies in the 2 cue condition.

A three way analysis of variance (Cue x Type x Group) performed using the solution time data, revealed significant main effects for Type ($F(1,176) = 159.84$, $p<.01$) and Group ($F(1,176) = 193.88$, $p<.01$) but no significant effect for Cue ($F(3,176) = 2.46$, $p > .05$) suggesting that the subjects in both groups were not using the precued figures in the 1, 2 and 3 cue conditions (See Appendix 2.1). There was, however, a significant linear trend for cue ($F(1, 176) = 7.25$, $p<.01$) suggesting that the solution times across cue conditions were to some extent additive. There was also a significant linear trend for the significant Cue by Group interaction to be discussed subsequently suggesting that, as shown in Table 4.16, the linear trend was greater for the nonretarded than the retarded subjects. This suggests that the nonretarded subjects were using the precued figures to some extent.

Thus, the assumption of additivity appears to have been met for these subjects as for the above average group in Experiment 1. This is not the case, however, for the retarded subjects. Their solution times show less decline across cue conditions than the below average group in Experiment 1. Further evidence for the suggestion that the retarded subjects are not using the precued figures is the comparatively high number of Underflow Trials they produce (See Tables 4.16 and 4.18). As mentioned before, these trials represent occasions when the subject presses the central key terminating the first half of the trial

less than 50msecs after the trial has commened. What this will do is inflate the length of the second half of the trial. Studies by Nettelbeck and his colleagues (described in Chapter 2) have suggested that retarded subjects take relatively longer to register information than do the nonretarded subjects and require approximately 350msecs for a simple discrimination. It therefore seems unlikely that any processing has taken place in this initial 50msecs.

Analysis using the simplex method tended to support the suggestion that the solution times for the nonretarded group are additive across cue conditions. Their results, together with those for the retarded subjects, are presented in Table 4.19.

TABLE 4.19

SIMPLEX MODEL MEAN SOLUTION TIMES FOR THE 0, 1, 2 AND 3 CUE CONDITIONS NONRETARDED AND RETARDED SUBJECTS

Nonretarded Subjects

		Predictor Variable Cue Condition			
		0	1	2	3
Predicted Variable	0	1.0000	.9613	.8634	.7663
	1		1.0000	.8820	.8514
	2			1.0000	.8542
	3				1.0000

Retarded Subjects

		Predictor Variable Cue Condition			
		0	1	2	3
Predicted Variable	0	1.0000	.9582	.9622	.9762
	1		1.0000	.9628	.9554
	2			1.0000	.9686
	3				1.0000

As can be seen, correlations are highest along the diagonal and taper off as they move further away from it. There are no breakdowns in simplical structure for the nonretarded group. For the retarded subjects the results are

not as consistent. The simplex is broken in two places by a relatively low correlation between the 0 and 1 cue condition and a relatively high correlation between the 0 and 3 cue conditions. One reassuring finding is that the correlations between the solution times for the 1,2 and 3 cue conditions indicate simplical structure. This suggests that the subjects in this experiment are using the same processes in each of these three cue conditions, but that they may be treating the 0 cue condition as a different task. Also reassuring is the finding that correlations between cue conditions are all quite high, a result not found for the below average group in Experiment 1.

The significant main effects for Type and Group are consistent with those found in Experiment 1, and confirm the finding that solution times for Type II analogies and retarded subjects are longer than those for Type I analogies and nonretarded subjects respectively. One other significant result was obtained, this being a significant interaction between Type and Group ($F(1,176) = 11.15$, $p < .01$). This suggests that the difference between groups is greater for the Type II analogies than the Type I analogies. This interaction almost reached significance in Experiment 1 but the highly significant result obtained here is probably due to the greater disparity in intellectual ability of the groups in this experiment.

A four way analysis of variance (Group x Session x Type x Cue with repeated measures for Session) revealed significant main effects for Session ($F(1,22) = 29.98$, $p < .01$) suggesting a practice effect as was found in Experiment 1 (See Appendix 2.2). Also as in Experiment 1 and as would be expected from the previous analysis, significant main effects were obtained for Group ($F(1,22) = 28.81$, $p < .01$) and Type ($F(1,22) = 243.10$, $p < .01$). There were again no significant interactions between Session and the other three factors suggesting that the practice effect was equivalent for both groups, analogy types and all cue conditions.

Analysis of the interval scores, therefore, suggests that there are significant differences between the solution times of the two groups and also in their use of the precued figures. While the nonretarded subjects' solution times appear to be (to some extent) additive, the retarded subjects' data shows little evidence of additivity. However, the nonretarded subjects solution times still do not show the dramatic decline from the 0 to 3 cue condition that Sternberg's subjects data reveal or the speed of responding produced by his subjects and it can be expected that this will be reflected in lower amounts of the variance being accounted for by the models in the model fitting procedure as was the case in Experiment 1.

4.7.2 COMPONENT SCORES

The component scores were predicted in the same manner as in Experiment 1. All four models of analogical reasoning were tested, each incorporating dual processing. The predictor variables were the number of AB/AC change combinations, the number of terms to be encoded (dependent upon the cue conditions) and the number of DD' value changes. Thus, solution times were obtained for 300 data points (15 AB/AC attribute change combinations x 5 DD' changes x 4 cue conditions). (Each point was the mean of at least one and as many as eight solution times as in Experiment 1).

Figures 4.7 (a)-(d) and 4.9 (a)-(d) present the solution times for true analogies, for each of the 15 AB/AC attribute change combinations, in each cue condition, for nonretarded and retarded subjects respectively. Figures 4.8 and 4.10 present the solution times for true and false Type I and Type II analogies for the nonretarded and retarded groups, respectively. As can be seen in Figures 4.7 and 4.8, the nonretarded subjects show evidence of conforming to

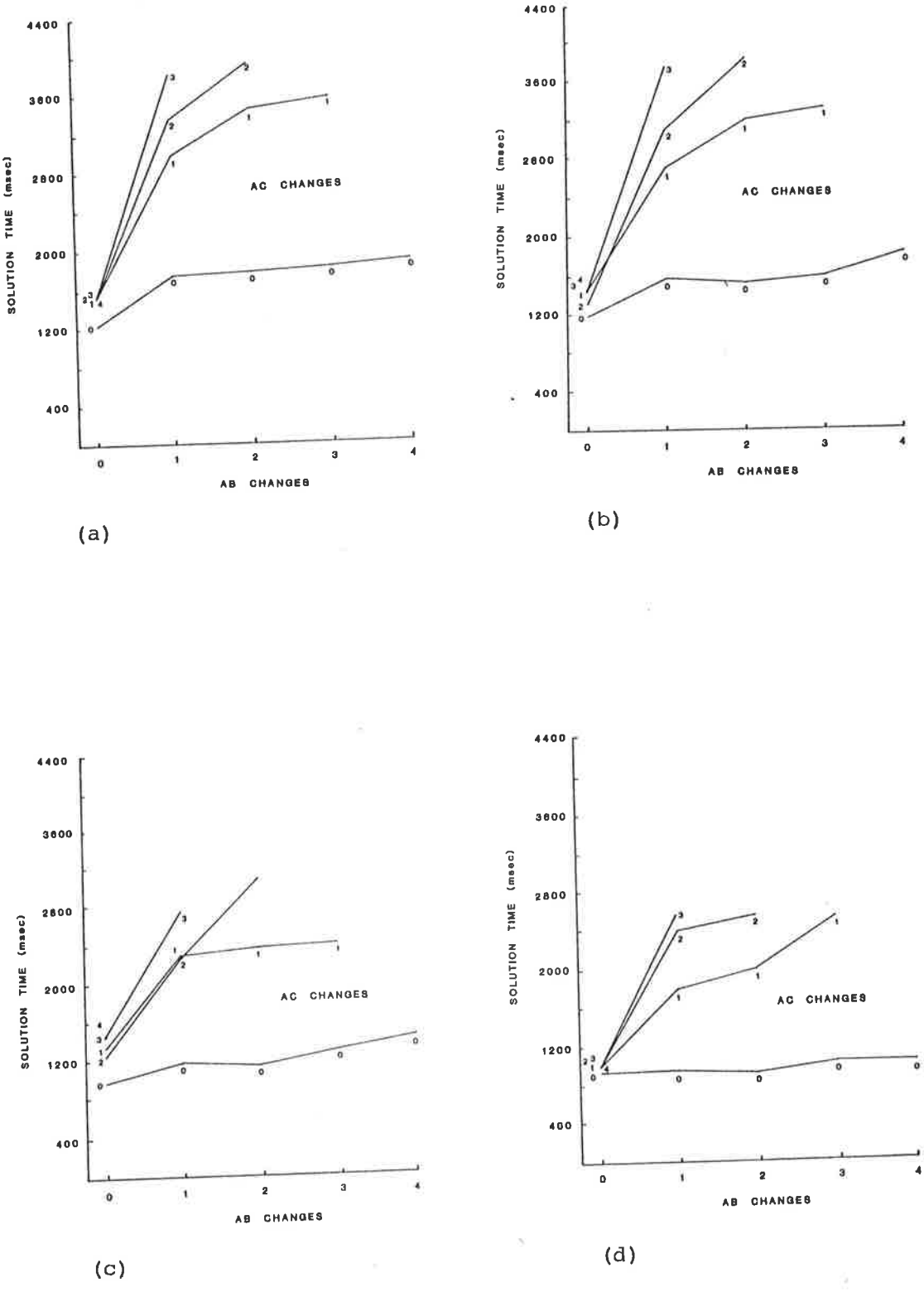


Figure 4.7 Mean solution times for 15 AB/AC attribute change combinations for true Type I and II analogies in each cue condition, nonretarded subjects
(a) 0 cue condition
(b) 1 cue condition
(c) 2 cue condition
(d) 3 cue condition.

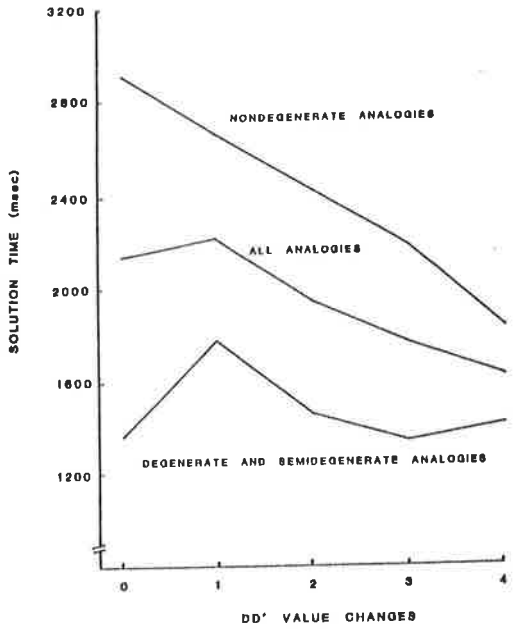
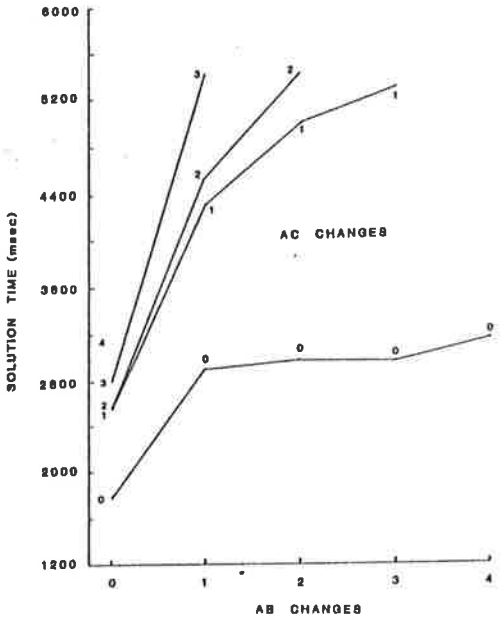
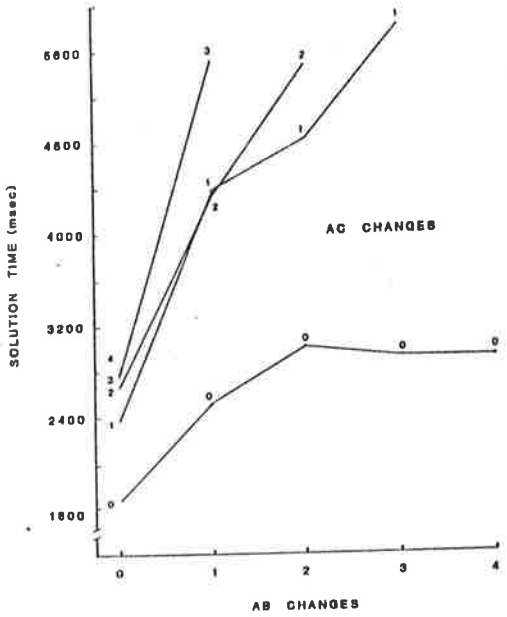


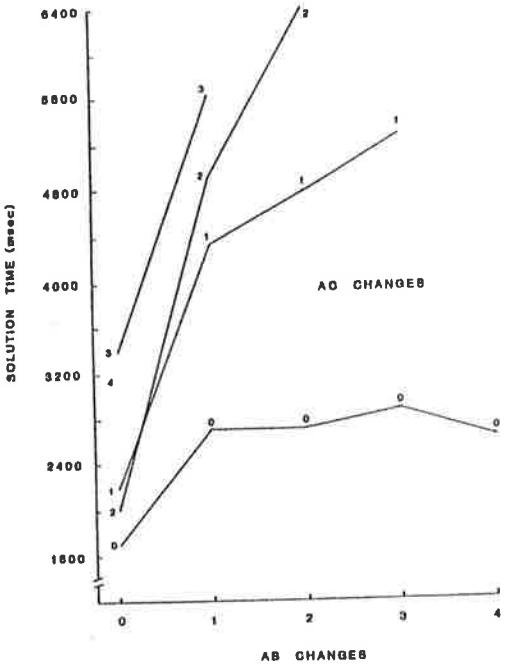
Figure 4.8 Mean solution times for true and false Type I and II analogies, nonretarded subjects.



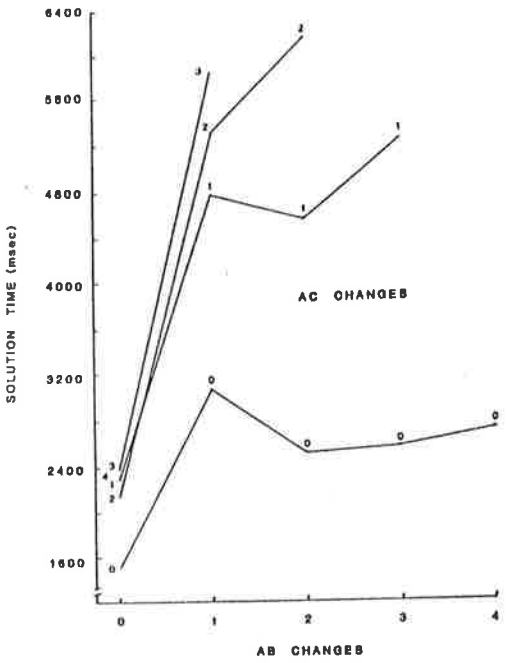
(a)



(b)



(c)



(d)

Figure 4.9 Mean solution times for 15 AB/AC attribute change combinations for true Type I and II analogies in each cue condition, retarded subjects
(a) 0 cue condition
(b) 1 cue condition
(c) 2 cue condition
(d) 3 cue condition.

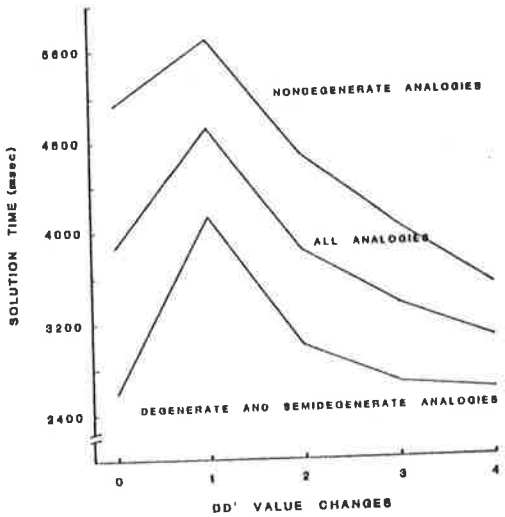


Figure 4.10 Mean solution times for true and false Type I and II analogies, retarded subjects.

the four points suggested by Sternberg (1977a) as reflecting the use of self-terminating processes. Slopes across value changes for Type II analogies decrease from the 0 to 3 cue condition indicating the use of fewer attribute-comparison processes (Figure 4.7); curves for Type II analogies have lower intercepts as the number of precued figures increases from the 0 to 3 cue condition, indicating that fewer terms are being encoded in the second half of the trial (Figure 4.7); true Type II analogies are solved more slowly than false analogies and solution times decrease with increasing degree of falsity (from 1 to 4 DD' value changes, Figure 4.8).

For the retarded group, two of the four points are met but two are only paritally met. There is some decline in intercept for these subjects from the 0 and 1 cue conditions to the 2 and 3 cue conditions suggesting that encoding is declining across cue conditions (Figure 4.9). Also, solution times decrease with increasing degree of falsity (ie from 1 to 4 DD' value changes, Figure 4.10). However, there is no decline in slope across value changes from the 0 to 3 cue condition (Figure 4.10). In fact, the 0 cue condition shows the least decline in slope for these subjects. This again suggests that these subjects may be treating the 0 cue condition (composite task) differently from the 1, 2 and 3 cue conditions. This would indicate a breakdown in the assumption of additivity. Also, true Type II analogies are not solved more slowly than all false analogies. Solution times for Type II analogies incorrect by 1 attribute (1 DD' value change) are solved the most slowly, although true analogies are solved more slowly than the false Type II analogies with 2,3 and 4 DD' value changes (Figure 4.10).

Thus, these subjects show some evidence of using self-terminating processes, but it is not as strong as that indicated by the nonretarded subjects. Alternatively, the fact that solution times do not decline across attribute

changes from the 0 to 3 cue condition may be due to these subjects not using the precued figures a point made with regard to the below average group in Experiment 1. If anything, it appears that in this experiment, the precued figures have tended to disrupt the processing of the retarded subjects, as evidenced by the very steep slopes obtained in the 1,2 and 3 cue conditions. This may be due to the retarded subjects attempting to follow the instructions they have received regarding the precues but being unable to do so. The finding that false Type II analogies incorrect by 1 attribute produce longer solution times than true analogies also suggests that these subjects may be making a checking response when solving these analogies. Both findings suggest a short-term memory load for these subjects in their attempt to use the precued figures.

The results obtained for the Type I analogies for both groups are similar to those obtained in the previous experiment. There is no steady decline in slope across attribute changes. Degenerate analogies tend to be solved more quickly than semidegenerate analogies, especially by the retarded group, as found in Experiment 1, and true Type I analogies are solved more quickly than false Type I analogies. This is especially noticeable in the case of the false 1 DD' value change analogies, and for the retarded subjects. As for the nondegenerate analogies of this type, the retarded subjects appear to find these analogies particularly difficult. Again, this suggests a checking response for these analogies. Overall, the results for the Type I analogies for both groups confirm the use of dual processing in the modelling analysis.

Tables 4.20 and 4.21 present the results of the model fitting procedure, incorporating dual processing for the nonretarded and retarded subjects, respectively. Model III was the best fitting model for the nonretarded subjects, accounting for 63.1% of the variance. Model IV followed closely

TABLE 4.20

MODEL FITS AND PARAMETER ESTIMATES, MODELS I TO IV

NONRETARDED SUBJECTS

Parameter Dropouts Dual Processing

					Parameter Estimates			
	% variance	Freg	df	a	x x'	y y'	z z'	c
MODEL I	54.3%	88	4,295	144	140	314	264	971
MODEL II	58.1%	102	4,295	115	206	369	414	954
*MODEL III	63.1%	126	4,295	110	244	662	258	1095
MODEL IV	62.9%	125	4,295	118	446	618	183	1153

TABLE 4.21

MODEL FITS AND PARAMETER ESTIMATES, MODELS I TO IV

RETARDED SUBJECTS

Parameter Dropouts Dual Processing

					Parameter Estimates			
	% variance	Freg	df	a	x x'	y y'	z z'	c
MODEL I	31.6%	34	4,295	- 81	-86	587	651	2862
*MODEL II	36.0%	41	4,295	- 84	80	734	903	2682
*MODEL III	36.0%	41	4,295	-101	211	1134	587	3021
MODEL IV	35.2%	40	4,295	- 75	195	1166	575	2996

* Best Fitting Model

accounting for 62.9% of the variance. Model II accounted for 58.1% of the variance and Model I for 54.3% of the variance. For the retarded subjects, Models II and III were indistinguishable as the best fitting model, both accounting for 36.0% of the variance. Model IV followed closely, accounting for 35.2% of the variance and Model I accounted for 31.6% of the variance. These fits for both groups are lower than the percentage of variance accounted for by the above and below average subjects in Experiment 1, using the same model fitting procedure.

The data were then reanalysed using the alternative model fitting procedure described and used in Experiment 1 . In this procedure the attribute-comparison processes inference, mapping and application do not drop out across cue conditions, although encoding remained unchanged from the original models. It is possible to obtain separate estimates for inference and application in Models I and IV because of dual processing which separates these processes in the Type I analogies. In the Type II analogies, inference and application are confounded.

As in Experiment 1, the percentage of variance accounted for using this method was significantly improved for both groups, suggesting that subjects were tending to encode the precued figures during the first half of the trial but leave attribute-comparison processing to the second half of the trial when the full analogy was present. For the nonretarded group (See Table 4.22), Models III and IV were virtually indistinguishable as the best fitting models. While Model IV accounted for marginally more of the variance, 73.1% as opposed to 73.0% for Model III, only three parameters were reliably estimated, the tolerance level being insufficient for the estimation of the application process. In other words, the amount of variance accounted for by this parameter in this model was trivial. Thus, Model III is slightly favoured over

TABLE 4.22

MODEL FITS AND PARAMETER ESTIMATES, MODELS I TO IV

ALTERNATIVE PROCEDURE

NONRETARDED SUBJECTS

No Parameter Dropouts Dual Processing

	% variance	Freg	df	a	Parameter Estimates x x'	y y'	z z'	c
MODEL I	60.5%	113	4,295	244	201	299	85	797
MODEL II	67.2%	151	4,295	244	147	369	400	552
*MODEL III	73.0%	200	4,295	244	212	617	180	723
*MODEL IV	73.1%	268	3,296	244	482	510	#	883

Tolerance level insufficient for further computation

TABLE 4.23

MODEL FITS AND PARAMETER ESTIMATES, MODELS I TO IV

RETARDED SUBJECTS

No Parameter Dropouts Dual Processing

	% variance	Freg	df	a	Parameter Estimates x x'	y y'	z z'	c
MODEL I	40.5%	50	4,295	55	131	593	387	2572
MODEL II	46.2%	63	4,295	55	214	669	729	2307
*MODEL III	49.3%	72	4,295	55	357	1039	334	2623
MODEL IV	47.7%	67	4,295	55	662	944	108	2852

* Best Fitting Model

Model IV. (Model II accounted for 67.2% and Model I for 60.5%). For the retarded subjects (presented in Table 4.23) Model III was the best fitting model, accounting for 49.3% of the variance. Model IV followed, accounting for 47.7% of the variance. Model II accounted for 46.2% of the variance and Model I for 40.5% of the variance.

Thus, while this alternative model fitting procedure provides a better fit to the data, for both groups, it is no better than the percentage of variance accounted for by the two groups in Experiment 1. One might have expected that the additional practice session for the nonretarded group would have improved the percentage of variance accounted for. In addition, one might have expected the inclusion of instructions to use the precued figures to improve the fit of the models, expecially since the additional practice session would have provided increased experience with using the precued figures. However, this was not the case. The results obtained so far are almost identical to those obtained for the comparable group in Experiment 1.

For the retarded group, a similar (although marginally lower) percentage of the variance was accounted for compared to the below average group in Experiment 1. However, Model III provides a slightly better fit to the data than Model IV, a reversal of the results obtained for the below average group in Experiment 1.

As in Experiment 1, all models provide similar explanations of the variance, especially for the retarded group. While Models III and IV are essentially indistinguishable, Models II and I are really not far behind these two models. Only 6% of the variance separates Models III and II for the nonretarded group and only 9% separates models IV and I for the retarded group. This again suggests that the models are all too alike mathematically or that subjects are using a mixture of models to solve the analogies.

As in Experiment 1, the encoding parameter is longer for the nonretarded than that for the retarded group and the attribute-comparison parameter estimates (i.e. for inference, mapping and application) are shorter, as is overall solution time. This tends to confirm the suggestion made by Sternberg (1977a, 1980a) that better reasoners spend more time on encoding information than poorer reasoners and that this produces advantages in conducting the remaining processes and in total solution time. Again, as mentioned in Experiment 1, this may be due to the retarded subjects having poorer short-term memories than the nonretarded subjects. If this is the case this also explains why they are less likely to make use of the precued figures since use of the precued figures requires the holding in memory of the information obtained from these figures in the first half of the trial while processing the nonprecued figures in the second half of the trial.

Table 4.24 presents the F regression table for Model III, the best fitting model for the nonretarded subjects (F regression tables for other models are presented in Appendix 2.3 and 2.4, for both model fitting procedures and both groups). Parameter estimates were highly reliable, except for the application parameter, which was still quite reliable. All regression Fs for the parameters were significant. The stepwise multiple regression table presented in the lower half of Table 4.24 indicates that each parameter made a significant contribution to the percentage of variance accounted for, the contribution of the inference, mapping and encoding parameters being quite valuable, the application parameter again being a less valuable predictor.

Table 4.25 presents the F regression tables for the retarded group for Model III. As can be seen in the top half of this table, parameter estimates for inference and mapping are highly reliable. However, this can not be said of

TABLE 4.24

F REGRESSION TABLE FOR ALTERNATIVE MODEL III

Nonretarded Subjects

Parameter	Time	Standard Error	B	Freg	df
a	244	19	.39	169	1,295
x	212	27	.29	62	1,295
y'	617	42	.52	211	1,295
z'	180	44	.13	17	1,295
c	723				

Stepwise Multiple Regression

Parameter	Cumulative R2	r	Cumulative Freg	Cumulative df
y'	.48	.70	279	1,298
x	.56	.60	189	2,297
a	.71	.39	247	3,296
z'	.73	.32	200	4,295

TABLE 4.25

F REGRESSION TABLE FOR ALTERNATIVE MODEL III

RETARDED SUBJECTS

Parameter	Time	Standard Error	B	Freg	df
a	55	47	.05	1	1,295
x	357	68	.26	28	1,295
y'	1039	107	.47	94	1,295
z'	334	110	.13	9	1,295
c	2623				

Stepwise Multiple Regression

Parameter	Cumulative R2	r	Cumulative Freg	Cumulative df
y'	.41	.64	206	1,298
x	.47	.55	134	2,297
a	.48	.05	90	3,296
z'	.49	.30	72	4,295

the parameter estimates for application and especially encoding. Indeed, the parameter estimate for encoding is not statistically significant. The beta weight is very small and the standard error of the estimate is very large. This, suggests that encoding of the precued figures is mainly occurring in the second rather than the first half of the trial.

The results of the stepwise multiple regression analysis shown in the lower half of Table 4.25 confirm that the encoding parameter is a poor predictor. While the other three parameters are all quite highly correlated with overall solution time, encoding is only marginally correlated. These results tend to confirm previous findings that the retarded subjects in this experiment are making very little use of the precued figures, and even less use of these figures than the below average group in Experiment 1.

Some of the additional model fits carried out in Experiment 1 were also conducted here. These included analyses for each cue condition seperately, Type II analogies only. Sessions 1 and 4 separately and dual processing in 1 DD' value change only. These results are presented in Table 4.26 with only the best fitting model being presented in the text. As the data obtained in this experiment, for both groups, were very similar to those obtained in Experiment 1, the additional model fits, namely dual processing in application only, self-terminating encoding, no mapping and model fits for each individual separately, were not performed here. F Regression tables for all analyses conducted are presented in Appendices 2.5 to 2.12.

Model fits for each cue condition separately: It was found in Experiment 1 that different models provided the best fit to the data in different cue conditions, a result not found by Sternberg (1977a). Due to these results, model fits for all

TABLE 4.26

MODEL FITS FOR ALL ADDITIONAL ANALYSIS

NON RETARDED AND RETARDED SUBJECTS

ANALYSES	MODELS			
Nonretarded Subjects	MODEL I	MODEL II	MODEL III	MODEL IV
Analysis of each cue condition separately				
0 cue	50.4%	59.7%	67.8%	69.0%*
1 cue	58.2%	66.0%	76.0%	76.5%*
2 cue	47.7%	56.1%	63.3%	64.6%*
3 cue	64.1%	70.4%	73.0%*	68.7%
Analysis of Type II nondegenerate analogies only	31.5%	62.5%	67.3%*	67.3%*
Analysis of Session 1 only	47.3%	50.8%	56.3%*	55.5%
Analysis of Session 4 only	50.0%	58.2%	65.0%	66.5%*
Analysis dual processing in 1 DD' value change only	60.7%	65.5%	73.4%	73.5%*
Retarded Subjects				
Analysis of each cue condition separately				
0 cue	31.0%	36.8%	39.8%*	39.4%
1 cue	41.0%	47.1%	49.8%*	48.8%
2 cue	44.4%	49.3%	53.5%*	50.6%
3 cue	47.1%	53.2%	55.3%*	53.1%
Analysis of Type II nondegenerate analogies only	6.0%	35.8%	42.5%*	42.4%
Analysis of Session 1 only	36.9%	38.9%	40.8%*	37.8%
Analysis of Session 4 only	21.8%	26.2%	27.6%*	26.7%
Analysis dual processing in 1 DD' value change only	39.8%	45.0%	50.0%*	48.6%

* Best fitting model

cue conditions were conducted here. As in Experiment 1, encoding becomes a constant when cue conditions are analysed separately with estimation of this parameter being dependent on there being more than one cue condition.

As in Experiment 1, Model IV became the best fitting model in the 0 cue condition, accounting for 69.0% of the variance. For the 1 cue condition, Model IV was again the model providing the best fit to the data, accounting for 76.5% of the variance, followed closely by Model III, which accounted for 76.0% of the variance. In the 2 cue condition, Model IV was still the best fitting model, accounting for 64.6% of the variance. Finally, in the 3 cue condition, Model III became the best fitting model accounting for 73.0% of the variance. Thus, the results are in between those obtained for the above and below average groups in Experiment 1. Like the above average group in Experiment 1 the nonretarded group in this experiment has become more exhaustive in processing from the 0, 1, and 2 cue conditions to the 3 cue condition. However, like the below average group in Experiment 1, they have maintained the use of the same model, namely Model IV, across the 0, 1 and 2 cue conditions only becoming more exhaustive in the 3 cue condition. One explanation for this result may be the fact that the nonretarded group received an extra session of practice similar to that received by the below average group in Experiment 1. Like the below average group, it appears to have made their processing more self-terminating and more stable across cue conditions.

For the retarded group, the best fitting model in the 0 cue condition was Model III, which accounted for 39.8% of the variance. Model IV followed closely accounting for 39.4% of the variance. Thus, these two models are virtually indistinguishable. Unlike the below average group in Experiment 1, the composite task (0 cue condition) actually accounts for less of the variance

than the analysis using all four cue conditions. A similar result was obtained for the below average group in Experiment 1 when the 1 cue condition was analysed separately. It is still difficult to determine why this might be so in both cases.

In the 1, 2 and 3 cue conditions, Model III remained the model providing the best fit to the data, accounting for 49.8%, 53.5% and 55.3% of the variance, respectively. Thus, like the below average group in Experiment 1 and the nonretarded group here, the retarded group tended to use the same model throughout all four cue conditions. This suggests that it is the practice session that produces this more consistent behaviour.

Model fits for Type II (nondegenerate analogies) only: As in Experiment 1, the nondegenerate (Type II) analogies were analysed separately to examine whether the same model that best fitted the full set of data (ie using both Type I and Type II analogies) also best fitted the data for the Type II or "real" analogies.

For the nonretarded group, Models III and IV were indistinguishable as the best fitting model, both accounting for 67.3% of the variance, a result similar to that obtained for the same group in Experiment 1 and Sternberg. For the retarded subjects, Model III remained the model providing the best fit to the data, accounting for 42.5% of the variance. These results are very similar to those obtained for the below average group in Experiment 1. Model III appears to be the model slightly favoured when solving the Type II nondegenerate analogies. Thus, again it appears that both groups of subjects are more exhaustive when processing the more difficult, Type II analogies.

Model Fits for Sessions 1 and 4 separately: In Experiment 1, it was found that processing appeared to become less exhaustive and more self-terminating

across sessions, for both groups. In addition, the percentage of variance accounted for was improved from the first to the last session for both groups but especially for the below average group.

For the nonretarded group in Session 1, Model III provided the best fit to the data accounting for 56.3% of the variance. In Session 4, Model IV became the best fitting model, accounting for 66.5% of the variance. For the retarded group, Model III provided the best fit to the data accounting for 40.8% of the variance in Session 1. In Session 4, Model III remained the model providing the best fit, however it only accounted for 27.6% of the variance.

Thus, for the retarded subjects the amount of variance accounted for actually declined from the first to the fourth session a reversal of the result obtained in Experiment 1 for the below average group. This result is surprising given that they produced faster solution times and lower error rates in Session 4 compared to Session 1. This suggests that the retarded subjects altered the way in which they were performing the task and that this altered method of processing has little in common with the models tested. Again, however, it is difficult to determine what method they are actually using.

Model fits for dual processing in 1 DD' Value change only: Since the Type 1 analogies false by 1 attribute (1 DD' value change) again produced longer solution times than other Type I analogies, for both groups, this alternative model fitting procedure was performed here.

For the nonretarded subjects the model fits were marginally improved. Model IV, the best fitting model, accounted for 73.5% of the variance, but Model III was almost indistinguishable from it, accounting for 73.4% of the variance. For the retarded subjects, model fits were also slightly improved, Model III

remaining the best fitting model and accounting for 50.0% of the variance. Thus, this procedure provided only a marginally improved fit to the data for both groups, but the application parameter was more reliably predicted.

4.7.3 ERROR RATES

Error rates for the nonretarded group were again very low, with a mean rate of 1.74%. This is similar to, although slightly higher than the mean rate obtained in the previous experiment by the comparable group of subjects (1.57%) and that obtained by Sternberg (1.4%). This again suggests that the initial practice session and more explicit instructions received by the nonretarded subjects in this experiment were not successful in improving their performance over that of the comparable group in Experiment 1. The mean error rate in Session 1 was slightly lower being 2.37% (compared to 2.74%) but was higher in Sessions 2 and 3, being 1.94% and 1.75% respectively (compared with 1.32% and 1.14% for the same sessions in Experiment 1). The subjects made fewer errors in Session 4, obtaining a mean rate of .90% (compared to 1.09%). Thus, the nonretarded subjects show less of a decline in error rates from the first to third session but a more dramatic decline from the third to the final session.

Error rates for the retarded group are again presented in more detail than for the nonretarded group and in the same manner as for the below average group in Experiment 1. Thus, three types of errors are presented; 1) the percentage of errors made prior to the first repetition; 2) the percentage of errors remaining after one repetition; and 3) the total percentage of errors. Table 4.27 presents these results.

TABLE 4.27

MEAN ERROR RATES

RETARDED SUBJECTS

Errors	Session 1	Session 2	Session 3	Session 4	All Sessions
1. % of errors correctly solved after 1 repetition	8.62	6.77	7.39	5.73	7.13
2. % of errors correctly solved after > 1 repetition	3.41	1.66	.90	.43	1.6
3. Total % of errors	12.03	8.43	8.29	6.16	8.73

As can be seen, error rates were still quite low, with a mean rate of 8.73%. However, they were much higher than for the nonretarded group and also slightly higher than for the below average group in Experiment 1, whose mean error rate was 7.24%. This was not unexpected given the lower overall intelligence level of the retarded subjects. Interestingly, this was due to the percentage of errors made prior to the first repetition. These errors did not decline consistently from the first to the fourth session in so far as there was an increase from Sessions 2 to 3. The retarded subjects in this experiment actually produced a lower mean error rate for errors remaining after one repetition. This may be due to the more explicit instructions these subjects received during their initial practice session.

4.8 CONCLUSION

The results obtained in this experiment were very similar to those obtained in

Experiment 1. Model III provided the best fit to the data for the nonretarded subjects, with a similar amount of variance being accounted for as in Experiment 1. A similar amount of variance was also accounted for by the retarded group compared to the below average group in Experiment 1. However, Model III became the best fitting model for these subjects rather than Model IV. As mentioned in the introduction, it might have been expected that these subjects would be more self-terminating in their processing given the findings of Sternberg and Rifkin (1979) that young children use Model IV while adults use Model III. The fact that the retarded subjects in this experiment are more exhaustive may be due to their having received more explicit instructions concerning the nature of the analogies and the cue conditions in their initial practice session, and the stress placed on accurate performance. It is also the case that the difference between Models III and IV as explanations for both groups' performance in both experiments, was never very great. Thus, while one model may be favoured, the other usually follows very closely as providing the next best fit, making it difficult to make any firm conclusions.

The reliability of the model fits was quite high for the nonretarded subjects, all parameters providing significant contributions to the percentage of variance accounted for. This was not the case for the retarded subjects, both the encoding and application parameters being less useful predictors than the inference and mapping parameters. The encoding parameter especially, was very poorly predicted and did not provide a statistically significant contribution to the total percentage of variance accounted for.

This is related to the further finding that for both groups but especially the retarded subjects, little use was being made of the precued figures. This is suggested by the lack of such a dramatic decline in solution times across cue

conditions for these groups in comparison to Sternberg's subjects and no significant main effect for cue in the analysis of variance. Further evidence is provided by the finding that the amount of variance accounted for by the data for both groups was improved when the alternative model fitting procedure, with no dropouts for inference and mapping across cue conditions, was used. As mentioned previously this alternative method meant that inference and mapping were assumed to be occuring in the second half of the trial irrespective of the cue condition. In the original models, inference was assumed to occur in the first half of the trial in the 2 and 3 cue conditions, while mapping was assumed to occur in the first half ot the trial in the 3 cue condition.

An initial practice session and more explicit instructions concerning the nature of the analogies and use of the precued figures did not result in significantly faster overall solution times or an improved use of the precued figures compared with the groups in Experiment 1. The fact that the instructions did not produce increased use of the precued figures by both groups suggests that it was not that they were too difficult for the retarded group to understand. Rather it appears that even though both groups understood the instructions, they did not follow them. This may be because they found it easier to press the central key and process the analogy when all four terms were present rather than process the precued figures and hold the results of this processing in short-term memory while they processed the nonprecued figures. As mentioned in Chapter 1, both Sternberg and Ketron (1979) and Cooper and Regan (1982) have found evidence that subjects instructed to use a particular strategy do not always do so even when they indicate that they "thought" they were using the instructed strategy. Also relevant here is Bethall-Fox et al (1984) finding that most subjects and especially lower ability subjects referred back to the precued figures on difficult items.

Interval scores were faster in all cue conditions for the nonretarded subjects in this experiment compared to those for the comparable group in Experiment 1, but were still much longer than those produced by Sternberg's subjects, and showed a similar change in times across cue conditions as the same group in Experiment 1. For the retarded group, there was no significant decline in solution times across cue conditions and these times were longer than those produced by the below average group in Experiment 1. This is probably due to these subjects being of lower intellectual ability than the comparable group in Experiment 1.

4.9 OVERALL CONCLUSION - EXPERIMENTS 1 AND 2

It appears that for the nonretarded subjects in Experiments 1 and 2, alternative Model III, incorporating dual processing, is the model which provides the best explanation of performance on an analogical reasoning task. All parameter estimates made a statistically significant contribution to the percentage of variance accounted for, for both groups (although the application parameter was less well predicted than inference, mapping and encoding). Model III assumes the use of two exhaustive processes, inference and encoding and two self-terminating processes, mapping and application. Thus, the first two analogy terms would be fully encoded and all attributes inferred. Processing would then become self-terminating with only as many attributes being mapped and applied in the last two figures as were necessary for a correct solution to be reached (fully exhaustive encoding would however, occur for these two figures). In Model IV, which followed closely as the next best fitting model, inference is assumed to be self-terminating, along with mapping and application. Thus, while all four analogy terms would be exhaustively encoded, only as many attributes as were required to yield a unique solution, would be inferred, mapped and applied.

Separate analyses for each cue condition, for Type II (nondegenerate analogies) only and for Sessions 1 and 4, tended to suggest that processing became more exhaustive from the 0 to 3 cue condition, was more exhaustive for the nondegenerate analogies but became more self-terminating across sessions, results different from those obtained by Sternberg (1977a). The first finding is probably due to the subjects not using the precued figures and thus, referring back and reprocessing precued figures in the second half of the trial, for the latter cue conditions. Sternberg only analysed the data for the 0 cue condition, (the composite task) and not for the remaining cue conditions. He found that Model III remained the best fitting model for this analysis. The second finding suggests that the more difficult analogies are solved more exhaustively than the simpler Type I analogies, and the last finding suggests that as experience with the task increases, more self-terminating processing is used. This is reflected in the faster solution times obtained for the fourth session compared to the first session and the significant main effect for Session in the analysis of variance. This was so, and especially for the Type II analogies, which were reduced by about 1000 msecs in all four cue conditions, from the first to the fourth session. The fact that Model IV was the best fitting model in both sessions, for Sternberg's subjects is probably due to his subjects having had more experience with the task than the subjects in Experiments 1 and 2. As mentioned previously, his subjects received more analogies per session which in turn produced longer experimental sessions. It might be suggested therefore, that the equivalence of the two models is not only due to their similarity in mathematical terms, but also because of the changes from exhaustive to self-terminating processing during the task depending on the cue condition, analogy type and experimental session.

For the below average and retarded groups, the results are less reliable and, in

an overall sense, less consistent. Model IV provided the best fit in Experiment 1, and Model III in Experiment 2. For both groups, these same models also provided the best fits to the data when each cue condition was analysed separately; Model IV for the below average group and Model III for the retarded group. As the nonretarded group in Experiment 2 also used the same model (Model IV) for three of the four (0, 1 and 2) cue conditions it was suggested that the initial session of practice received by all three groups was responsible for this result.

In addition, the overall amount of variance accounted for by the retarded and below average groups' data is much lower than that for the nonretarded groups. Moreover, as mentioned previously, there tends to be less difference between the amounts of variance accounted for by all four models for these subjects. This is most likely due to a number of factors, for example, the nonuse of the precued figures by these subjects, their high level of random variability and the fact that they may take longer to adopt the most appropriate strategy, especially when the task is complex. (Belmont et al, 1982; Bray, 1979). As mentioned in Chapter 2, Sternberg has stated that as the complexity of a task increases, the ability of mathematical models to explain the data is reduced. Whether these factors are ameniable to alteration through experimental variables remains to be seen.

For the nondegenerate analogies, Models III and IV were essentially indistinguishable for both groups as the best fitting model, a result consistent with that obtained by Sternberg (1977a). However, while these models accounted for more of the variance in comparison to the analysis using both analogy types for the below average group in Experiment I, slightly less of the variance was accounted for using these analogies for the retarded subjects in Experiment 2. This suggests that for the retarded group, the data for these analogies are being poorly predicted. This may be due to their high random variability or nonuse of

the precued figures, or their use of processes different from those postulated by the models. Further experimentation, where reliable parameter estimates are obtained, is required before any firm conclusions can be made.

For both groups, results comparable to those obtained using nonretarded subjects were found when separate analyses for Sessions 1 and 4 were performed. Processing showed a tendancy, although this was less strong for the retarded group, to become more self-terminating across sessions as experience with the task increased. While this conflicts with Sternberg and Rifkin's (1979) suggestion that the developmentally young use more self-terminating processes because they place less load on memory, it is possible that both are true. Sternberg and Rifkin (1979) found that young children were significantly slower to respond than their adult subjects and made more errors, while the nonretarded subjects here produced shorter solution times and lower error rates over time. Thus, while the use of self-terminating processes and long solution times may be indicative of a load on short-term memory, the use of self-terminating processes and fast solution times may result from mastery of the task. For the below average and retarded subjects solution times were slower than for nonretarded subjects and showed less improvement from Session 1 to Session 4.

The most significant result, and one obtained for all groups in both experiments is that subjects were not making as much use of the precued figures as Sternberg's subjects appear to have done. This was the case even when more explicit instructions regarding use of the precued figures was provided. The subjects, and especially the below average and retarded groups showed a reluctance to use the precued figures. It was simpler to press the cental key and have the full analogy present for processing. This causes the interval scores obtained to be less additive, especially for the below average

and retarded groups. This in turn, violates the assumption of additivity which makes the estimation of component scores and the model fitting procedure less valid. The model fitting procedure rests on the assumption that the method of precueing decomposes the composite task into additive subtasks. This may be part of the reason why such a poor percentage of the variance is accounted for by the models for the below average and retarded groups. If the additivity assumption is violated then the models can not be assumed to be accurately predicting solution times. The alternative model fitting procedure used in these two experiments attempted to overcome the problem of the violation of the assumption of additivity and was successful to some extent. However, it only approximates what is taking place when it assumes that the parameters, inference and mapping are being carried out in the second half rather than the first half of the trial, in the 2 and 3 cue conditions.

The experiment to follow represents an attempt to improve the use of the precued figures by both nonretarded and retarded groups. In so doing it is hoped that the assumption of additivity will be fully met thus making more valid the model fitting procedures and the parameter estimates for each component process. One reason why the subjects do not use the precued figures is that they are available in the second half of the trial. It is easier for them to process the whole analogy when it is presented in the second half of the trial than to process the precued terms, hold these in short-term memory and process the nonprecued terms.

In the experiment to follow, therefore, the presentation of the analogy was altered so that subjects had to preprocess these figures before the start of the second half of the trial. This was done by having the precued figures removed after the end of the first half of the trial. Thus the second half of the trial no longer consisted of the full analogy but only of the nonprecued figures.

CHAPTER 5

THE EFFECT OF REMOVING THE PRECUED FIGURES ON THE ABILITY TO REPLICATE STERNBERG'S ORIGINAL RESULTS

5.1. INTRODUCTION TO EXPERIMENT 3

From the results of Experiments 1 and 2 it became apparent that both above and below average subjects and retarded subjects were not making full use of the precued figures. This finding raises two questions. Firstly, why are these results different to those of Sternberg (1970) and secondly, is it possible to modify the task in some way so that use of the precued figures becomes essential to the successful execution of the task.

The first question can not be answered easily, given that the tasks were very similar in both experiments. As suggested in the discussion section of the previous chapter, it appears that Sternberg has used either more intelligent subjects than the above average subjects used in Experiments 1 and 2 or more trials and therefore more practice for his subjects on the task. Thus, it might be suggested that Sternberg's subjects had a greater opportunity to learn to use the precued figures. His subjects participated in a total of seven sessions. Sessions 1, 6 and 7 were concerned with ability testing while Sessions 2 to 5 involved the People Piece analogy task. These latter sessions were twice as long as those experienced by the above average subjects in Experiments 1 and 2 and consisted of approximately double the number of trials.

In addition, in the introductory session, subjects were given an explanation about "why it was important to understand how people solve analogies" (Sternberg, 1977a, p. 176). Thus they were aware of what the experiment was investigating and hence were not naive about the aims of the experiment.

They also received a monetary bonus for low error rates (Sternberg 1977a) which may have contributed to their overall better performance. The subjects in Experiments 1 and 2 of this thesis were not told the purpose of the experiment until after the finish of the final session, and they received no monetary incentives.

The further testing of the reliability and validity of Sternberg's componential method and results would therefore appear to rest with attempting to find a method of securing the use of the precued figures while not altering the nature of the task. Sternberg (1977a) has previously suggested another method of stimulus presentation although he did not use it. This alternative method involves presenting the precued figures in the first half of the trial but presenting only the nonprecued figures in the second half of the trial. It does appear that this method might be a possible solution to the difficulties experienced in Experiments 1 and 2. The disappearance of the precued figures after the end of the first half of the trial prevents the subject from referring back to these figures in the second half of the trial, and thus forces the subject to process them in the first half of the trial.

Some problems, however, can be envisaged as occuring using this method. Firstly, while the implication is that there will be no difference between the processes involved in this type of task and the one previously used, there is no assurance that this will in fact be so. If results very similar to those found by Sternberg are obtained then it would suggest that the subjects in this experiment are using the precued figures in a similar manner to Sternberg's subjects. If similar results are not obtained then it would suggest that the alteration to the method of stimulus presentation has altered the nature of the task and the processes required to perform it.

Secondly, and related to the above point, there is a possibility that this task may make heavier demands on short-term memory than the original task. The subject must hold in working memory a representational form of the precued figures and the relationships between them in the 1,2 and 3 cue conditions. However, as in point one, given Sternberg's result of a strong decline in solution time across cue conditions and a high percentage of the variance accounted for, it would appear that his subjects are not referring back to the precued figures in the second half of the trial and therefore are holding precued information in memory. If a memory component were involved, one might expect this to be reflected in the cue times for the 1,2 and 3 cue conditions. Specifically, one might expect these cue times to be significantly longer than the cue times for the 0 cue condition where no memory component is required.

As can be observed in Table 4.16 (Chapter 4) this is not the case with Sternberg's data. This therefore, lends support to the suggestion that his subjects were highly practiced, as they did not need to spend more time storing in memory the precued figures in the 1, 2 or 3 cue conditions. However, Mullholland et al (1980) found that a model that took into account an increased load on short-term memory for more difficult geometric analogy items accounted for significantly more of the variance than a simple linear model. One might therefore find evidence of a memory load in the experiment to follow.

Thirdly, it is possible that the memory conponent required will be too great for the retarded subjects and they will be unable to perform the task. As discussed in Chapter 2,there is the suggestion that the mentally retarded have a short-term memory deficit although controversy still surrounds the possible origin of this deficit. Irrespective of the possible cause, the existence of some sort of memory deficit appears to be clear and the fact that this may affect

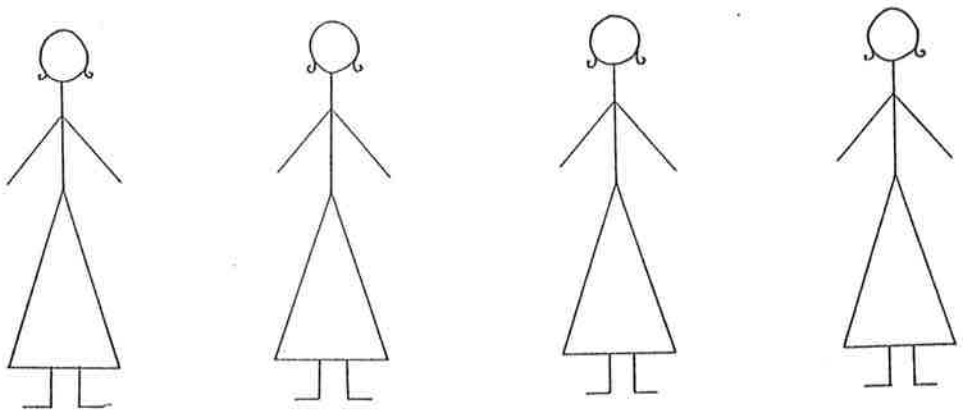
the retarded subject's performance on this task can not be discounted.

Related to this is the finding obtained by Sternberg and Rifkin (1979) that the developmentally young are more likely to use self-terminating processes in the booklet form of the People Piece Analogy task because of the increased memory component required by exhaustive processing. Thus one might expect that the retarded subjects in this experiment will use more self-terminating processes than the nonretarded subjects, with Model IV, the fully self-terminating model, providing the best fit to their data.

Experiment 3, therefore, attempted to obtain evidence of use of the precued figures similar to that obtained by Sternberg (1977a) using above average subjects but using a different method of stimulus presentation. It was also concerned with investigating whether retarded subjects would be capable of performing the task given the possibility of an increased load on short-term memory. It was hoped that the disappearance of the precued figures at the end of the first half of the trial would ensure that these figures were processed during this period. This would mean that the decomposition of the composite task into subtasks and the extraction of individual processes would be possible during the mathematical modelling analysis. A brief explanation of the processes involved in each half of each trial, in each cue condition will indicate why this is so. This explanation may also be followed with reference to Figure 5.1 (a)-(d) which presents examples of the new method of precueing. The 0 cue condition remains unchanged from the previous experiments, with all processes occurring in the second half of the trial (Figure 5.1(a)). In the 1 cue condition, the first figure is presented in the first half of the trial, so presumably encoding of this figure can take place. The last three figures are presented in the second half of the trial so together with the encoding of the final three figures, Figure 5.1 (b), the inference, mapping and application

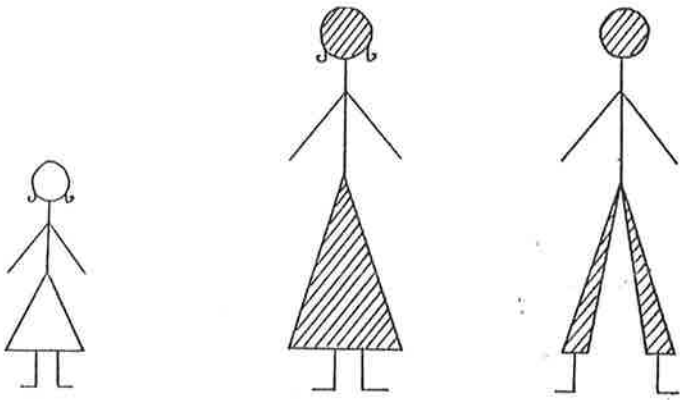
Figure 5.1 The modified precueing method in the 0, 1, 2 and 3 cue conditions.
(a) 0 cue condition
(b) 1 cue condition
(c) 2 cue condition
(d) 3 cue condition



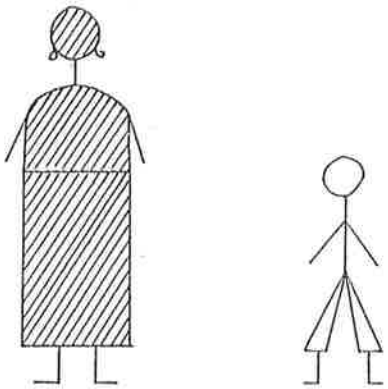


(a)

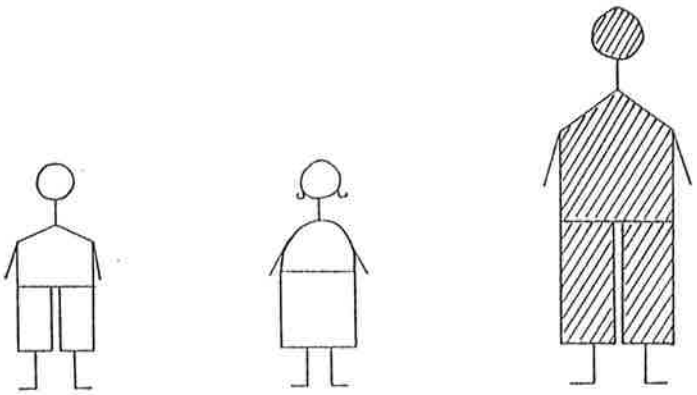




(b)



(c)



(d)

processes can take place. In the 2 cue condition (Figure 5.1(c), the first two figures are presented in the first half of the trial, so encoding of these two figures and the inference process can take place at this time. The last two figures are presented in the second half of the trial, where encoding of these figures, plus the mapping and application processes can take place. Finally, in the 3 cue condition, the first three figures are presented in the first half of the trial so encoding of these three figures can occur, plus the inference and mapping processes. Thus the second half of the trial in this condition consists of the last figure only, when encoding of this figure and the application process can occur (Figure 5.1 (d). The times obtained from the second half of each trial, the solution times, represent the times used in the linear regression model fitting procedure.

5.2 METHOD

5.2.1 SUBJECTS

Twenty-four subjects participated in Experiment 4. 12 subjects were Psychology I students at the University of Adelaide. Their mean age was 20.4 years (range 17 to 33). No intelligence scores were available for this group, however, its members were presumed to be of above average intelligence. Twelve further subjects were all employees of Bedford Industries Rehabilitation Centre. Their mean age was 19.3 years (range 16 to 21). Individual intelligence scores were not available for all subjects, due to the practice at present adopted by some Australian Government Agencies of not making available actual IQ scores unless special permission is obtained. The subjects general level of intellectual functioning using the system adopted by the AAMD was, eight subjects classified as borderline retarded (IQ range 70-85) and four subjects classified as falling within the mildly retarded range (IQ range 55-70). A predominance of borderline subjects was used, as opposed to mildly retarded subjects, because of the possibility of a memory load

associated with the altered method of stimulus presentation. There was no known organic cause of the retarded subjects' intellectual impairment. No subjects were taking prescribed drugs and all were free of any physical disability. All subjects volunteered to participate in the experiment and remained naive concerning the experimental aims.

5.2.2 APPARATUS

The apparatus used in this experiment was identical to that used in Experiments 1 and 2. The computer program used to present the analogies was however, modified so that the precued figures no longer remained present during the second half of each trial.

5.2.3 DESIGN

The design of this experiment was the same as that described in Experiments 1 and 2. The three types of analogies, degenerate, semidegenerate (Type I) and nondegenerate analogies (Type II) were used. There were again 15 possible combinations of attribute changes from the A to B and A to C analogy terms and 5 possible attribute changes between the correct (0) and incorrect (1,2,3,4,) D term of each analogy and four cue conditions (0,1,2, and 3).

In addition, another set of 176 analogies was constructed which was equivalent in design to those already in use. Thus the same numbers of true and false degenerate, semidegenerate and nondegenerate analogy types were used with the same combinations of AB, AC and DD' attribute value changes. However, the actual analogy items were different from those in the original set. This was done so that a different set of analogies could be used by the retarded subjects in their initial practice session as opposed to their experimental testing sessions.

5.2.4 PROCEDURE

The procedure followed in this experiment was in most instances identical to that used in Experiment 1. As the additional practice session provided for nonretarded subjects in Experiment 2 did not alter their performance significantly from the performance of the nonretarded subjects in Experiment 1, it was dispensed with in this experiment. Thus the nonretarded subjects in this experiment participated in four experimental sessions. Each session was divided into four blocks of analogies. Each block consisted of a different cue condition and each analogy type (whether degenerate, semidegenerate or nondegenerate) was represented in each block in the same manner as in Experiments 1 and 2. Cue order was identical to that used in Experiment 1, but form order was not balanced over sessions. All subjects began each session with the degenerate analogies and finished with the nondegenerate analogies. This was done in an attempt to reduce the complexity of the task for the retarded subjects.

Instructions were the same as those provided in Experiment 2. Thus, at the start of the first session, nonretarded subjects were presented with a set of 16 cards, each card having one of the 16 People Piece figures drawn on it. Each figure consisted of a different combination of the four binary attributes that make up the analogies, height [tall-short], weight [fat-skinny], colour [coloured in - not coloured in] and sex [male-female]. The subjects were instructed to sort the cards four times, each time on the basis of a different attribute, so as to familiarise themselves with the figures to be seen during the experimental task.

A second set of cards and 48 computer practice trials were then used, to explain the nature and forms of each of the different types of analogies and

the cue conditions. Subjects were informed that the figures presented in the first half of the trial in the 1,2 or 3 cue conditions would disappear after they terminated this part of the trial, by pressing the central key. Thus they were told that the second half of each trial would consist of the nonprecued figures only, these being the last three, two or one figures in the 1,2 and 3 cue conditions respectively. The 0 cue condition remained unchanged with just the fixation dot appearing in the first half of the trial and all four figures appearing in the analogy in the second half of the trial. As in Experiment 2, the subjects were presented with the card examples and computer practice trials of each analogy type, separately. The experimenter solved the first computer example of each type and then asked the subject to attempt to solve the remaining analogies of that type. Subjects were asked to respond verbally true or false before pressing the appropriate response key so that errors could be immediately corrected and explained.

Subjects were then presented with four blocks of experimental trials, each block consisting of a different cue condition, but always starting with the degenerate analogies. Subjects were informed that they were being timed for both parts of the trial, and accordingly, to go as fast as possible without making too many errors. Accuracy rather than speed was stressed. Subjects were told that any errors would be repeated at the end of the block and if they found a particular analogy difficult they should slow down and attempt to solve the analogy correctly rather than make an error and correct it at the end of the block. For example, subjects were told "Go as fast as you can without making too many errors, but its more important to get them right, so slow down if you find some analogies harder". Errors were replayed at the end of each block of trials until answered correctly. This pattern was followed for each subject over their remaining three sessions. Sessions lasted on average

25-30 minutes with a decrease in time from the first to the final session, presumably due to increased practice on the task.

The same procedure was to be followed for the retarded subjects with the addition of an initial practice session. This practice session began in the same manner as the nonretarded subjects' first session. The subjects were asked to sort the 16 figure drawings by each of the four attributes separately, after which the card examples of each of the analogy types and the computer practice trials were presented and explained. The experimenter solved the first two analogies in each type and then instructed the retarded subjects to solve the remaining analogies. As subjects had to verbally state their choice of response before pressing the appropriate key, errors were explained and corrected as they were made. On completion of these trials, the subjects received the set of 176 practice analogies divided into four blocks as in a typical experimental session starting with the 0 cue condition. It was found however, that of the twelve subjects, seven were still experiencing difficulties with the task at the end of this practice session. These difficulties were primarily due to the disappearance of the precued figures after the end of the first half of each trial in the 1, 2 and 3 cue conditions, since most subjects were able to complete the first block of trials presented in the 0 cue condition. Table 5.1 presents the performance of each subject in each cue condition, with regard to difficulties experienced. Difficulties were generally experienced with all the precue conditions (1,2 and 3), no one cue condition standing out as being most troublesome.

Five subjects were unable to complete more than two or three blocks because of lack of time (subjects were generally not kept from their work for more than 50 minutes). Due to this lack of understanding of the task after the practice session it was decided not to proceed with the experiment for any of the retarded subjects.

TABLE 5.1

THE DEGREE OF DIFFICULTY EXPERIENCED BY RETARDED SUBJECTS WITH THE ALTERED METHOD OF PRECUEING

Subject	0 Cue Condition	1 Cue Condition	2 Cue Condition	3 Cue Condition	Cue Conditions where difficulties were experienced
S_1	-	+	*	+	1,2,3
S_2	-	-	-	*	3
S_3	-	*	*	+	1,2,3
S_4	-	-	-	-	
S_5	-	-	-	-	
S_6	-	-	-	-	
S_7	-	+	+	insufficient time to include this condition	1,2
S_8	*	insufficient time to include this condition	*	insufficient time to include this condition	0,2
S_9	-	-	-	-	
S_{10}	-	+	+	insufficient time to include this condition	1,2
S_{11}	-	insufficient time to include this condition	-	-	
S_{12}	+	insufficient time to include this condition	*	insufficient time to include this condition	0,2
Total Subjects	2	4 (3 did not do this condition	6	3 (4 did not not do this condition	7 Subjects

\- No difficulty experienced
\+ some difficulty experienced
* great difficulty experienced

5.3 RESULTS AND DISCUSSION

As in Experiments 1 and 2, the results section is divided into three areas; Interval scores, Component scores and Error rates. All results are for nonretarded subjects only.

5.3.1 INTERVAL SCORES

Tables 5.2 and 5.3 present the means and standard deviations for the cue and solution times over all sessions and for the first and last sessions individually for each type of analogy. Also shown are the equivalent results obtained by Sternberg (1977a).

It can be seen that the solution times for overall and Type I and II analogies show a far greater decline from the 0 to the 3 cue condition than in previous experiments. This is especially the case for the Type II analogies. Conversely the cue times show a greater increase over cue conditions. These results suggest that the altered method of stimulus presentation, has been successful in forcing the nonretarded subject to use the precued figures. Comparison of the interval scores for the nonretarded subjects on this experiment and those in the previous experiments is not really valid for the 1, 2 and 3 cue conditions because of the alteration in the method of precueing. Comparison between groups for the 0 cue condition is however, possible. The nonretarded subjects in this experiment produced similar cue times but slightly shorter solution times in the 0 cue condition compared to similar subjects in Experiments 1 and 2.

The solution times from these subjects are still, however, longer than those obtained by Sternberg's subjects especially in the 0 and 1 cue conditions. The difference between the groups is even more pronounced for the cue times.

TABLE 5.2

INTERVAL SCORES FOR NONRETARDED SUBJECTS AND STERNBERGS SUBJECTS

Overall Means (for both Analogy Types)

	Cue Condition 0	1	2	3
Nonretarded Subjects				
Cue time	644	2117	2644	3260
SD	534	1466	2043	1999
No of Observations	2112	2112	2112	2112
Underflow Trials	10	0	1	1
Solution Time	2317	2194	1372	938
SD	1396	1203	786	504
No of Observations	2112	2112	2112	2112
Overflow Trials	0	0	0	0
Sternberg's Data				
Cue times	530	755	952	1147
SD	131	187	261	363
No of Observations	4608	4608	4608	4608
Solution Times	1423	1328	947	681
SD	235	222	193	170
No of Observations	4608	4608	4608	4608

TABLE 5.3

INTERVAL SCORES FOR TYPE I AND TYPE II ANALOGIES

NONRETARDED SUBJECTS

	Cue Conditions 0	1	2	3
Type I Analogies				
All Sessions				
Cue Time	656	1217	1736	1438
SD	632	966	1668	1019
No of Observations	960	960	960	960
Underflow Trials	5	0	1	0
Solution Time	1362	1212	1042	794
SD	797	626	508	316
No of Observations	960	960	960	960
Overflow Trials	0	0	0	0
Session 1				
Cue Time	845	1624	2255	1678
SD	983	1143	1756	1062
No of Observations	230	240	240	240
Underflow Trials	3	0	1	0
Solution Time	1842	1533	1346	933
SD	943	748	539	283
No of Observations	240	240	240	240
Overflow Trials	0	0	0	0
Session 4				
Cue Time	507	963	1176	1281
SD	296	739	932	896
No of Observations	240	240	240	240
Underflow Trials	0	0	0	0
Solution Time	1108	991	855	698
SD	684	442	327	244
No of Observations	240	240	240	240
Overflow Trials	0	0	0	0

TABLE 5.3 (Continued)

	Cue Condition			
	0	1	2	3
Type II Analogies				
All Sessions				
Cue Time	631	3016	3552	5082
SD	435	1966	2417	2978
No of Observations	1152	1152	1152	1152
Underflow Trials	5	0	0	1
Solution Time	3272	3177	1701	1082
SD	1995	1780	1063	691
No of Observations	1152	1152	1152	1152
Overflow Trials	0	0	0	0
Session 1				
Cue Time	762	3320	4125	5739
SD	615	1992	2733	3150
No of Observations	288	288	288	288
Underflow Trials	5	0	0	1
Solution Time	4017	3646	2025	1284
SD	2171	1652	1266	679
No of Observations	288	288	288	288
Overflow Trials	0	0	0	0
Session 4				
Cue Time	572	2812	3108	4524
SD	341	1938	2270	2649
No of Observations	288	288	288	288
Underflow Trials	0	0	0	0
Solution Times	2750	2822	1524	923
SD	1653	1791	953	556
No of Observations	288	288	288	288
Overflow Trials	0	0	0	0

The subjects in this experiment are spending far more time processing the precued figures than did those in Sternberg's experiment. This is probably due to the increased memory load in this experiment.

A two way analysis of variance (Cue x Type) using the solution time data revealed significant main effects for Cue ($F(3, 88) = 79.01$, $p<.01$) and Type ($F(1, 88) = 262.16$, $p<.01$) (See Appendix 3.1). A significant interaction between Cue and Type was also obtained ($F(3,88) = 33.29$, $p<.01$) suggesting that the difference between cue conditions is greater for the solution times to Type II than Type I analogies. This can be seen by referring to Table 5.3. Type I solution times show little decline over cue conditions while Type II solution times show a marked decline. This suggests that the Type I analogies are less affected by the precue manipulation and supports use of the dual processing component in the model fitting procedure in the next section.

There was also a significant linear trend for cue condition ($F(1,88) = 221.98$, $p<.01$) suggesting, together with the significant main effect for cue condition, that the solution times are additive. This is further supported by the results of the simplex model analysis (shown in Table 5.4). Correlations near the principal diagonal of the matrix are highest and taper off as they move away from the diagonal, forming a simplex. The simplex breaks down only once with a slightly higher correlation being obtained for the solution times to the 0 and 2 cue conditions than for the 1 and 2 cue condtion.

TABLE 5.4

SIMPLEX ANALYSIS, MEAN SOLUTION TIMES FOR THE 0, 1, 2 AND 3 CUE CONDITIONS, NONRETARDED SUBJECTS

	Predictor Solution Times Cue Conditions			
	0	1	2	3
Predicted Variables				
0	1.0000	.9833	.9825	.9564
1		1.0000	.9768	.9552
			1.0000	.9785
				1.0000

A separate three way analysis of variance (Session x Type x Cue with repeated measures for Session) was carried out using the data from Sessions 1 and 4 to examine whether performance improved over sessions, and to examine whether this improvement was greater for a particular type of analogy or cue condition (See Appendix 3.2). A significant main effect was obtained for Session ($F(1,11) = 54.33$, $p < .01$) indicating that, as in Experiments 1 and 2, performance improved from Session 1 to Session 4. Significant main effects were also obtained for Type ($F(1,11) = 316.63$, $p < .01$) and Cue ($F(3,33) = 94.34$, $p < .01$) as would be expected from the previous analysis using the full set of data. Two significant interactions were also obtained between Session and Type ($F(1,11) = 7.44$, $p < .05$) and Session and Cue ($F(3,33) = 15.19$, $p < .01$). The former indicates that the decrease in solution times to the Type II analogies was greater than that for the Type I analogies from Session 1 to Session 4. The interaction between Session and Cue is due to the difference between the mean solution times for the 0 and 1 cue conditions being much reduced in the fourth session compared to the first session.

5.3.2 COMPONENT SCORES

The derivation of component scores has been described in detail previously. The model fitting procedure was based on 300 data points, each point representing a different type of analogy. All four models described by Sternberg (1977a) were tested, each incorporating dual processing.

Figure 5.2 (a)-(d) present the solution times for the 15 AB and AC attribute changes, combinations for true analogies in each cue condition, and Figure 5.3 presents the solution times for true and false Type I and II analogies. As mentioned in Experiment 1, Sternberg (1977a) has suggested that some level of self-terminating processing is indicated by four findings: (1) a decline in slope across attribute changes from the 0 to the 3 cue condition, indicating a reduction in the number of attribute-comparison processes required (Figure 5.2); (2) displacement of all curves downward from the 0 to the 3 cue condition, indicating the reduction in encoding time required (Figure 5.2); (3) true Type II analogies producing longer solution times than false Type II analogies, because they require more attribute-comparison processes on average than false analogies (Figure 5.3); and (4) solution times for false Type II analogies declining with increasing degree of falsity i.e. from 1 to 4 DD' value changes (because more attribute-comparison processes are required when the analogy is incorrect by one attribute (1DD' value change) than when it is incorrect by four attributes (4DD' value changes) (Figure 5.3).

As can be seen from the respective figures, all these criteria are met by the solution times for Type II analogies obtained in this experiment. The solution times for the Type I analogies are also consistent with the findings of both Sternberg and in Experiments 1 and 2, with very little decline in solution time

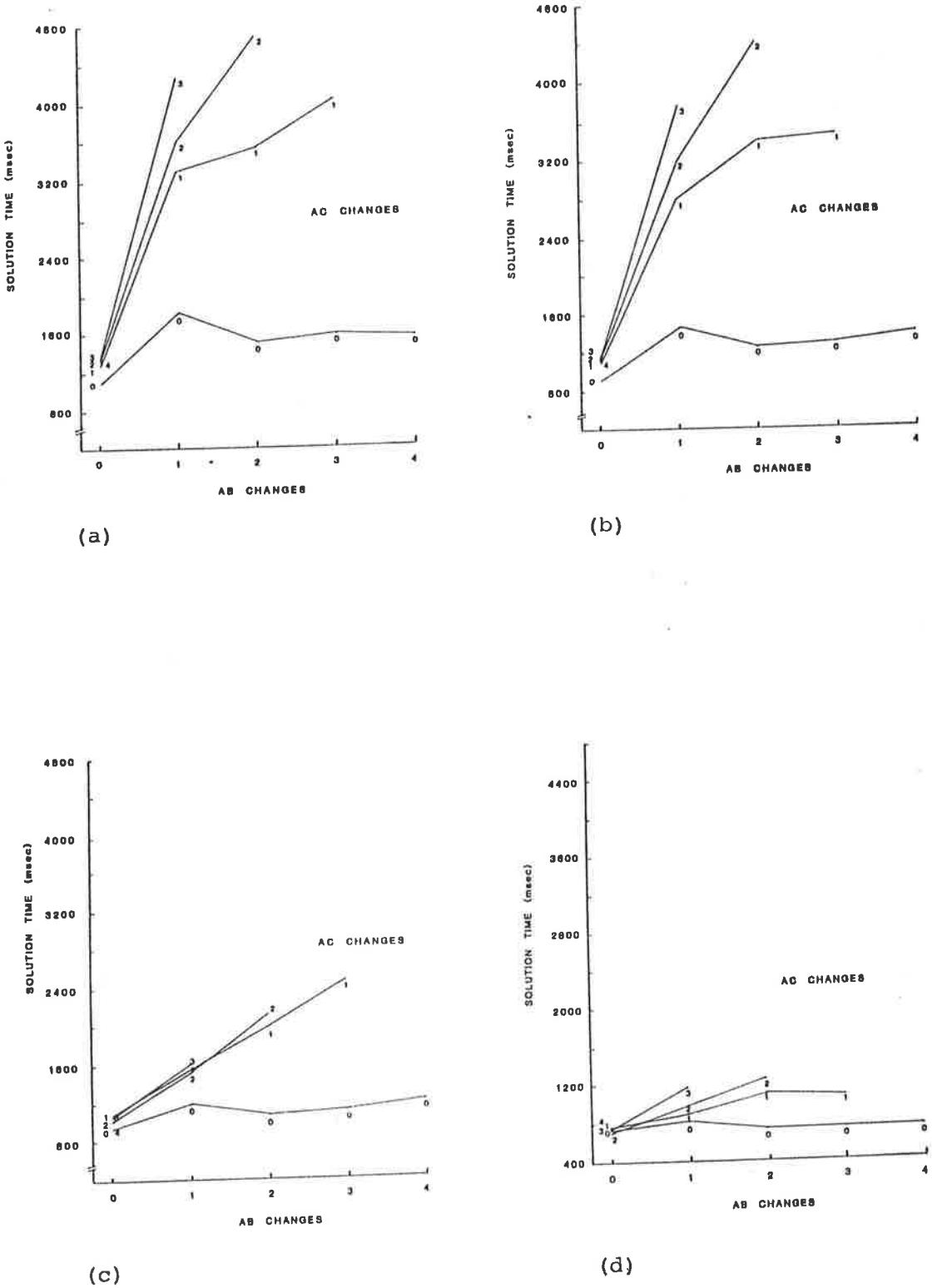


Figure 5.2 Mean solution times for 15 AB/AC attribute change combinations for true Type I and II analogies in each cue condition, nonretarded subjects
(a) 0 cue condition
(b) 1 cue condition
(c) 2 cue condition
(d) 3 cue condition.

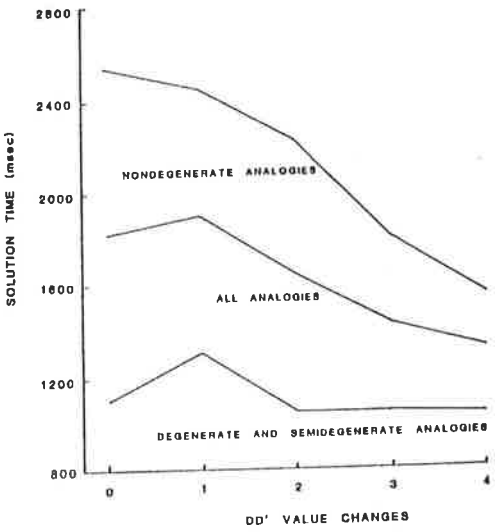


Figure 5.3 Mean solution times for true and false Type I and II analogies , nonretarded subjects.

across attribute changes and cue conditions, thus justifying the use of dual processing.

Model III was found to be the best fitting model, accounting for 84.1% of the variance. However, the fit of Model IV was very similar, accounting for 83.6% of the variance. Model II accounted for 79.7% of the variance and Model I for 77.1% of the variance. Table 5.5 presents the results of the model fitting procedure for all models and the parameter estimates for each of the component processes. It can be seen that subjects tend to spend most of their time on the mapping and encoding processes (170 msecs x four figures to encode = 680 msecs in total). These results are very similar to those obtained by Sternberg (1977a) although slightly less of the variance is accounted for by the best fitting model. Sternberg accounted for 92% of the variance. He also found that only 1% of the variance separated Models III and IV, the best fitting models, and that subjects spent most time on the encoding process.

Table 5.6 presents the F regression table for Model III (F Regression tables for other models are presented in Appendix 3.3). Parameter estimates were highly reliable, although the parameter estimate for self-terminating application time only just reached significance and therefore was not as well predicted as the other three processes. The less reliable predicability of the self-terminating application process is reflected in the stepwise multiple regression table shown in the lower half of Table 5.6. The increments in the squared multiple correlations of the predicted versus observed solution times shows that each parameter, apart from application, made a significant contribution to the amount of variance accounted for.

As the solution times for this experiment provided the greatest percentage of

TABLE 5.5

MODEL FITS AND PARAMETER ESTIMATES
MODELS I TO IV, NONRETARDED SUBJECTS

				Parameter Estimates (Msecs)				
	% variance	Freg	df	a	x x'	y y'	z z'	c
MODEL I	77.1%	248	4,295	175	530	358	56	681
MODEL II	79.7%	290	4,295	176	500	393	287	498
MODEL III	84.1%	391	4,295	170	537	716	120	648
MODEL IV	83.6%	376	4,295	187	980	620	-44	775

* Best Fitting Model

TABLE 5.6

F REGRESSION TABLE MODEL III,
NONRETARDED SUBJECTS

Parameter	Time(msecs)	Standard Error	B	Freg	df
a	170	19	0.23	80	1,295
x	537	31	0.48	297	1,295
y'	716	41	0.45	302	1,295
z'	120	39	0.07	9	1,295
c	648				

Parameter	Cumulative R^2	r	Cumulative Freg	Cumulative df
y'	.53	.73	334	1,298
x	.80	.89	578	2,297
a	.84	.91	504	3,296
z'	.84	.92	391	4,295

variance accounted for and a different experimental design was used compared to Experiment 1, additional alternative model fits similar to those carried out by Sternberg (1977a) and in Experiment 1 were conducted here. These included model fitting analyses for each cue condition separately, and also Type II (nondegenerate) analogies only, Sessions 1 and 4 separately, dual processing in the application process only, for self-terminating encoding, no mapping and dual processing in 1 DD' value change only. These results are presented in Table 5.7 so only the amount of variance accounted for by the best fitting model for each analysis is presented in the text (Linear regression tables for these model fits are presented in Appendices 3.4 to 3.14). In addition, as in Experiment 1 model fits for individual subjects were performed.

Model fits for each cue condition separately: As in Experiments 1 and 2 using the nonretarded subjects data, Model IV became the best fitting model for the 0 cue condition, accounting for 88.5% of the variance. Due to the finding that model fitting for the 0 cue condition (ie the composite task only) produced a different model compared to the analysis using all four cue conditions, analyses were performed on the remaining three cue conditions separately.

In the 1 cue condition, Model III became the best fitting model, accounting for 86.3% of the variance. This differs from Experiment 2 but is the same as the results obtained in Experiment 1. This is probably due to the fact that like the above average group in Experiment 1 this group did not receive an initial practice session.

In the 2 and 3 cue conditions, model fits will be considerably reduced in comparison to those obtained in Experiments 1 and 2. This is due to the fact that the attribute-comparisons processes, inference and mapping are assumed to drop out in these cue conditions; inference in both the 2 and 3 cue

TABLE 5.7

MODEL FITS FOR ALL ADDITIONAL ANALYSES

NONRETARDED SUBJECTS

ANALYSES	MODEL			
	MODEL I	MODEL II	MODEL III	MODEL IV
Analysis of each cue condition separately				
0 cue	68.2%	75.2%	85.5%	88.5%*
1 cue	79.9%	83.2%	86.3%*	81.6%
2 cue	46.0%	52.6%*	51.2%	
3 cue	12.2%*		12.2%*	
Analysis for Type II nondegenerate analogies only	67.6%	75.0%	80.4%	82.4%*
Analysis of Session 1 and 4 separately				
Session 1	74.8%	75.7%	77.7%*	76.0%
Session 4	61.7%	66.3%	70.9%	72.3%*
Analysis of dual processing in application only	53.0%*	46.0%	49.0%	49.0%
Analysis using self-terminating encoding	77.0%	80.1%	83.7%*	80.2%
Analysis using no mapping	66.9%	67.9%		72.8%*
Analysis using dual processing in 1DD' value change only	77.5%	81.7%	85.3%*	84.3%

* Best Fitting Model

conditions, and mapping in the 3 cue condition. Thus for the 2 cue condition, parameter estimates will be based on two parameters only, mapping and application, encoding being a constant in all analyses performed with one cue condition only and inference having dropped out. In the 3 cue condition, parameter estimation will be based on one parameter only, the application parameter. As a consequence of these changes, Models III and IV will be indistinguishable in the 2 cue condition because both contain the same processes self-terminating mapping and application. Similarly in the 3 cue condition, Models II, III, and IV will all be indistinguishable, each containing self-terminating application time. This should, however, distinguish it from Model I which includes exhaustive application. It is still possible therefore to examine the type of model the subjects are using to perform these processes, even though it can be expected that the percentage of variance accounted for will be dramatically reduced, especially in the 3 cue condition.

For the 2 cue condition only, Model II became the best fitting model, accounting for 52.6% of the variance. In the 3 cue condition, all models were indistinguishable, each accounting for 12.2% of the variance. The results of this final analysis using the 3 cue condition may be less reliable because only one parameter could be predicted but the trend from the 0 to 2 cue conditions is towards progressively more exhaustive processing. This may be due to subjects becoming more exhaustive in their processing as the difficulty of the task increases. For example, the 1, 2, and 3 cue conditions place a greater load on memory than the 0 cue condition because of the disappearance of the precued figures. However, this explanation may be more difficult to apply to the results obtained in Experiments 1 and 2.

The results obtained here are consistent with those obtained for the nonretarded subjects in Experiment 1, but differ from those obtained for the

nonretarded subjects in Experiment 2. In Experiment 2, the nonretarded subjects maintained the use of Model IV over three of the cue conditions, Model III appearing as the best fitting model in the 3 cue condition only. This suggests that the practice session the nonretarded subjects received in Experiment 2 made them more consistent in the use of a particular model across cue conditions.

Model Fits for Type II analogies only: Model IV became the best fitting model for the Type II (nondegenerate) analogies accounting for 82.4% of the variance. These results are similar to those obtained in Experiments 1 and 2 using comparable subjects. In these earlier experiments it was not possible to distinguish between Models III and IV as the best fitting models. In this experiment Model IV provides a slightly better fit than Model III which accounted for 80.4% of the variance. This is opposite to the findings for below average and retarded subjects in previous experiments, these subjects tending to use Model III rather than Model IV when solving these more difficult analogies.

Model fits for Sessions 1 and 4 Separately: In Session 1, Model III was still the best fitting model accounting, for 77.7% of the variance. However in Session 4, Model IV became the best fitting model, accounting for 72.3% of the variance. Again these results are very similar to those in Experiments 1 and 2 for similar subjects where Model III provided the best fit in the first session, while Model IV provided the better fit in Session 4. The results obtained here tend to confirm a trend towards the use of more self-terminating processes across sessions. This suggests that as familiarity with the task increases for nonretarded subjects more self-terminating processes are used.

Dual Processing in Application Only: As mentioned in Experiment 1, this type

of analysis assumes that dual processing occurs during the application process only and not during the other attribute comparison processes, inference and mapping. Using this method, all model fits were significantly reduced with Model I becoming the best fitting model, accounting for 53% of the variance. It appears, therefore, that dual processing in all three attribute-comparison processes is taking place.

Self-terminating encoding: In all four models previously tested, encoding is assumed to be exhaustive with only the attribute-comparison processes becoming increasingly self-terminating across models. This assumption as mentioned in Experiment 1, suggests that all attributes of each analogy term are encoded, even though some of the attributes may be of little relevance to the solution of the analogy. This is especially the case for later analogy terms (i.e. the C and D terms) where only the most relevant attributes need be encoded. Self-terminating encoding avoids this possibly unneccessary encoding of attributes.

Model III remained the best fitting model for this analysis accounting for 83.7% of the variance. It appears that self-terminating encoding provides almost as good a fit as exhaustive encoding. Sternberg (1977a) himself found only a 1% reduction in the fit for Model III (but as much as 10% in Model IV) but decided that there was no reason to adopt this alternative process over exhaustive encoding. However, the closeness of the percentage of variance accounted for by the two forms of encoding suggests that self-terminating encoding can not be rejected either. It is possible that subjects use both exhaustive and self-terminating encoding when solving the analogies, becoming more exhaustive if the analogy proves particulary difficult.

No Mapping: With no mapping component, Models II and III become

indistinguishable, Model II previously including exhaustive mapping and Model III, self-terminating mapping. As with dual processing in application only, all model fits were greatly reduced. Model IV became the best fitting model, accounting for 72.8% of the variance. Thus it appears that the mapping component makes a significant contribution to the predictive power of all four models.

Dual Processing in IDD' value change only: This procedure was conducted here because in previous experiments it was found to account for slightly more of the variance and to better predict the application process. As in previous experiments the model fits were found to be slightly improved compared with the best fitting model, Model III, now accounting for 85.3% of the variance. The application parameter was also better predicted.

Individual Differences Analysis: As can be seen in Table 5.8, individual model fits for each subject separately revealed interesting results. Firstly, all model fits were greatly reduced, the best fitting model, Model IV (for S7) accounting for 69% of the variance, and the worst fitting model, Model I (for S4) accounting for 31% of the variance. The reduction in the percentage of variance accounted for can be partially explained by the greater variability one would expect to find in the solution times for individual subjects than in the mean group data. However, some of the poorness of fit might also be due to some subjects using a different method of solution than that described by the models tested. For example, the data obtained from S4 is poorly predicted by all four models suggesting that this subject is not solving the analogies in the way predicted by any of the models.

Secondly, Model IV appears as the best fitting model for the greatest percentage of subjects, followed by Model III; six subjects are best fitted by Model IV, while four subjects are best fitted by

TABLE 5.8

MODEL FITS FOR EACH INDIVIDUAL SEPARATELY

NONRETARDED SUBJECTS

SUBJECT	MODEL I	MODEL II	MODEL III	MODEL IV
S1	41.2%	45.7%	47.7%	48.7%*
S2	59.6%	60.3%*	60.0%	56.4%
S3	46.9%	51.7%	59.1%	63.0%*
S4	31.0%	33.8%	35.5%	36.4%*
S5	37.9%	42.6%	48.2%	50.4%*
S6	48.3%	48.9%	50.3%*	48.3%
S7	62.1%	63.9%	68.8%	69.0%*
S8	52.2%	52.2%*	52.2%	47.9%
S9	51.1%	52.7%	54.5%*	52.9%
S10	55.1%	56.6%	60.4%*	59.2%
S11	53.0%	55.9%	58.4%	58.6%*
S12	62.6%	63.6%	64.1%*	58.1%

* best fitting model

Model III. The more exhaustive model, Model II provides the best fit for two subjects, but no subjects are best fitted by the fully exhaustive model, Model I.

Thus, as was found for the nondegenerate analogies when analysed separately, Session 4 analysed separately, and the 0 cue condition analysed separately, Model IV provides a slightly better fit to the data than Model III, for at least half the subjects in this experiment. This inconsistency in the best fitting model when comparing group and subject data is probably due to the fact that Model IV provides the best fit for marginally more subjects, but Model III is slightly more consistent in accounting for a high percentage of variance for most subjects. In fact, comparing only the fact that Model III always follows closely as the next best fitting model after Model IV, it is probable that this is due to it being the next most self-terminating model. If there were a more self-terminating model than Model IV, with for example self-terminating encoding throughout, it might follow as providing a better fit to the data than Model III.

The individual analyses tend to reveal that all models provide a similar fit to each individual's data with no model standing out as providing the best fit. This may be due to subjects using all four types of models on some occasions during the task. As Bethell-Fox et al, (1984) have suggested, different models or strategies may be used for different analogy items. More difficult items may produce more exhaustive processing while simpler items may produce more self-terminating processing.

5.3.3 ERROR RATES

Error rates were slightly higher than those for the nonretarded subjects in previous experiments with a mean of 2.83% compared to 1.57% and 1.74% in

Experiments 1 and 2 respectively. This was not unexpected given the removal of the precues in this experiment.

Errors declined across sessions with the most dramatic decrease being between Sessions 1 and 2, a result also obtained by Sternberg (1977a) and in Experiment 1. A less dramatic drop also ocurred between Sessions 2 and 3. The mean error rate was 5.26% for Session 1, 3.13% for Session 2, 1.75% for Session 3 and 1.18% for Session 4. The error rates across sessions therefore appear to suggest that as experience with the task increases, difficulties experienced by the subjects because of the disappearance of the precued figures declines.

5.4 CONCLUSION

The two most significant findings from this experiment were firstly, that the retarded subjects were unable to perform the task after an initial practice session (sufficient for adequate performance in Experiments 1 and 2) and secondly, that the nonretarded subjects produced data that, when analysed, were very similar to the original results obtained by Sternberg (1977a).

With regard to this latter finding the following points should be made. Firstly, the replication was only achieved after the method of stimulus presentation had been altered from that originally used by Sternberg. The method used here does appear to have been successful in forcing the subjects to solve the analogies in a way which provides evidence for the proposed method of task decomposition described by Sternberg (1977a). The results of the model fitting procedure also tend to confirm Sternberg's finding that Model III incorporating dual processing provides a good explanation of the way subjects solve analogies, although as Sternberg also found, there is little to choose between Model III and Model IV.

The fact that all four processes contribute statistically significant amounts to the variance also suggests that each of these processes is actually used by the subjects. The reduction in the percentage of variance obtained (84.1%) as compared to Sternbergs results (91.8%) may be partially attributable to a number of factors. For example, the data in this experiment being based on 176 rather than 288 analogies and for 12 rather than 16 subjects.

The results, while consistent with those obtained by Sternberg in relation to the use of the precued figures, also show a number of consistencies with the results obtained for the nonretarded subjects in Experiments 1 and 2. Processing tends to become more exhaustive from the 0 to the 3 cue condition as was found for the nonretarded group in Experiment 1. Again this supports the view that the results obtained for the below average retarded groups in Experiments 1 and 2 and for the nonretarded group in Experiment 2, where processing remained constant across cue conditions, were due to the initial practice session these three groups of subjects received.

There is also a trend toward the use of more self-terminating processing across sessions, as was found for the above and below average subjects in Experiment 1 and the nonretarded subjects in Experiment 2. This again suggests that processing becomes faster with experience of the task, partly because it becomes more self-terminating. Sternberg found Model IV to be the best fitting model in both Sessions 1 and 4. Since his subjects received more trials in their first session than the subjects here, it might suggest that the move to more self-terminating processing occurred from Session 1 to Session 2 for them.

Sternberg and Rifkin (1979) have suggested that young children use self-terminating processes to avoid too great a load on memory. As mentioned

in Chapter 4, it may also be the case that self-terminating processes are used by adults when they have fully mastered the task, their use being less related to a need to avoid a greater load on memory but more related to wishing to solve the analogies as quickly as possible in which case the self-terminating method is the most efficient. The efficient use of self-terminating processing is suggested by faster solution times and low error rates, as evidenced by the nonretarded subjects in this experiment in their final session.

The results for the nondegenerate analogies were slightly different from those obtained in previous experiments and by Sternberg with Model IV slightly favoured over Model III for the nonretarded subjects in this experiment. The results of the individual model fits provided a further insight into the ability of the four models of analogical reasoning tested to account for the way nonretarded subjects solve analogies. Models III and IV remain virtually indistinguishable in the analyses for each individual separately. Where Model III provided the best fit to the data, Model IV generally followed closely as the model providing the next best fit and vice versa. Further to this, all models tended to provide similar fits to the data (similar amounts of the variance were accounted for). In most cases, quite small amounts of variance separate the best from the worst fitting model, for individual subjects. As mentioned previously it is possible that subjects alter the type of model or strategy they use depending on the difficulty of the item, becoming more exhaustive as item difficulty increases.

Finally, the higher percentage of errors made in this experiment may have been due to the additional load on memory especially in the initial sessions, which was not present in Experiments 1 and 2. Support for this comes from an

examination of the cue times for the subjects in this experiment (see Table 5.1). These show a far greater increase from the 0 cue condition to the 1,2 and 3 cue conditions than those obtained by Sternberg (1977a) suggesting a greater load on memory in these latter conditions. The fact that evidence of this memory factor is predominantly to be found in the cue times, and not in the solution times suggests that its inclusion in the model fitting procedure, which is based on the solution times, is not required.

The finding that the retarded subjects were unable to perform the task after an initial practice session, raises a number of questions. Firstly, it suggests that in previous experiments, the retarded subjects relied on the presence of all four analogy terms (both precued and nonprecued figures) in the second half of the trial to enable them to solve the analogies. This may explain why even when instructed to do so, they made little use of the precued figures in Experiments 1 and 2. Secondly, it seems likely that the inability to do the task in this experiment was due to the increased load on memory introduced by the form of stimulus presentation. It is also likely that this form of stimulus presentation increased the complexity of the task so that retarded subjects could not perform adequately on it after only one practice session. The task requirements were that subjects understand the nature of the Type I and Type II analogies by the end of the practice session, plus be able to solve both types of analogies in four different cue conditions each of which placed different loads on memory.

The finding that the retarded subjects were unable to perform the task after an initial practice session, raises a number of questions. Firstly, it suggests that in previous experiments, the retarded subjects relied on the presence of all four analogy terms (both precued and nonprecued figures) in the second half of the trial to enable them to solve the analogies. This may explain why even

when instructed to do so, they made little use of the precued figures in Experiments 1 and 2. Secondly, it seems likely that the inability to do the task in this experiment was due to the increased load on memory introduced by the form of stimulus presentation. It is also likely that this form of stimulus presentation increased the complexity of the task so that retarded subjects could not perform adequately on it after only one practice session. For example, the task requirements were that subjects understand the nature of the Type I and Type II analogies by the end of the practice session, plus be able to solve both types of analogies in four different cue conditions each of which placed different loads on memory. It was noticeable that some subjects seemed to consider the different cue conditions were different tasks rather than the same task presented in different ways. Thus, the presence of a number of different cue conditions seemed to make the task more complex for the retarded subjects than for the nonretarded subjects. It would be interesting to examine whether reducing the complexity of the task and the memory load enabled the retarded subjects to perform adequately. If the subjects were still unable to perform the task after it had been simplified this would suggest that the load on short-term memory was too great for these subjects. The experiment to follow presents an attempt to reduce the complexity of the task.

5.5 INTRODUCTION TO EXPERIMENT 4

As discussed in Chapter 2, studies by both Belmont, Ferretti and Mitchell (1982) and Bray and his colleagues (1972, 1973, 1978, 1979; Bray and Justice and Simon, 1978; Bray, Goodman and Justice, 1982) have suggested an interaction between task complexity and intellectual capacity for strategy production. Bray and his colleagues especially, have investigated the ability of retarded subjects to perform a complex task. Bray (1978) conducted a study, where task complexity was reduced, and found that minimal instructions were sufficient for retarded subjects to perform the task adequately where previously they had required explict instructions. These findings suggest that if the complexity of the People Piece Analogy Task could be reduced without changing the nature of the task, the retarded subjects may be able to perform the task using the altered method of stimulus presentation.

Experiment 4, therefore, was designed to investigate whether a less complex task would enable the retarded subjects to solve the analogies, when the precued figures disappeared after the termination of the first half of the trial. This was done by modifying the People Piece Analogy task so that only two rather than four cue conditions were used. The two cue conditions retained were the 0 and 2 cue conditions, the former consisting of the presentation of no precued figures in the first half of the trial and all four figures in the second half of the trial and the latter consisting of the presentation of the first two figures in the first half of the trial and the second two figures in the second half of the trial. The 1 and 3 cue conditions present in the previous experiment were no longer used.

The 0 and 2 cue conditions were retained because they allowed the estimation of unconfounded parameters. This can best be explained by reference to Table

5.12. From the mathematical equations for each model it can be seen that the 2 cue condition allows the separation of the inference and application parameters because the inference parameter has been performed in the first half of the trial, while application occurs in the second half of the trial. If the 1 cue condition were retained, inference and application would be confounded in Models I and IV. If the 3 cue condition were retained, mapping would become a constant since it has been performed in the first half of the trial and thus no estimate could be obtained for it.

The one disadvantage of the removal of the 1 and 3 cue conditions is that the simplex model can no longer be constructed because there are now only two rather than four cue conditions. Four cue conditions are required (or at least three) to construct a correlation matrix.

In effect this reduction in task complexity also reduced the possible load on memory because only one rather than three conditions now required the information processed in the first half of the trial to be retained in memory while the information in the second half of the trial was processed. If the retarded subjects were to experience a memory load problem, this would occur in the 2 cue condition, where the first two figures and their relationship would need to be retained in short-term memory, while processing of the remaining two figures occurred.

It was decided to try to improve performance by this method and by having one more practice session. This would make a total of four sessions, two of practice followed by two experimental sessions. While Phillips and Nettelbeck, (1984) found seven sessions of practice significantly improved retarded subjects performance on the S. Sternberg (1969, a,b) memory scanning task, it was decided to adopt the approach of Bray on this occasion.

This was partially due to the problems associated with removing subjects from their work for a significant period of time on a number of occasions. The subjects in this series of experiments came from a centre more orientated to work and production than the subjects in Phillips and Nettelbeck's (1984) study where the emphasis was placed on social skills training and less skilled production work.

A nonretarded group was also included so that the performance of both groups could be compared and to examine whether having two rather than four cue conditions altered the way in which the task was approached by nonretarded subjects.

5.6 METHOD

5.6.1 SUBJECTS

Twenty-four subjects participated in this experiment. 12 subjects were first year Psychology students at the University of Adelaide. Their mean age was 17.8 years (range 17 to 21 years). No intelligence scores were available for these subjects but they were assumed to be of above average intelligence. The retarded group consisted of the same 12 subjects who had participated in the initial practice session in the previous experiment, Experiment 3, but had been unable to complete it. They were all employees of Bedford Industries Rehabilitation Centre, and had a mean age of 19.3 years (range 16-21). As mentioned in Experiment 3, eight subjects were classified as borderline retarded while four subjects fell into the mildly retarded range, using the AAMD classification system. There was no known organic cause of the retarded subjects intellectual impairment. No subjects were taking prescribed medication or had any physical disabilities. All subjects volunteered to particpate in the experiment.

5.6.2 APPARATUS

The apparatus used was identical to that used in all previous experiments. The computer program was, however, modified so that only two cue conditions, the 0 and 2 cue conditions, were presented rather than the four cue conditions (0,1,2 and 3) previously used.

5.6.3 DESIGN

The design of the experiment was slightly altered by the modifications made to produce a less complex task. Thus, three types of analogies, degenerate, semidegenerate and nondegenerate, were still used, as were the 15 possible attribute change combinations between the A and B and A and C terms and the 5 attribute change possibilities between the true and false forms of each analogy (DD' value change = 0, 1,2,3, or 4). However, the number of cue conditions was decreased from four to two. This meant a total of 150 rather than 300 data points were now available for use as predictors of solution time (15 AB/AC change possibilities x 5 DD' value change possibilities x 2 cue conditions) in mathematical modelling.

5.6.4 PROCEDURE

All subjects participated in two experimental sessions so that each analogy could be presented in each cue condition. The same set of 176 analogies were used but this was divided into two blocks of 88 trials per session as opposed to four blocks of 44 trials per session as in previous experiments. Each block consisted of eight degenerate analogies, 32 semidegenerate analogies (16 of each form A:A::B:B and A:B::A:B) and 48 nondegenerate analogies with equal numbers of true and false analogies of each type in each block.

In addition, each block corresponded to a cue condition, thus subjects received both cue conditions (0 and 2) in each session counterbalanced for order. Six subjects began with the 0 cue condition in Session 1 (and therefore began with the 2 cue condition in Session 2), and six with the 2 cue condition in Session 1 (and therefore with the 0 cue condition in Session 2). Form order was not counter balanced, all subjects starting with the degenerate analogies and finishing with the nondegenerate analogies, in each block, in each session. This was done so as not to add further complexity to the task. All subjects were informed that they were being timed and that they were to go as fast as possible without making too many errors. If they found the analogies difficult they were instructed to go slower and get the analogies right. For example, they were told "Go as fast as you can without making too many mistakes, but it is more important to get the analogies right".

As in the previous experiment, the nonretarded subjects began the first session by sorting the 16 People Piece Figure Cards four times by each of the four attributes, height [tall-short], weight [fat-skinny], sex [male-female], and colour [coloured in-not coloured in]. They were then presented with the second set of 16 cards and 48 practice trials on the computer and the nature of the task was explained. The 0 cue condition was explained via the cards only, the 48 practice trials on the computer all being presented in the 2 cue condition.

The degenerate analogies were explained first using the cards and computer practice trials, followed by the semidegenerate analogies and finally the nondegenerate analogies were explained. Each of these analogy types included examples of true and false forms. Subjects were asked to respond verbally true or false before pressing the response key so that errors could be immediately corrected. The subjects then proceeded with the first block of

experimental trials followed by a second block. In a subsequent session (one or two days later) the blocks were presented in reverse order. As in previous experiments, errors were replayed at the end of each block until answered correctly during the experimental sessions.

The retarded subjects received an initial practice session as in previous experiments. As these subjects had already participated in one practice session using the four cue conditions (one week previously), the cards and practice trials were dispensed with. The nature of the task was, however, re-explained and the types of analogies to be presented, redescribed. The subjects were told that the number of cue conditions had been reduced, making the task simpler so that they might find it easier to understand and solve the analogies. The 0 cue condition was then presented, starting with the degenerate analogies, followed by the semidegenerate and finally the nondegenerate analogies. As in previous experiments, subjects were instructed to find the relationship between the first set of figures i.e. what elements changed between the figures and then see if the same elements changed in the second set of figures, for the nondegenerate Type II analogies. For the Type I analogies they were instructed to match the last figure with one of the preceeding figures. Some subjects still experienced difficulties with the nondegenerate analogies and the experimenter endeavoured to explain the nature of this type of analogy. Errors were not replayed at the end of this block. The subjects were then presented with a block of trials in the 2 cue condition. All subjects were able to complete the analogies in the 2 cue condition with relatively few errors.

Although some subjects still experienced problems with the nondegenerate analogies, their performance was far superior to that in the previous

experiment where four cue conditions were used, and was acceptable for that required in the experimental sessions. It was therefore decided to continue with the experiment for these subjects and they particpated in two experimental sessions under the same task conditions as the nonretarded subjects. Retarded subjects also received immediate, positive feedback after each trial correctly solved, in both the training and experimental sessions.

5.7 RESULTS AND DISCUSSION

5.7.1 INTERVAL SCORES

Interval scores for both nonretarded and retarded groups are presented in Tables 5.9 to 5.11. Table 5.9 presents the overall mean data for both groups. Tables 5.10 and 5.11 separate these data by group, analogy type and session. As in Experiment 3 it appears that the additivity assumption has been met. Cue scores increase and solution times decrease from the 0 to 2 cue conditions for both groups. It was not possible to construct a simplex model for these data due to the fact that only two cue conditions were used. However, a three way analysis of variance (Cue x Type x Group) using the solution scores revealed a highly significant difference between cue conditions ($F(1,88) = 29.67$, $p < .01$) (See Appendix 4.1). Other highly significant main effects were obtained for Type ($F(1,88) = 65.31$, $p. < .01$) and Group ($F(1,88) = 51.18$, $p < .01$). Thus, solution times for Type I and Type II analogies were significantly different as would be expected from the results of previous experiments. In addition, the mean solution times produced by each group were also significantly different.

As in Experiment 3, there was also a significant interaction between Cue and Type ($F(1,88) = 14.48$, $p < .01$) suggesting that the difference between cue conditions was greater for Type II than Type I analogies. It appears that

TABLE 5.9

INTERVAL SCORES FOR NONRETARDED AND RETARDED SUBJECTS AND STERNBERG'S SUBJECTS

Overall Means (For Both Analogy Types)

Nonretarded Subjects	Cue Condition	
	0	2
Cue Time	619	2247
SD	630	1714
No of Observations	2112	2112
Underflow Trials	10	0
Solution Times	2163	1314
SD	1292	761
No of Observations	2112	2112
Overflow Trials	0	0

Retarded Subjects	Cue Condition	
	0	2
Cue Time	1195	3370
SD	870	3113
No of Observations	2112	2112
Underflow Trials	12	2
Solution Time	4008	2528
SD	2968	2325
No of Observations	2112	2112
Overflow Trials	4	0

Sternbergs Subjects	Cue Condition	
	0	2
Cue Time	530	952
SD	131	261
No of Observations	4608	4608
Solution Times	1423	947
SD	235	193
No of Obervations	4608	4608

TABLE 5.10

INTERVAL SCORES FOR TYPE I AND TYPE II ANALOGIES

NONRETARDED SUBJECTS

Type I Analogies

All Sessions	Cue Conditions 0	2
Cue Time	601	1193
SD	711	1316
No of Observations	960	960
Underflow Trials	8	0
Solution Time	1099	1003
SD	693	514
No of Obervations	960	960
Overflow Trials	0	0

Session 1			Session 2		
Cue Time	641	1423	Cue Time	561	964
SD	789	1591	SD	621	911
No of Observations	480	480	No of Observations	480	480
Underflow Trials	3	0	Underflow Trials	5	0
Solution Time	1221	1126	Solution Times	976	880
SD	853	598	SD	452	375
No of Observations	480	480	No of Observations	480	480
Overflow Trials	0	0	Overflow Trials	0	0

Type II Analogies

All Sessions	Cue Conditions 0	2
Cue Times	636	3300
SD	548	2112
No of Observations	1152	1152
Underflow Trials	2	0
Solution Time	3227	1624
SD	1890	1007
No of Observations	1152	1152
Overflow Trials	0	0

Session 1			Session 2		
Cue Time	679	3489	Cue Times	593	3111
SD	638	2159	SD	437	2048
No of Observations	576	576	No of Observations	576	576
Underflow Trials	0	0	Underflow Trials	2	0
Solution Time	3527	1783	Solution Time	2927	1464
SD	2036	1153	SD	1679	805
No of Observations	576	576	No of Observations	576	576
Overflow Trials	0	0	Overflow Trials	0	0

TABLE 5.11

INTERVAL SCORES FOR TYPE I AND TYPE II ANALOGIES

RETARDED SUBJECTS

Type I Analogies

All Sessions	Cue Condition 0	Cue Condition 2
Cue Time	1177	2344
SD	843	2402
No of Observations	960	960
Underflow Trials	5	1
Solution Time	2530	1924
SD	1936	1518
No of Observations	960	960
Overflow Trials	0	0

Session 1			Session 2		
Cue Time	1236	2629	Cue Time	1118	2060
SD	895	2774	SD	784	1919
No of Observations	480	480	No of Observations	480	480
Underflow Trials	1	0	Underflow Trials	4	1
Solution Time	2453	2058	Solution Time	2607	1790
SD	1838	1644	SD	2026	1367
No of Observations	480	480	No of Observations	480	480
Overflow Trials	0	0	Overflow Trials	0	0

Type II Analogies

All Sessions	Cue Condition 0	Cue Condition 2
Cue Time	1212	4396
SD	896	3823
No of Observations	1152	1152
Underflow Trials	7	1
Solution Times	5485	3132
SD	3999	3132
No of Observations	1152	1152
Overflow Trials	4	0

Session 1			Session 2		
Cue Times	1204	4268	Cue Time	1220	4524
SD	866	3723	SD	924	3917
No of Observations	576	576	No of Observations	576	576
Underflow Trials	4	1	Underflow Trials	3	0
Solution Times	5463	3119	Solution Times	5507	3144
SD	3915	2709	SD	4081	2899
No of Observations	576	576	No of Observations	576	576
Overflow Trials	1	0	Overflow Trials	3	0

solution times for Type I analogies are unaffected by the method of stimulus presentation. Cue times for these analogies, however, show evidence of the effectiveness of the altered method of stimulus presentation. (Tables 5.9 to 5.11 for both groups). This is noticeable for both groups but especially for the nonretarded subjects and provides support for the use of the dual processing in the model fitting procedure.

A four way analysis of variance (Group x Session x Type x Cue with repeated measures for Session) was conducted to examine whether performance improved from Session 1 to Session 4 (See Appendix 4.2). Significant main effects were obtained for Session ($F(1,22) = 6.88$, $p < .05$), Group ($F(1,22) = 17.34$, $p < .01$), Type ($F(1,22) = 140.70$, $p < .01$) and Cue ($F(1,22) = 71.09$, $p < .01$). There was also a significant interaction between Group and Session ($F(1,22) = 6.06$, $p < .05$).

This interaction indicated that the nonretarded subjects' solution times decreased significantly from the first to the second session while the retarded subjects solution times remained relatively unchanged. While this may be interpreted as evidence for nonretarded subject showing greater improvement after one session than retarded subjects (as found by Phillips and Nettelbeck, 1984) in the context of this experiment it is probably due to the retarded subjects having already participated in two previous practice sessions whereas the nonretarded subjects initially received only 48 practice trials. The retarded subjects' performance has therefore stabilized although it can not be concluded that with further sessions solution times would not further decrease.

5.7.2 COMPONENT SCORES

Derivation of the component scores was identical to the method used in previous experiments, except that the model fitting procedure was based on 150 rather than 300 data points. This was due to the reduction in the number of cue conditions used, which produced 150 rather than 300 different analogy types. Table 5.12 presents the new mathematical equations for these models. All four models were tested, each incorporating dual processing.

Figures 5.4(a)-(b) and 5.6(a)-(b) present the solution times for the 15 AB/AC attribute change combinations for true analogies in each cue condition and Figures 5.5 and 5.7 present the solution times for the 5 DD' value change possibilities for both Type I and Type II analogies (0 = true, 1, 2, 3 and 4 = false) for both nonretarded and retarded groups, respectively. Both groups show evidence of using self-terminating processing when solving Type II analogies, with their solution times to Type II analogies declining across cue conditions, curves being displaced downwards in the 2 as opposed to the 0 cue condition (Figures 5.4(a)-(b) and 5.6(a)-(b) for nonretarded and retarded groups, respectively), and solution times for false type II analogies declining with increasing degree of falsity (Figures 5.5 and 5.7 for nonretarded and retarded groups, respectively). One point for inferring the use of self-terminating processes is not entirely met and this is that all false Type II analogies be solved more quickly than true Type II analogies. Reference to Figures 5.5 and 5.7 for nonretarded and retarded groups, respectively, indicate that false analogies which are incorrect by 1 DD' value change were solved more slowly than the true analogies (0 DD' value changes). This is especially evident for the retarded subjects' data. One possible explanation of this finding is that the subjects are making a checking response before responding as was suggested in previous experiments. This may be more exaggerated here because of the

TABLE 5.12

NEW MATHEMATICAL EQUATIONS FOR MODELS I TO IV USING THE MODIFIED METHOD OF STIMULUS PRESENTATION

MODEL I

0 cues	ST_0	=	4a	+	fx	+	gy	+	fz	+ c
2 cues	ST_2	=	2a	+		+	gy	+	fz	+ c

MODEL II

0 cues	ST_0	=	4a	+	fx	+	gy	+	f'z'	+ c
2 cues	ST_2	=	2a	+		+	gy	+	f'z'	+ c

MODEL III

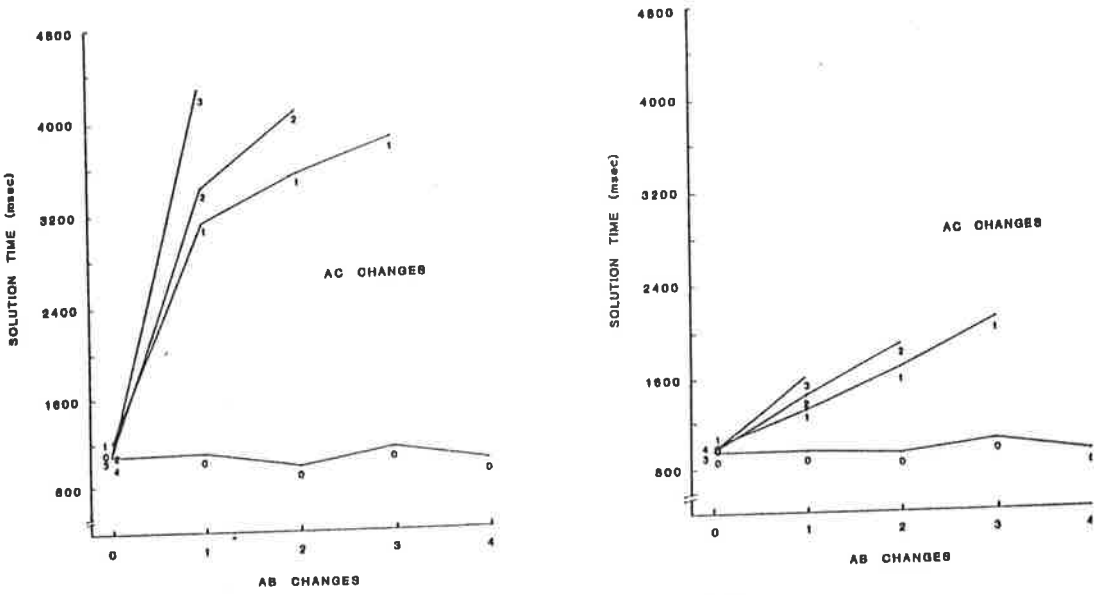
0 cues	ST_0	=	4a	+	fx	+	g'y'	+	f'z'	+ c
2 cues	ST_2	=	2a	+		+	g'y'	+	f'z'	+ c

MODEL IV

0 cues	ST_0	=	4a	+	f'x'	+	g'y'	+	f'z'	+ c
2 cues	ST_2	=	2a	+		+	g'y'	+	f'z'	+ c

SYMBOL DEFINITION

STi	=	Solution Time
a	=	exhaustive encoding time
x	=	exhaustive inference time
y	=	exhaustive mapping time
z	=	exhaustive application time
x'	=	self-terminating inference time
y'	=	self-terminating mapping time
z'	=	self-terminating application time
c	=	constant preparation and response time
N	=	total number of features
T	=	truth index (0 = true; 1 = false)
f	=	number of features changed from A to B
g	=	number of features changed from A to C
h	=	number of D features correctly matched to D'
f'	=	[(N + T) / (N - h + 1)] x (f) / (N)
g'	=	[(N + T) / N - h + 1)] x (g) / (N)



(a) (b)

Figure 5.4 Mean solution times for 15 AB/AC attribute change combinations for true Type I and II analogies in each cue condition, nonretarded subjects
(a) 0 cue condition
(b) 2 cue condition.

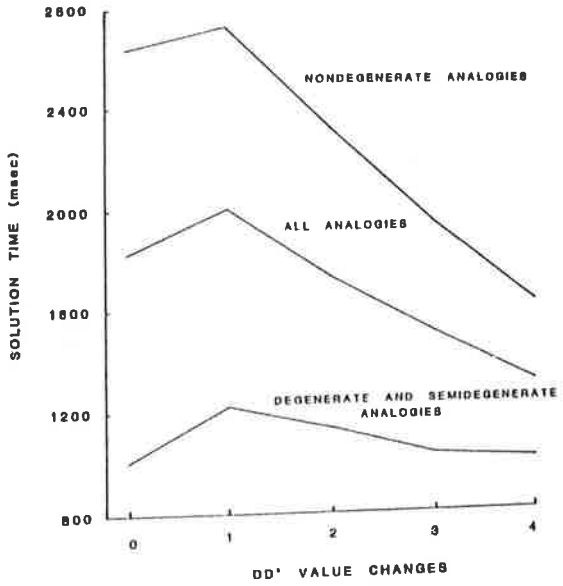


Figure 5.5 Mean solution times for true and false Type I and II analogies, nonretarded subjects.

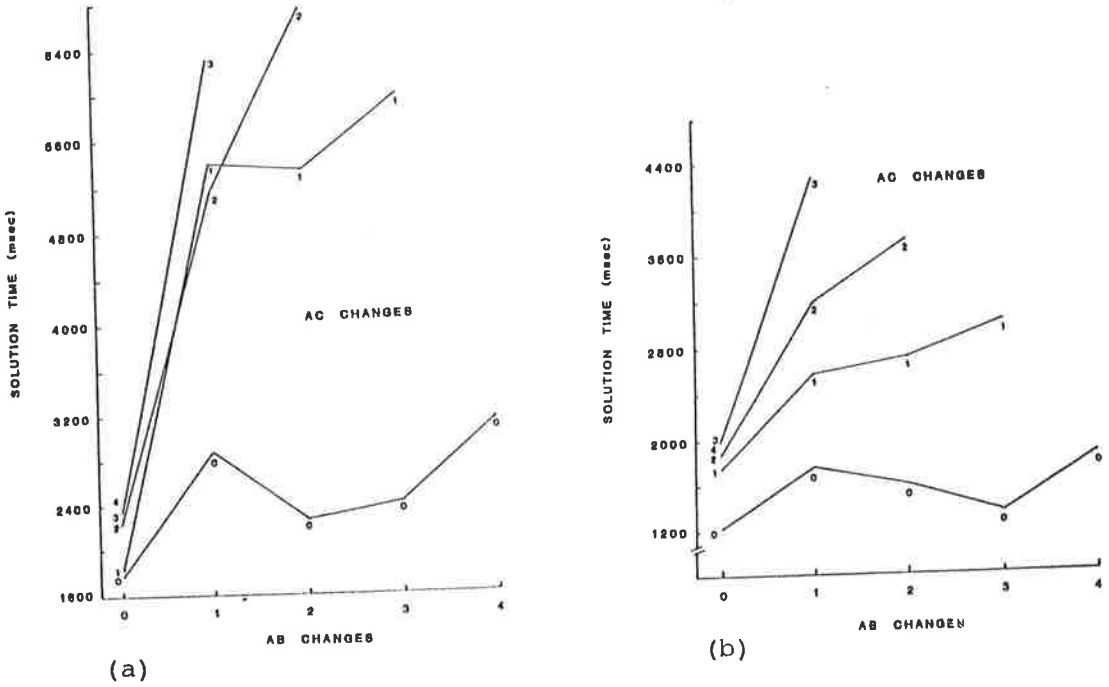


Figure 5.6 Mean solution times for 15 AB/AC attribute change combinations for true Type I and II analogies in each cue condition, retarded subjects
(a) 0 cue condition
(b) 2 cue condition.

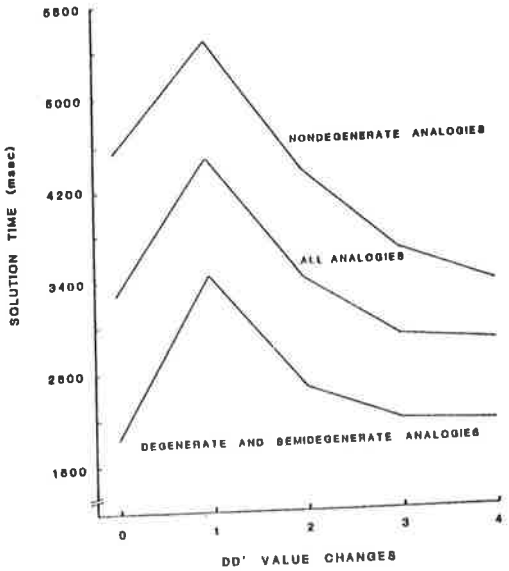


Figure 5.7 Mean solution times for true and false Type I and II analogies, retarded subjects.

increased load placed on short-term memory by the disappearance of the precued figures in the second half of the trial in the 2 cue condition. Examination of the solution times for Type II analogies with 0 and 1 DD' value changes in the 0 and 2 cue conditions revealed this to be the case, for both nonretarded subjects and retarded subjects (see Appendices 4.11 and 4.12 respectively). In addition, the retarded subjects appear to be affected in the 0 cue condition also. This may be due to the modified method of precueing making them more cautious in both cue conditions.

It is surprising that this result was not also obtained for the nonretarded subjects in the previous experiment where it might be assumed that a similar load on memory would occur. This may be due to this effect only occurring in the 2 cue condition for the nonretarded subjects and, therefore, being masked in the previous experiment, by the 1 and 3 cue conditions. Examination of the 300 data points for the subjects in Experiment 3 revealed that both the 2 and 3 cue conditions were affected but especially the 2 cue condition for these subjects (Appendix 3.15). This may be due to the fact that in the 2 cue condition, the inferred relationship between the first two precued figures must be retained in memory. In the 1 cue condition, inference, mapping and application all occur in the second half of the trial so only the first figure must be retained in memory. In the 3 cue condition, inference and mapping both occur in the first half of the trial so the subject can develop a mental image of what the correct D term should be, and simply retain this in memory to compare to the presented D term.

The solution times obtained for the Type I analogies from the nonretarded subjects are again consistent with those obtained by Sternberg (1977a) and for comparable groups in Experiments 1, 2 and 3. There is very little change in solution times across all attribute change combinations and for true and false

analogies. The retarded subjects' solution times to Type I analogies are not as invariant as those obtained for the nonretarded subjects. However, they are still a lot less variable than those obtained for the Type II analogies. The retarded subjects appear to find the false Type I analogies with only one attribue different from the true form especially difficult. This again may be due to the use of a checking procedure as was suggested for Type II analogies incorrect by one attribute. The results for both groups, however support the use of the dual processing.

Model III was found to be the best fitting model for the nonretarded subjects, accounting for 80.3% of the variance followed by Model IV which accounted for 79.6% of the variance Model II accounted for 76.5% of the variance and Model I for 73.5% of the variance. These results are presented in Table 5.13. Thus, again it is difficult to distinguish between Models III and IV although Model III is slightly favoured over Model IV because this latter model fit produces a negative estimate for the self-terminating application parameter.

The slightly reduced overall fit for all models compared to those obtainedwhen four cue conditions were used in the previous experiment may be due to a number of factors. Firstly, the reduced number of data points to be used as predictors and secondly, the fact that subjects particpated in only two rather than four sessions and thus were probably less highly practiced than the subjects in the previous experiment.

For the retarded subjects, Model III also provided the best fit to the data, accounting for 64.5% of the variance, followed by Model II which accounted for 62.9% of the variance. Model IV followed with 61.1% of the variance accounted for and finally Model I which accounted for 60.7% of the variance.

TABLE 5.13

MODEL FITS AND PARAMETER ESTIMATES
MODELS I TO IV

Nonretarded Subjects

	% variance	Freg	df	a	Paramter Estimates x x'	y y'	z z'	c
MODEL I	73.5%	101	4,145	101	588	349	47	789
MODEL II	76.5%	118	4,145	114	549	384	294	551
MODEL III	80.3%	148	4,145	95	606	667	82	789
MODEL IV	79.6%	141	4,145	110	1077	600	-97	930

TABLE 5.14

MODEL FITS AND PARAMETER ESTIMATES
MODELS I TO IV

Retarded Subjects

	% variance	Freg	df	a	Parameter Estimates x x'	y y'	z z'	c
MODEL I	60.7%	56	4,145	413	750	548	212	1074
MODEL II	62.9%	62	4,145	411	757	620	522	842
*MODEL III	64.5%	66	4,145	375	865	1024	186	1250
MODEL IV	61.1%	76	4,145	433	1328	986	#	1302

* Best Fitting Model
\# F level or tolerance level insufficient for further computation.

These results are presented in Table 5.14. The percentage of variance accounted for by all four models is a significant improvement over the percentage of variance accounted for in previous experiments, using retarded subjects. It is still, however, far below that accounted for by the nonretarded subjects. There is still a lot of unexplained variance due possibly to the greater processing variability of these subjects. This is the case even though these subjects have been presented with a simplified task and have received in effect two practice sessions.

The retarded subjects differed from the nonretarded subjects in this experiment in that Model II rather than Model IV was the next best fitting model after Model III. At first this might seem surprising as in Experiments 1 and 2 Model IV generally followed (Experiment 2) or slightly bettered Model III (Experiment 1) as the best fitting model for retarded subjects. It also goes against evidence presented by Sternberg and Rifkin (1979) who found that the developmentally young tend to use more self-terminating processing than their older counterparts. Sternberg and Rifkin state that younger children use more self-terminating processes because they can not hold the information relating to all attributes in their memory at one time. However, the fact that the retarded subjects in this experiment appear to be using more exhaustive processing is probably due to their being forced to process both the precued and nonprecued figures more exhaustively because they can no longer refer back to the precued figures in the second half of the trial.

One other feature that varies from the data obtained using retarded subjects in Experiments 1 and 2 and the results obtained by Sternberg (1977a) and Sternberg and Rifkin (1979) is that the retarded subjects in this experiment are spending a far greater percentage of their time on encoding. Sternberg

and Rifkin (1979) have suggested that older and better reasoners spend more time on encoding than younger and poorer reasoners and that this results in a saving in the inference, mapping and application processes and an overall reduction in solution time. The fact that the retarded subjects are spending longer on encoding in this experiment is again probably due to the disappearance of the first two figures in the 2 cue condition.

The retarded subjects are being forced to encode the precued figures more carefully, just as they were found to be more exhaustive in their use of the inference, mapping and application processes than previously. However, this greater amount of time spent on encoding does not appear to have resulted in a consequent saving in the inference and mapping processes although application processing time is reduced. Thus, while the retarded subjects are being forced to encode more carefully, this has not resulted in a saving in the rest of their processing, or if so, only minimally. This may be due to the subjects being more thorough in all their processing as use of a more exhaustive model would suggest. This in turn may result in a greater load on memory. As will be discussed subsequently the higher error rate obtain by these subjects would tend to support this latter conclusion.

Table 5.15 presents the F Regression table for Model III for the nonretarded subjects (F Regression tables for other models are presented in Appendix 4.3 for both groups). Parameter estimates were again highly reliable except for the possible exception of self-terminating application time. The stepwise multiple-regression data shown at the bottom of the table indicates that each parameter made a substantial contribution to the percentage of variance accounted for, again except for the self-terminating application parameter.

TABLE 5.15

F REGRESSION TABLES, MODEL III

Nonretarded Subjects, Experiment 4

Parameter	Time (msecs)	Standard Error	B	Freg	df
a	95	34	.17	18	1,145
x	606	49	.55	152	1,145
y'	667	56	.48	141	1,145
z'	82	61	.05	2	1,145
c	789				

Stepwise Multiple Regression

Parameter	Cumulative R^2	r	Cumulative Freg	Cumulative df
y'	.45	.67	121	1,148
x	.79	.89	278	2,147
a	.80	.89	196	3,146
z'	.80	.90	148	4,145

TABLE 5.16

F REGRESSION TABLE, MODEL III

Retarded Subjects

Parameter	Time (msecs)	Standard Error	B	Freg	df
a	375	84	.25	20	1,145
x	865	121	.43	51	1,145
y'	1024	138	.40	55	1,145
z'	186	151	.06	2	1,145
c	1250				

Stepwise Multiple Regression

Parameter	Cumulative R^2	r	Cumulative Freg	Cumulative df
y'	.31	.56	66	1,148
x	.59	.77	108	2,147
a	.64	.80	87	3,146
z'	.64	.80	86	4,145

Table 5.16 presents the F Regression table for the retarded subjects for the preferred model, Model III. As with the nonretarded group data, parameter estimates were highly reliable, except for the self-terminating application parameter. The stepwise multiple regression data are shown in the bottom half of the table. The increase in the squared multiple correlation of the predicted versus predictor solution times indicates that each parameter (apart from self-terminating application) contributed a significant amount to the percentage of variance accounted for.

As in Experiments 1, 2 and 3 some additional model fits were also carried out in this experiment. These included model fits for each cue condition separately, for the Type II, nondegenerate analogies only, for Sessions 1 and 2 separately, for self-terminating encoding and for dual processing in 1DD' value change only. These results are presented in Table 5.17 for both groups, so only the best fitting model will be presented in the text (F Regression tables for these additional procedures are presented in Appendices 4.4 to 4.10). In addition, individual model fits were conducted for each subject. These results are presented in Table 5.18. The alternative models incorporating dual processing in application only and no mapping were not analysed here as they provided much poorer fits to the data in the previous experiment.

Model fits for each cue condition separately: As in all previous experiments, the encoding parameter becomes a constant for these analyses. In addition, as in Experiment 3, inference drops out in the 2 cue condition, so only two parameters can be predicted, mapping and application. This also causes Models III and IV to become indistinguishable these models originally being differentiated by the inference process.

TABLE 5.17

MODEL FITS FOR ALL ADDITIONAL ANALYSES

NONRETARDED SUBJECTS AND RETARDED SUBJECTS

Nonretarded Subjects	MODEL I	MODEL II	MODEL III	MODEL IV
Analysis of each cue condition separately				
0 cue	75.8%	79.1%	86.3%*	84.9%
2 cue	50.0%	52.5%*	47.7%	
Analysis of Type II nondegenerate analogies only	61.1%	73.8%	77.1%	79.4%*
Analysis of sessions 1 and 2 separately				
Session 1	70.3%	72.6%	74.7%*	73.4%
Session 2	68.6%	71.9%	77.0%*	76.9%
Analysis using self-terminating encoding	73.5%	76.5%	80.3%*	79.6%
Analysis using dual processing in 1 DD' value change only	73.6%	76.9%	80.6%*	79.3%
Retarded Subjects				
Analysis of each cue condition separately				
0 Cue	58.2%	60.6%	62.9%*	58.5%
2 Cue	32.7%	35.4%*	35.3%	
Analysis of Type II nondegenerate analogies only	58.6%	64.5%	67.5%	67.9%*
Analysis of Sessions 1 and 2 separately				
Session 1	55.1%	57.3%	59.5%*	56.1%
Session 2	54.4%	55.8%	56.0%*	52.6%
Analysis using self-terminating encoding	60.7%	62.9%	64.5%*	61.9%
Analysis using dual processing in 1DD' value change only	60.6%	62.9%	64.7%*	61.4%

* Best Fitting Model

Unlike Experiments 1, 2 and 3, Model III remained the best fitting model in the 0 cue condition for the nonretarded subjects, accounting for 86.3% of the variance. However, again as can be seen in Table 5.17 there was relatively little difference between the variance accounted for by Models III and IV. In the 2 cue condition, Model II became the best fitting model accounting for 52.5% of the variance.

Thus these subjects show a similar trend toward the use of more exhaustive processes across cue conditions as was found for the three comparable groups in Experiments 1, 2 and 3. However, their results are also consistent with those obtained by Sternberg (1977a) in that the same model as accounted for most of the variance for the overall data, also accounted for most of the variance for the data from the 0 cue condition analysed separately.

For the retarded group, Model III again remained the best fitting model, accounting for 62.9% of the variance in the 0 cue condition. In the 2 cue condition, Model II was the best fitting model accounting for 35.4% of the variance. However, Model III - IV was almost indistinguishable from it, accounting for 35.3% of the variance. Thus unlike the below average and retarded groups in Experiments 1 and 2 but similar to the nonretarded subjects in Experiments 1, 2 and 3, the retarded subjects here show a trend toward more exhaustive processing across cue conditions. While this may be partly due to their having received in effect an additional session of practice compared to the similar groups in Experiments 1 and 2, it is perhaps more likely due to the modification made to the method of stimulus presentation which has forced the retarded subjects to adopt more exhaustive processing in order to use the precued information.

Model Fits for the nondegenerate analogies: As for the same group in

Experiment 3, Model IV became the best fitting model for these analogies for the nonretarded group accounting for 79.4% of the variance. This was also the case for the retarded group, although Models IV and III were virtually indistinguishable. Model IV accounted for 67.9% of the variance, while Model III accounted for 67.5% of the variance. In Experiments 1 and 2, Model III had provided the best fit to the data for the below average and retarded groups. However, as was the case here, very little separated the amount of variance accounted for by both models, thus making it difficult to favour one model over the other.

Model fits for each session separately: For the nonretarded subjects in Session 1, Model III provided the best fit to the data accounting for 74.7% of the variance. In Session 2, for these subjects, Model III remained the best fitting model, accounting for 77.0% of the variance. Thus unlike the results for previous experiments, using nonretarded subjects, there is no trend towards more self-terminating processing from the first to the final session. This result is not really surprising considering these subjects participated in two rather than four sessions. It is quite possible that if they had participated in four sessions, their data would also have shown the same trend to more self-terminating processing.

For the retarded subjects in Session 1, Model III was again the best fitting model, accounting for 59.5% of the variance. In Session 2, the best fittingmodel remained Model III, which accounted for 56.0% of the variance. Thus, these results are very similar to those obtained for the nonretarded subjects in this experiment. However, it is more difficult to draw the same conclusion as was drawn for those subjects, as the retarded subjects participated in two practice sessions prior to their experimental sessions, making a total of four sessions in all. In this case, one might have expected

processing to become more self-terminating in the experimental sessions as was found for Session 4 in those experiments using four experimental sessions. This suggests that the initial practice sessions have produced more stable performance in terms of the use of exhaustive and self-terminating processes. The fact that Model III rather than Model IV is used in both sessions and that Model II rather than Model IV follows as the next best fitting model is probably due to the method of stimulus presentation (i.e. the disappearance of the precued figures after the end of the first part of the trial) having placed a greater load on short-term memory.

Self-terminating encoding: For nonretarded subjects, Model III remained the best fitting model with self-terminating encoding and indeed did not vary from the fit obtained using exhaustive encoding, accounting for 80.3% of the data. All other model fits also produced identical model fits to those obtained using exhaustive encoding. Model I will of course be the same as previously, as no self-terminating encoding is assumed to occur for this model. However, this does not explain the results for Models II, III and IV. The only difference between using self-terminating and exhaustive encoding is that the regression constant is greater using the former method. (see Appendix 4.9).

The same result was obtained using the retarded subjects' data. Model III provided the best fit and an identical fit to Model III using exhaustive encoding, accounting for 64.5% of the variance. Again the only difference between this analysis and that obtained using exhaustive encoding was a greater regression constant for each of the models (Appendix 4.9). As mentioned in the previous experiment, Sternberg found only a 1% reduction in the fit of Model III using self-terminating encoding. This may tend to suggest that subjects are flexible in the use of self-terminating or exhaustive processing. For example, they may use self-terminating encoding for simpler

Type II analogies but exhaustive processing for the more difficult Type II analogies, with greater numbers of attribute changes between the AB and AC terms.

Dual Processing in 1 DD' Value Change Only: As in all previous experiments, this type of model fitting procedure provided a slightly better fit to the data than the original model where self-terminating application was generally very poorly predicted. Model III remained the best fitting model accounting for 80.6% of the variance for the nonretarded subjects. The same was also true for the retarded subjects, with the best fitting model being Model III, accounting for 64.7% of the variance and application was better predicted.

Model fits for each individual in each group separately: As in Experiment 3, some interesting results were obtained when model fits for each individual were carried out. (These results are presented in Table 5.18). Firstly, as in Experiment 3, model fits are, in general, reduced when individual rather than group data are used due to the greater random variability of the individual data and to the fact that some individuals are using processes quite different from those predicted and tested by the four models. Secondly, as in Experiment 3, Model IV becomes the best fitting model for a majority of the subjects, in both groups.

In fact, all the retarded subjects in this experiment are best fit by Model IV when individual analyses are performed. For the nonretarded group, seven subjects are best fit by Model IV, one subject by Model III, three subjects by Model II and one subject by Model I (where two models accounted for the same amount of variance, to the first decimal place, as for subjects, S3, S7 and S9, the best fitting model was chosen to the second decimal place).

TABLE 5.18

MODEL FITS FOR EACH INDIVIDUAL SEPARATELY
NONRETARDED AND RETARDED SUBJECTS

	MODEL I	MODEL II	MODEL III	MODEL IV
Nonretarded Subjects				
S1	50.3%	53.5%	57.1%	60.9%
S2	39.9%	40.2%*	40.0%	32.3%
S3	56.9%	58.0%	60.5%*	58.8%
S4	40.8%	40.7%	46.7%	51.8%*
S5	26.7%	28.2%*	28.2%	27.3%
S6	57.1%	61.5%	66.6%	68.3%*
S7	66.8%*	66.8%	65.7%	51.6%
S8	53.4%	56.7%	62.8%	64.8%*
S9	51.8%	51.8%*	51.0%	45.7%
S10	48.9%	53.6%	61.5%	69.6%*
S11	46.9%	53.6%	61.4%	66.4%*
S12	18.8%	23.6%	24.8%	27.1%*
Retarded Subjects				
S1	47.9%	51.2%	51.7%	51.9%*
S2	40.0%	41.7%	42.9%	44.5%*
S3	34.4%	39.9%	41.2%	47.6%*
S4	36.3%	40.4%	41.4%	44.7%*
S5	26.3%	32.4%	33.2%	42.5%*
S6	29.9%	31.0%	32.3%	41.4%*
S7	36.6%	36.8%	37.2%	46.2%*
S8	38.6%	39.5%	40.1%	41.3%*
S9	47.7%	51.4%	52.1%	52.3%*
S10	27.3%	33.0%	34.2%	40.4%*
S11	45.7%	49.3%	50.0%	51.0%*
S12	21.3%	25.8%	25.9%	37.6%*

* best fitting model

For the nonretarded subjects, where a particular model provided the best fit, the next best fitting model generally followed closely, although this is slightly less pronounced than in Experiment 3 . For the retarded subjects, in about half the cases, Model IV provides an obviously better fit than the three more exhaustive models. In the remaining cases, Model III follows closely as the next best fitting model. This latter finding may be part of the cause of Model III becoming the best fitting model using the mean of all the retarded subjects' data. This may also be so in the case of the nonretarded subjects. It appears that analysis using the group data produces support for more exhaustive processing while the individual model fits support greater use of self-terminating processes. This was also the case in Experiment 3 but in a less dramatic way. Certainly, the individual model fits provide support for the suggestion that subjects vary the type of model used depending on the actual item.

5.7.3 ERROR RATES

Error rates for nonretarded subjects were again slightly higher than for the comparable groups in Experiments 1 (1.57%) and 2 (1.74%) producing a mean of 4.01%. They were also higher than those obtained in Experiment 3 (2.83%). The mean error rate for Session 1 was 4.78% and for Session 2, was 3.22%. The fact that these subjects obtained a higher rate of errors than the nonretarded subjects in all previous experiments may be due to their having had less experience with the task, participating in only two rather than four or five experimental sessions as in previous experiments.

The mean error rates for the retarded subjects are presented in the same way as in previous experiments i.e. 1) errors made prior to any repetitions, 2) errors still remaining after one repetition and 3) total percentage of errors.

Two more mean error rates are also included 4) mean error rates for the 0 cue condition, and 5) mean error rates for the 2 cue condition. These results are presented in Table 5.19.

TABLE 5.19

MEAN ERROR RATES, RETARDED SUBJECTS

ERRORS	SESSION 1	SESSION 2	ALL SESSIONS
1. % of errors produced error at the end of each block	9.61	10.51	10.06
2. % of errors correctly solved after one repetition	3.84	3.45	3.65
3. Total % of errors	13.45	13.97	13.71
4. % of errors made in the 0 cue condition	4.02	5.02	4.52
5. % of errors made in the 2 cue condition	9.42	8.95	9.19

As can be seen, the mean error rate of 13.71% is almost double that produced by the below average (7.24%) and retarded subjects (8.73%) in Experiments 1 and 2 respectively. This is most likely due to the alternative method of stimulus presentation used in this experiment placing an additional load on memory. A break down of the error rates for these subjects, by cue conditions, supports this claim. The mean error rate for the 0 cue condition was 4.52%, while for the 2 cue condition, it was 9.19%, almost double the rate for the 0 cue condition.

Mean error rates across sessions were very stable, being 13.45% in Session 1 and 13.97% in Session 2. This stability over sessions is probably due to the fact that these subjects participated in two practice

sessions prior to the experimental session. Thus their error rate is more stable than the nonretarded subjects mean error rate (who only participated in two experimental sessions and no practice sessions). Phillips and Nettelbeck (1984) found using seven practice sessions on the S. Sternberg memory scanning task, that scores for retarded subjects continued to decline on the sessions and it is possible that this would have occured in this experiment if more sessions had been provided.

5.8 CONCLUSION

A number of conclusions can be drawn from the results of this experiment. Firstly, the use of a simplified task with a reduced load on memory proved sufficient to enable the retarded subjects to perform the task in comparison to Experiment 3. This suggests that it was the complexity of the task used in Experiment 3 that was the major cause of the retarded subjects' inability to perform the task. This is given support by the fact that these same subjects completed the task satisfactorily in Experiment 4. However, these subjects did, have in effect, two practice sessions which included explicit instructions regarding the solution of the analogies. This practice, in addition to the reduced complexity, may have contributed to the retarded subjects ability to perform the task in Experiment 4. In addition, decomposition of these subjects error rates by cue condition still suggested the effect of a memory load in the task, errors being much greater in the 2 cue compared to the 0 cue condition. Secondly, the percentage of variance explained by the retarded subjects' data was greatly improved from Experiments 1 and 2. This is most likely due to the two initial practice sessions these subjects received and may also be due to the modified method of stimulus presentation making the subjects do the task in a way closer to that predicted by the componential method. However, the

percentage of variance accounted for by these subjects remained far below that explained by the nonretarded subjects' data and their level of random variability was still very high.

Together with the increase in the percentage of variance accounted for by the retarded subjects' data was the finding that these subjects spent a greater proportion of their time on encoding compared to the below average and retarded subjects in previous experiments. This was most likely due to the modified method of stimulus presentation. However, the increase in encoding time did not result in a saving in all later processes as has been found by Sternberg (1977a) and Sternberg and Rifkin (1979) for better and older reasoners. Application time was reduced but the inference and mapping components were unaffected. The retarded subjects did not appear to be able to take full advantage of the enforced increase in the amount of time spent on encoding. This suggests that their longer encoding times reflect time spent on attempting to maintain the encoded material in memory rather than freeing them to carry out other processes more quickly.

Thirdly, the use of a simplified form of People Piece Analogy task does not appear to have affected the decomposition of the composite task or the estimation of component processes. This is suggested by the finding that a large percentage of the variance was accounted for by the nonretarded subjects. The small reduction in the amount of variance accounted for by these subjects in comparison to the nonretarded subjects in Experiment 3 may be due in part to the reduction in the number of cue conditions giving only 150 rather than 300 data points to predict. In addition, it may be due to this groups' data being slightly less stable, their having participated in only two rather than four experimental sessions. This is supported by the finding that the error rate for the nonretarded subjects was higher than in previous

experiments where four cue conditions were used (and therefore four sessions).

In addition, the retarded group here showed similar results to the nonretarded group with regard to separate analyses for the 0 and 2 cue conditions, and the nondegenerate analogies. This suggests that, unlike the below average and retarded groups in experiments 1 and 2, the retarded subjects produced results qualitatively similar to those of the nonretarded subjects, even though their results are still very different quantitatively from the latter group. This may be due to the introduction of the altered method of precueing making them perform the task in a way predicted by the componential method and to the fact that these subjects received two rather than just one session of practice.

Individual model fits for both groups again suggested that the indistinguishability of models and especially Models III and IV was a reflection of the fact that subjects alter the strategy or processes they use to solve the analogies. This is consistent with suggestions made by Bethell-Fox et al, (1984) Coooper, (1980a,b) and Mathews et al, (1978). Comparison between the individual analyses also suggests that while the group data support more exhaustive processing, individual analyses support more self-terminating processing, especially in the case of retarded subjects. This type of result, together with the changes in the best fitting model for Type II analogies and across cue conditions and sessions makes it difficult to draw firm conclusions about which model the subjects are actually using.

Finally, and similarly, consideration must be given to the inability of some of the alternative model fits to be distinguished from each other. Model III with exhaustive encoding, Model III with self-terminating encoding and Model III

with dual processing in I DD' value change only, all provided excellent fits to the data for the nonretarded subjects and quite good fits to the data for the retarded subjects. Sternberg (1977a) has suggested that information processing models based on the subtractive method are often flawed by this type of finding. He has further suggested that a confounded parameter is indicated by an unreasonably large parameter estimate for a particular process. The regression constant representing the preparation-response process in this experiment and in most previous experiments is quite large, especially for the retarded subjects. It is quite possible that another unidentified process is contained within this process or the other identified processes are also partially confounded here. In addition, it appears that part of this finding is due to subjects being flexible in their use of particular models or set of processes.

5.9 OVERALL CONCLUSION

Taking into account the results and conclusions reached in both Experiments 3 and 4, the following general conclusions can be made. Firstly, the modified method of stimulus presentation (where the precued figures were removed after the end of the first part of the trial) appears to have been successful in decomposing the composite task in a way that allows the estimation of parameters as described by Sternberg (1977a). This is suggested by the higher percentage of variance accounted for using this procedure and also by the interval scores obtained. Solution times decline significantly across cue conditions and conversely cue times increase across cue conditions. The simplified task using only two rather than four cue conditions also appears not to have affected the extraction of individual component process estimates.

There are a number of advantages in using this simplified task. For example, only two rather than four experimental sessions are required to obtain the

necessary data. In addition, the retarded subjects are able to perform this task with a maximum of two practice sessions (with the possibility that one practice session would suffice). This method allows the flexibility of having one or more practice sessions which would be less possible using all four cue conditions especially where there are time constraints present. The fact that the fit using both the four and two cue conditions was less than that obtained by Sternberg (1977a) may be due to a number of factors, including the reduction in the number of analogies actually used (from 288 to 176 analogies) and the consequent reduction in the number of sessions; the use of less highly practiced or less intelligent subjects and the possibility that the memory component here is having some affect on the subjects' performance. While it was assumed that the memory factor would be most likely to have had an affect on the cue scores, it is possible that the solution scores were also affected.

Another important finding was that the modified method of precueing used in conjunction with the simplified task provided data from retarded subjects that accounted for a higher percentage of the variance than previously obtained and also greatly increased the time they spent on encoding the precued figures. It appears that further experiments using People Piece Analogies, with the intention of investigating retarded subjects performance, would be advised to incorporate these two modifications into their experimental design. The modified method of stimulus presentation also appears to be more likely to produce results similar to those obtained by Sternberg (1977a) using nonretarded subjects.

The percentage of variance explained by the retarded subjects' data is still lower than that obtained using nonretarded subjects. Further experiments are required to investigate whether a greater amount of variance could be

explained, for example, by using a training procedure or further practice sessions. Finally, it appears that both nonretarded and retarded subjects are generally using Model III or Model IV when solving the analogies. This confirms both the results obtained in Experiments 1 and 2 and the original results obtained by Sternberg (1977a). This finding suggests, together with the high percentage of variance accounted for, that both groups of subjects are using self-terminating mapping and application processes (the two processes in which Models III and IV are identical) but that it is difficult to determine whether subjects are using exhaustive (Model III) or self-terminating (Model IV) encoding and inference processes. It also appears that the exhaustiveness of the processes used can be influenced by experimental manipulation since Model II followed Model III as the best fitting model in Experiment 4, for the retarded subjects and by within subject variables such as the difficulty level of actual analogies.

Furthermore, the results suggest that while the retarded subjects might actually use Model IV if left uninstructed, the introduction of additional practice sessions, explicit instructions and a modified method of stimulus presentation (as in Experiments 2 and 4) produces more exhaustive processing on the part of these subjects. Thus it might be concluded that it changes the way the subjects approach the task. In so doing it improves their performance in terms of the amount of variance accounted for. Their interval scores however, indicate that they are still much slower overall than the nonretarded subjects and their variability (as reflected by the standard deviations for each interval score) is also much greater. The fact that the regression constant for these subjects is also much larger than for the nonretarded subjects may be due to their use of an additonal confounded process or just to the fact that they are much slower in carrying out the preparation - response processes.

Therefore, the basic conceptualisation of the models with the inclusion of five processes, encoding, inference, mapping, application and preparation - response, appears to account quite well for the way in which these two groups of subjects solved the People Piece Analogies. However, examination of individual difference analyses and additional model fits suggests that there are within and between subject differences in the types of processes used to solve the analogies, and that the componential method as it is at present formulated can not easily account for these factors. In addition, the actual method of stimulus presentation used by Sternberg (1977a) does not appear to be successful in decomposing the composite task into additive subtasks at least in the experiments here. The alternative method of stimulus presentation used in Experiments 3 and 4 appears to have been much more satisfactory. Also it does not appear to have altered the extraction of parameter estimates, even when the task was simplified so that retarded subjects could perform it.

CHAPTER 6

THE EFFECTS OF STRATEGY TRAINING ON THE PERFORMANCE LEVEL OF MENTALLY RETARDED SUBJECTS

6.1 INTRODUCTION TO EXPERIMENT 5

Experiment 5 was an attempt to train the use of a specific strategy in a mentally retarded group and also to examine whether generalisation could be achieved in a "far" transfer task if the trained strategy incorporated certain self-regulatory skills. In addition, the complexity of the People Piece Analogy task used in Experiments 1, 2 and 3 was reduced in order to enhance the adoption of strategic behaviours by these subjects, to reduce their variability and to decrease the number of experimental sessions required so that training sessions could be included. Thus, the same task as that used in Experiment 4 with only two cue conditions was used, but with one difference. The precued figures were not removed after the end of the first half of the trial, but remained present in the second half of the trial as was the case in Experiments 1 and 2 where four cue conditions were used.

Due to the general lack of training studies involving analogies a training strategy had to be developed that was relevant to this type of problem. Evans (1968) developed a computer program that solved geometric analogies. One significant advantage of computer simulations of human performance is that they require a rigorous task-analysis. Evans identified two principle operations which would enable his program to successfully solve analogies 1) the decomposition of the patterns comprising the analogy terms into their constituent elements (similar to Sternberg's encoding component), and 2) the determination of the transformation that relate the elements in

the A and B terms to those in the C and D terms (similar to Sternberg's inference and mapping components). To achieve this, firstly the A and B terms were compared and the elements in both were identified, and matched. From these a set of transformation rules were generated. The types of transformations recognised by Evan's program included the addition and removal of elements plus rotation, reflection and spatial displacement of elements. As Evans' program worked on a forced choice format where more than one D option was provided, this process was then conducted for each C-D pair. A gross comparison of the A/B and C/D terms was made to eliminate any obviously incorrect D options, essentially by comparing the number of elements present in all terms. If some D options still remained, the elements of the A and B terms were mapped onto the elements of each C-D pair by comparing the transformation rules corresponding to each set of pairs. The D option producing the greatest overlap of rules was then selected.

These aspects of Evan's program were adopted in the training procedure in this experiment. As there were always four elements in the People Piece analogies (height, sex, weight and colour) each subject was instructed to identify the dimensions of the elements that changed from the A to B terms and those that remained the same. The subject was then instructed to discover whether this pattern of dimensional changes and nonchanges was the same for the C and D terms. As a true/false format was used, rather than a forced-choice format, the subject was instructed to respond true if the transformation pattern remained identical for the A/B and C/D pairs or to respond false if they differed.

To ensure that the subjects were actually using this method of analogy solution, they were instructed to use an elaborative technique similar to that used by Kestner and Borkowski (1979) and Kendall et al (1980). This type of

technique was also used because it appeared to encourage self-testing in the subject, and required the subject's active participation.

As mentioned in Chapter 2, Kestner and Borkowski's (1979) interrogative strategy training routine involved four parts: 1) stating the physical relationship between the two items presented; 2) asking a "why" question about the physical relationship; 3) telling what is known about each item individually; and 4) using this information to generate a reason "why" the two items go together. In other words, the subjects in Kestner and Borkowski's experiment were made very familiar with the items and the relationship between them. This is somewhat analogous to the decomposition of analogy terms into their constituent elements, performed by Evans' program. Thus, in this experiment, the subjects were instructed to elaborate the dimensional changes and nonchanges in the elements of the A and B terms and then to ascertain whether the same dimensional changes occurred in the C and D terms.

Resnick and Glaser (1976) have also suggested that problem detection is an important part of successful problem solving behaviour. They write "the way problems are initially detected and therefore encoded, ... probably affects the quality of the observed solution behaviour" (Resnick and Glaser, 1976, p. 222). It is obvious that if the subject is unaware that there is a problem to solve or decides on an inefficient method of doing so, then his/her performance on the task will be adversely affected. It was hoped that by having the subjects elaborate the changes and nonchanges between each pair of analogy terms, the difficulties of problem detection would be avoided by emphasising to the subject what the actual problem to be solved was.

Resnick and Glaser (1976) also encouraged their subjects to "look ahead" by

verbalising the goals of their behaviour on a task and suggesting strategies they might use to achieve these goals. In this experiment, subjects were asked to state how they should attempt to solve the analogies at the start of the second day's training (i.e. by looking for the changes and nonchanges between the first two figures and comparing these changes to those in the third and fourth figures).

In addition, many studies (Belmont et al, 1978; Brown et al, 1979; Kendall et al, 1980 and Kestner and Borkowski, 1979) have demonstrated the importance of stressing the value of the strategy for use in the presented task and also in other tasks requiring similar strategies. Thus, at the end of each session, subjects were informed of the value of the trained strategy for solving analogies.

Finally, one other aspect was included in the training strategy procedure, that being immediate, positive feedback. It was hoped that immediate feedback would encourage subjects to check and monitor their reponses. This feedback was the same as that provided in Experiments 2 and 4, and consisted of the word "Good" said after every analogy which was solved correctly, in both the training and experimental sessions.

The work of Bray (1979) has suggested that there may be an interaction between extensiveness of instructions, task complexity and the adoption of strategic behaviours. Thus, to enhance the adoption of the trained strategy in this experiment, task complexity was reduced by using two rather than four cue conditions and having the full analogy present in the second half of the trial while instructions were made more explicit by the use of a training procedure.

To examine whether the training procedure was indeed effective, a control

group (Control Group 1) received two sessions of practice rather than two training sessions. It would be hypothesised that if the training procedure was effective, the control group would perform poorly compared to the experimental group receiving training. Finally, a second control group was included to examine whether, if the training procedure was found to improve performance over that of the practice sessions, it would also improve performance on a "far" (Brown, 1978) generalisation task. Thus, both the experimental group and Control Group 2 were tested using the coloured form of the Ravens Progressive Matrices. The Ravens Coloured Progressive Matrices were used because they approximate the type of analogical reasoning used to solve the People Piece Analogies, and also because they test general intelligence. If the training procedure proved successful at a generalisation level, it would be expected that the experimental group would score significantly higher on the coloured Progressive Martices than Control Group 2, when both these group were matched for intellectual ability

6.2 METHOD

6.2.1 SUBJECTS

Thirty-six subjects participated in Experiment 3. All were employees of Bedford Industries Rehabilitation Centre. They were divided into three groups approximately matched for IQ, using their full scale scores on the Weschler Adult Intelligence Scale, and will hence forth be referred to as the Experimental Group and Control Groups 1 and 2. The mean age of the Experimental group was 21.8 years (range 18-26) and their mean IQ was 72.8 with a range of 66 to 77. The mean age of Control Group 1 was 26.6 years (range 18 to 38). The mean IQ of Control Group 1 was 73.5 with a range of 65 to 83. The mean age of Control Group 2 was 28.6 years (range 20 to 43) and their mean IQ was 72.6 with a range of 65 to 79. It can be

seen that the mean age of the control groups was somewhat older than the experimental group. This was necessary to achieve approximately equivalent IQ scores. There was no known organic cause of the subjects' intellectual impairment. In addition, none of the subjects had any physical disabilities likely to affect performance, nor were they taking prescribed drugs. All subjects volunteered to participate and remained naive to the experimental aims.

6.2.2 APPARATUS

The apparatus used in this experiment was identical to that used in all previous experiments. In addition, the coloured form of the Ravens Progressive Matrices was administered to both the Experimental Group and Control Group 2.

6.2.3 DESIGN

The design of Experiment 5 was identical to that used in Experiment 4 so that a less complex task could be used and to allow the use of a different set of analogies in the training and testing sessions. The complexity of the task was reduced by dividing the analogies into two blocks of 88 trials as in Experiment 4 rather than four blocks of 44 trials as in Experiments 1,2 and 3 thus reducing the number of cue conditions from four to two. The cue conditions retained were the 0 and 2 cue conditions as these were the only two conditions necessary for the extraction of unconfounded parameters.

The only difference between the design of this experiment and that of Experiment 4 was that the precued figures remained present during the second half of the trial. This was done to see whether given a less complex task, training would be sufficient to make the subjects use the precued figures.

6.2.4 PROCEDURE

The Experimental Group participated in a total of seven sessions. The initial two sessions were concerned wholly with training. Each subject was first introduced to the task using the two sets of cards and 48 practice computer trials used previously. In addition, as in Experiment 4, the 48 practice computer trials were presented in the 2 cue condition only. Each trial was presented in two parts as explained in previous experiments and the nature of the response was also identical. For example, in the practice trials the first two figures in each analogy would appear on the computer screen. After extracting the changes and nonchanges between these two figures, the subject pressed the centre key on the response apparatus and the last two figures appeared. The subject extracted the relationship between these two figures and compared it to that between the first two figures. Then she/he responded true or false depending on the decision they had come to regarding the equivalence of the relationship between the first two and the last two figures.

The cards were used to describe each analogy type (degenerate, semidegenerate and nondegenerate) and the 0 and 2 cue conditions. Then the trials corresponding to each analogy type were presented via the computer. It was stressed that subjects should process the relationship between the first two figures in the 2 cue condition before pressing the centre key. Subjects were instructed to respond verbally "true" or "false" to the practice trials so response errors could be immediately corrected and explained. In addition, the first two trials of each analogy type were solved for the subject, by the experimenter.

On completion of the practice trials, the first block of trials from the set of 176 practice analogies was presented, using the 2 cue condition and always

commencing with the degenerate analogies. Here the subjects were first introduced to the elaboration strategy. Elaboration was not trained for the degenerate and semidegenerate analogy types, as these types had no changes between the first three figures in the case of the former or no changes between the first and second or first and third figures in the case of the latter type. However, on the nondegenerate analogies subjects were instructed to verbally state the attributes that changed and those that didn't change from the A to B analogy terms. The experimenter solved the first two nondegenerate analogies demonstrating the elaborative strategy. Subjects were informed that the attribute changes could be of only four types (height, sex, colour and weight) or combinations of these attributes. They were then instructed to compare the changes in the C and D pair to those they had verbalised in the A and B pair. If unsure of this instruction, the experimenter said "You said (for example) height and colour changed from the first to the second figure but sex and weight didn't, does height and colour change from the third to the fourth figure?". If yes, subjects were told this was an example of a true analogy, if no, the analogy was false. During the first session, subjects were encouraged to verbalise all the attribute changes and nonchanges so that subjects took into account all four dimensions. If the subject only verbalised one attribute change when more than one had occurred, she/he was asked whether this was the only changing attribute and was reminded that sometimes two or three attributes could change on any one analogy.

In addition to this training, use of the cues in the 2 cue condition was encouraged for the Type II analogies by instructing the subjects to elaborate the changing and nonchanging attributes in the A and B terms before pressing the centre key. Subjects received positive feedback for correct responses. Incorrect responses were explained and corrected, usually by having the subject re-elaborate the changing and nonchanging attributes and indicating

unmentioned attribute changes. When the first session was terminated the subjects were reminded of the value of the elaborative strategy for solving People Piece analogies.

At the start of the second session, each subject was asked to state what strategy she/he should use to solve the analogies. If the subject was unsure the experimenter explained that the subject should identify the attribute changes and nonchanges in the first and second figures and then compare these to the changes and nonchanges in the third and fourth figures. Two blocks of analogies were then presented to each subject, again beginning with the degenerate analogies and the 2 cue condition. The subject was encouraged to verbalise the attribute changes during the first block of nondegenerate analogies. However, in the second block she/he was instructed to elaborate the changes covertly "in your head". Positive feedback ("good") was given on all trials correctly responded to and errors were corrected at the end of each block, using the overt elaboration technique. Finally, the subject was reminded that the strategy was a helpful one for solving analogies.

After the completion of the training sessions, the subjects participated in two experimental testing sessions using the alternative set of 176 analogies. While no mention was made of the trained strategy, the use of the precued figures in the 2 cue condition was reinforced. The 0 and 2 cue conditions were presented balanced for order across subjects, six subjects receiving the 0 cue condition first in the third session and six, the 2 cue condition first. This order was reversed in the fourth session. The subjects were encouraged to respond as soon as they had reached a solution but were told that accuracy was more important than speed. They were told "Go as fast as you can without making too many errors. But it is more important to get the analogies right". Errors were repeated until correctly solved at the end of each block. Positive

immediate feedback was given throughout both sessions.

Four months later, these subject participated in three further sessions. The fifth and sixth sessions represented maintenance sessions. Would the subjects maintain their performance level of Sessions 3 and 4 suggesting their continued use of the elaborative strategy? An attempt was made to divide the subjects into prompted and unprompted groups with the prompted group being asked to recall the strategy they had originally been trained to use. However, most subjects spontaneously indicated that they remembered the task and the trained strategy and so this aspect of the maintenance phase was not undertaken.

During Session 7, the coloured form of the Ravens Progressive Matrices was administered to the subjects in the Experimental Group , six at a time. Prior to the administration of the test, all subjects were reminded of the elaborative strategy training they had received and it was suggested that a similar type of strategy could be used in the present task - to look for the changes and nonchanges between the items. The Coloured Ravens Progressive Matrices, acted as a "far" generalisation task. While there are similarities between this and the analogy task, significant modifications would be required if the trained strategy was to be adopted successfully in this task. Both tasks require the extraction of relationships between items, however, the format of the two tasks is different. In the coloured Progressive Matrices multiple answer options are provided but they are not presented in a strictly analogical format (i.e. A:B::C:D).

Control group 1 participated in four sessions. These sessions consisted of two initial sessions of practice with no training and were followed by two experimental sessions. During the initial practice session, subjects were

instructed to sort the 16 cards on which were drawn each of the People Piece Analogy figures by each of the four attributes separately. They then received the cards used to explain the different types of People Piece Analogies and the 48 computer practice trials. The subjects then received the first block of analogies (using the practice set of 176 trials) all subjects commencing with the 2 cue condition. Subjects received feedback during this block of trials after each analogy solved correctly. Subjects were instructed to respond verbally so that errors could be immediately corrected. Subjects then received the second block of trials in the 0 cue condition. Errors were not replayed at the end of either block. No information concerning verbalisation of the changes between the first two figures and the second two figures was given.

In the second practice session, the same procedure was followed. However, subjects received no feedback after each trial in either block and no mention was made of the elaboration strategy used by the Experimental Group. Errors were rerun at the end of the first block and explained. At the end of the second block, errors were replayed until subjects solved them correctly.

In Sessions 3 and 4, Control Group 1 received the alternative set of 176 analogies. Again, subjects received no feedback after each trial in either session. Errors were repeated at the end of each block until correctly solved.

Instructions were given to both the Experimental and Control groups to use the precued figures. They were told in the 2 cue condition "it is more important to spend more time on the first part of the trial so you don't have to look back at the figures presented in this part when you get to the second part of the trial. It is better to be slower on the first part so you will be quicker on the

second part". Each session lasted approximately 35 minutes ranging from about 45 minutes in the first session to 25 minutes in the final session for both groups.

Control group 2 participated in only one session, in which the coloured form of the Ravens Progressive Matrices was administered, the subjects being tested in two groups of six subjects.

6.3 RESULTS AND DISCUSSION

As in Experiments 1,2,3 and 4 this section is divided into three subsections; Interval Scores, Component Scores, and Error rates. In addition, there is a final subsection concerned with the results obtained using the Ravens Progressive Matrices for the Experimental Group and Control Group 2.

6.3.1 INTERVAL SCORES

Interval scores were again divided into cue times and solution times. Tables 6.1 to 6.4 present the mean cue and solution times for each cue condition over all sessions and for Sessions 1 and 2 separately, for both the Experimental Group (initial and maintenance phases separately) and Control Group 1. The interval scores are also divided into those for Type I (semidegenerate and degenerate) analogies and Type II (nondegenerate) analogies.

As can be seen in Table 6.1, cue times increase and solution times decrease from the 0 to 2 cue condition for both groups (initial and maintenance phase for the experimental group). However, these changes are not nearly as great as those observed in Experiment 4, using similar subjects, where the precued figures disappeared after the end of the first half of the trial. For the

TABLE 6.1

INTERVAL SCORES, FOR EXPERIMENTAL GROUP, INITIAL AND MAINTENANCE PHASES AND CONTROL GROUP 1

	Overall Means	
	Cue Conditions	
	0	2
Experimental Group (Initial Phase)		
Cue Time	866	1657
SD	608	1618
No of Observations	2112	2112
Underflow Trials	65	70
Solution Time	3575	2939
SD	2994	2434
No of Observations	2112	2112
Overflow Trials	6	1
Experimental Group (Maintenance Phase)		
Cue Time	954	1992
SD	647	2131
No of Observations	2112	2112
Underflow Trials	43	29
Solution Time	3370	2868
SD	2696	2445
No of Observations	2112	2112
Overflow Trials	2	1
Control Group 1		
Cue Time	762	907
SD	684	801
No of Observations	2112	2112
Underflow Trials	69	66
Solution Time	3870	3849
SD	3809	3904
No of Observations	2112	2112
Overflow Trials	10	7

TABLE 6.2

INTERVAL SCORES FOR TYPE I AND TYPE II ANALOGIES, EXPERIMENTAL GROUP, INITIAL PHASE

	Cue Condition	
	0	2
Type I Analogies		
All Sessions		
Cue Time	869	1218
SD	534	1080
No of Observations	960	960
Underflow Trials	15	28
Solution Time	2185	1986
SD	1785	1523
No of Observations	960	960
Overflow Trials	0	0
Session 3		
Cue Time	944	1213
SD	545	1016
No of Observations	480	480
Underflow Trials	2	8
Solution Time	2342	2199
SD	1780	1764
No of Observations	480	480
Overflow Trials	0	0
Type II Analogies		
All Sessions		
Cue Time	862	2095
SD	674	2018
No of Observations	1152	1152
Underflow Trials	50	42
Solution Time	4964	3891
SD	3840	3087
No of Observations	1152	1152
Overflow Trials	6	1
Session 5		
Cue Time	939	2112
SD	735	1954
No of Observations	576	576
Underflow Trials	26	12
Solution Time	5598	4311
SD	4307	3402
No of Observations	576	576
Overflow Trials	5	1
Session 4		
Cue Time	795	1223
SD	511	1141
No of Observations	480	480
Underflow Trials	13	20
Solution Time	2028	1223
SD	1777	1199
No of Observations	480	480
Overflow Trials	0	0
Session 6		
Cue Time	785	2078
SD	596	2079
No of Observations	576	576
Underflow Trials	24	30
Solution Time	4330	3470
SD	3183	2670
No of Observations	576	576
Overflow Trials	1	0

TABLE 6.3

INTERVAL SCORES TYPE I AND TYPE II ANALOGIES
EXPERIMENTAL GROUP, MAINTENANCE PHASE

	Cue Condition				
	0	2		0	2
Type I Analogies					
All Sessions			Session 6		
Cue Time	963	1455	Cue Time	917	1251
SD	591	1260	SD	483	1157
No of Observations	960	960	No of Observations	480	480
Underflow Trials	9	8	Underflow Trials	3	5
Solution Time	2064	1886	Solution Time	1790	1787
SD	1419	1471	SD	1053	1603
No of Observations	960	960	No of Observations	480	480
Overflow Trials	0	0	Overflow Trials	0	0
Session 5					
Cue Time	1010	1660			
SD	678	1325			
No of Observations	480	480			
Underflow Trials	6	3			
Solution Time	2338	1985			
SD	1664	1318			
No of Observations	480	480			
Overflow Trials	0	0			
Type II Analogies					
All Sessions			Session 6		
Cue Time	944	2528	Cue Time	921	2450
SD	698	2737	SD	647	2777
No of Observations	1152	1152	No of Observations	576	576
Underflow Trials	34	21	Underflow Trials	24	15
Solution Time	4676	3850	Solution Time	4444	3731
SD	3539	3130	SD	3497	3090
No of Observations	1152	1152	No of Observations	576	576
Overflow Trials	2	1	Overflow Trials	0	0
Session 5					
Cue Time	968	2606			
SD	745	2694			
No of Observations	576	576			
Underflow Trials	10	6			
Solution Time	4908	3969			
SD	3567	3165			
No of Observations	576	576			
Overflow Trials	2	1			

TABLE 6.4

INTERVAL SCORES FOR TYPE I AND TYPE II ANALOGIES
CONTROL GROUP 1

	Cue Condition	
	0	2
Type I Analogies		
All Sessions		
Cue Time	816	868
SD	668	846
No of Observations	960	960
Underflow Trials	22	32
Solution Time	2557	2720
SD	2435	3024
No of Observations	960	960
Overflow Trials	0	1
Session 3		
Cue Time	824	973
SD	633	984
No of Observations	480	480
Underflow Trials	12	22
Solution Time	2467	2973
SD	2328	3140
No of Observations	480	480
Overflow Trials	0	0
Type II Analogies		
All Sessions		
Cue Time	707	946
SD	699	753
No of Observations	1152	1152
Underflow Trials	47	34
Solution Time	5182	4978
SD	4805	4619
No of Observations	1152	1152
Overflow Trials	10	6
Session 4		
Cue Time	609	893
SD	407	737
No of Observations	576	576
Underflow Trials	25	16
Solution Time	4962	4772
SD	4709	4482
No of Observations	576	576
Overflow Trials	5	1

	Cue Condition	
	0	2
Session 4		
Cue Time	807	763
SD	702	664
No of Observations	480	480
Underflow Trials	10	10
Solution Time	2648	2467
SD	2534	2883
No of Observations	480	480
Overflow Trials	0	1
Session 3		
Cue Time	804	999
SD	891	765
No of Observations	576	576
Underflow Trials	22	18
Solution Time	5404	5184
SD	4890	4744
No of Observations	576	576
Overflow Trials	5	5

Experimental Group, cue times in both phases were similar to those obtained by the nonretarded subjects in Experiments 1 and 2 and show that some preprocessing is taking place in the first half of the trial. The solution times are however, longer for this group and show less decline from the 0 to 2 cue condition. This suggests that even though more processing is taking place in the first half of the trial in the 2 cue condition, experimental subjects are reprocessing the precued figures to some extent in the second half of the trial. Thus, training does not appear to have resulted in as much use of the precues as removing them in the second part of the trial. For Control Group 1, the increase in cue times and especially the decrease in solution times from the 0 to 2 cue condition is minimal and similar to the results obtained for the retarded subjects in Experiment 2.

A three way (Group x Type x Cue) analysis of variance using the solution times revealed significant main effects for Type ($F(1,132) = 83\ 65$, $p < .01$) and Group ($F(2,132) = 3.12$, $p < .05$) (See Appendix 5.1). There was no significant main effect for Cue and no significant interaction between Cue and Group which suggests that the precued figures were not being used in the 2 cue condition by either group. The main effect for Type was highly significant, suggesting that in both cue conditions, the Type I analogies were solved more quickly than the Type II analogies. These results are confirmed by examination of Figures 6.1(a)-(b), 6.3(a)-(b) and 6.5(a)-(b) for both groups and are consistent with the results obtained in all previous experiments. The group effect was significant at the .05 level only. This is not surprising and is probably due to there being minimal differences between the two phases for the experimental group which cancelled out the effect of the control group. To investigate this, planned comparisons were carried out between the initial and maintenance phases of the Experimental Group and both phases of the

Experimental Group and Control Group 1. These comparisons revealed that there was no significant difference between the solution times for both phases of the Experimental Group ($F(1,132) = .19$, $p > .05$), but that solution times for both phases of the Experimental Group were faster than those for Control Group[1] ($F(1,132) = 6.06$, $p < .05$). This suggests that the training procedure has been successful in improving the performance of the Experimental Group over that of the control group and in maintaining that performance. It has not, however, been successful in improving the use of the precued figures. This is supported by the finding that Underflow trials (that is, cue times shorter than 50 msecs) are very numerous in this experiment, for both groups and for both analogy types. In fact, Underflow trials are more numerous for the Type II analogies, suggesting that the retarded subjects in all groups found it easier to refer back to the precued figures in the second half of the trial and ignore them in the first half of the trial for these more difficult analogies.

These results therefore, suggest that the assumption of additivity has not been completely met, although the solution times for the Experimental Group indicate some use of the precued figures in the 2 cue condition. In addition, these results suggest that the training procedure has been successful in increasing use of the precued figures over that of just practice and instruction (Experiment 2, retarded group). However, it may have little advantage over two sessions of practice with explicit instructions and disappearance of the precued figures in the second half of the trial (Experiment 4, retarded group). Finally, the significant main effect for Type suggests use of dual processing in the model fitting procedure. The Type 1 analogies are solved much more quickly and show little decline across attribute changes or cue conditions (See Figures 6.1, 6.3, and 6.5).

A four way analysis of variance (Group x Session x Type x Cue Condition with repeated measures for Session) was also conducted to examine if there was an improvement in performance from Session 1 to Session 2 (See Appendix 5.2). Significant main effects were obtained for Session ($F(1,33) = 16.10$, $p < .01$), Type ($F(1,33) = 112.21$, $p < .01$) and Cue ($F(1,33) = 11.32$ $p < .01$). The former indicates that performance improved across the two sessions while the latter two results mirror the previous analysis.

6.3.2 COMPONENT SCORES

The component scores were predicted in the same manner as in all previous experiments. As in Experiment 4, prediction was based on 150 rather than 300 data points due to there being only two rather than four cue conditions. The predictor variables were the 15 AB/AC attribute change combinations, the 5 DD' value changes and the number of terms to be encoded (4 and 2 for the 0 and 2 cue conditions, respectively). All four models tested incorporated dual processing. Figures 6.1(a)-(b), 6.3(a)-(b), 6.5(a)-(b) present the solution times for true analogies, in each of the 15 AB/AC change combinations and in each cue condition for the Experimental Group (initial and maintenance phases) and the Control Group 1, respectively. Figures 6.2, 6.4, and 6.6 present the solution times for true and false Type I and Type II analogies collapsed across cue conditions for the two phases of the Experimental Group and Control group 1, respectively.

Figures 6.1(a)-(b) and 6.3(a)-(b) indicate that the four factors suggesting use of self-terminating processes are being met to some extent for the Experimental Group in both phases of the experiment. Slopes decline across value changes from the 0 to 2 cue conditions suggesting that the attribute-comparison processes are dropping out in the 2 cue condition. Also, curves show some

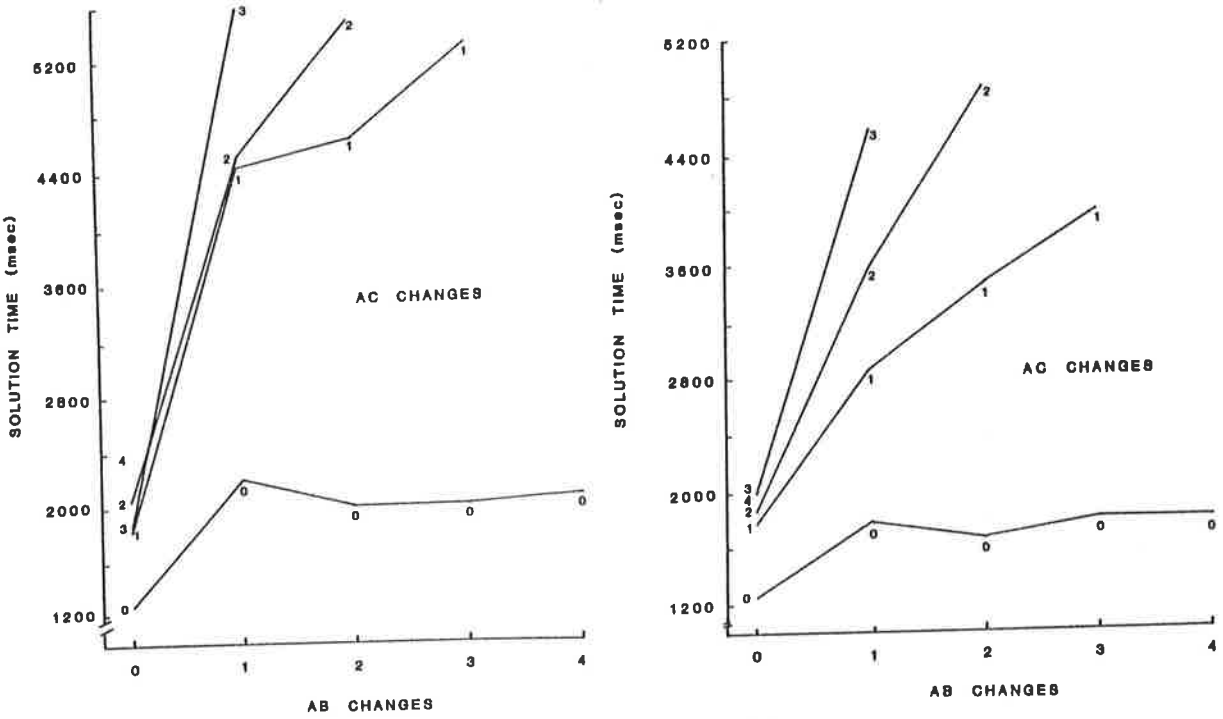


Figure 6.1 Mean solution times for 15 AB/AC attribute change combinations for true Type I and II analogies in each cue condition, experimental group, initial phase.
(a) 0 cue condition
(b) 2 cue condition

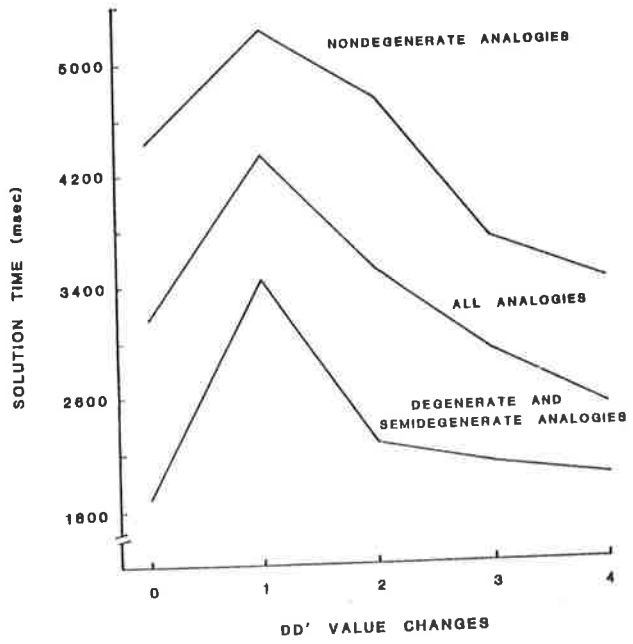


Figure 6.2 Mean solution times for true and false Type I and II analogies, experimental group, initial phase.

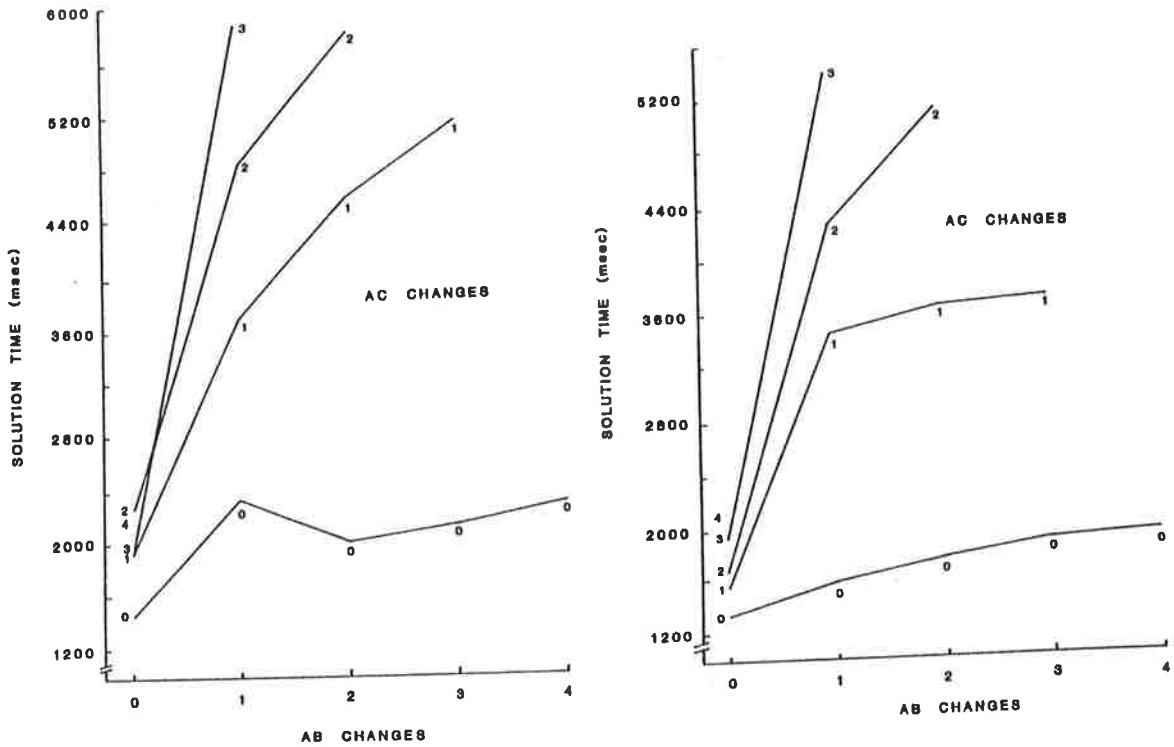


Figure 6.3 Mean solution times for 15 AB/AC attribute change combinations for true Type I and II analogies in each cue condition, experimental group, maintenance phase.
(a) 0 cue condition
(b) 2 cue condition

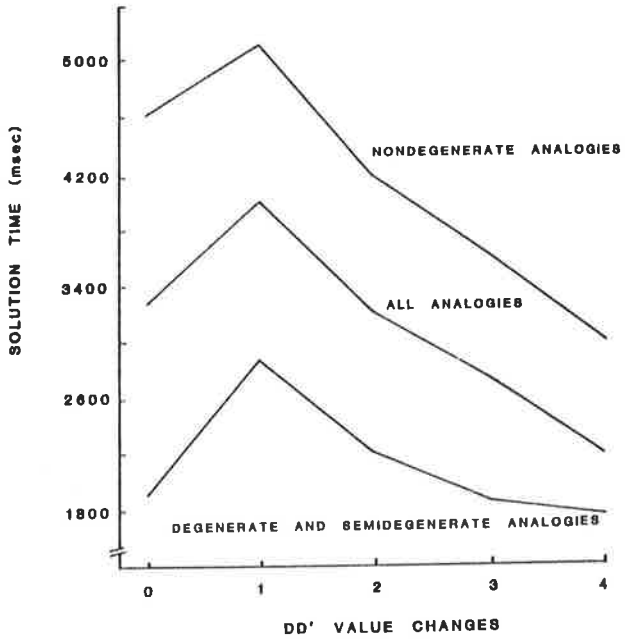


Figure 6.4 Mean solution times for true and false Type I and II analogies, experimental group, maintenance phase.

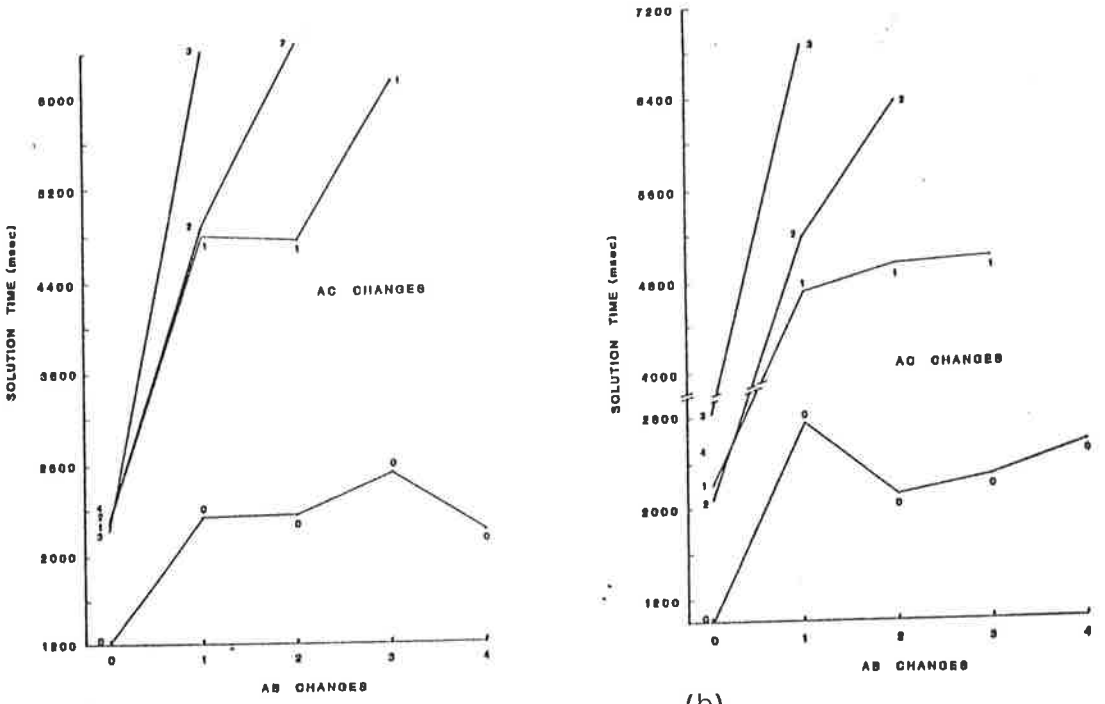


Figure 6.5 Mean solution times for 15 AB/AC attribute change combinations for true Type I and II analogies in each cue condition, control group 1.
(a) 0 cue condition
(b) 2 cue condition.

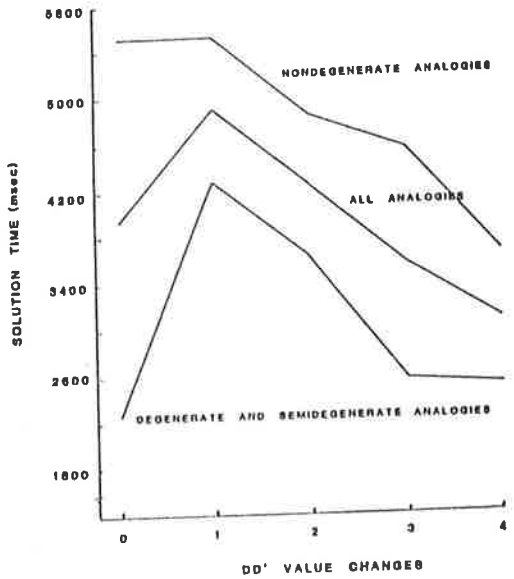


Figure 6.6 Mean solution times for true and false Type I and II analogies, control group 1.

displacement downwards from the 0 to 2 cue condition suggesting that some pre-encoding is taking place. Solution times decrease with increasing degree of falsity (Figures 6.2 and 6.4), but, as for the nonretarded and retarded groups in Experiment 4 and the retarded group in Experiment 2, true Type II analogies are not solved more slowly than all false Type II analogies (Figures 6.2 and 6.4). Again, analogies false by 1 DD' value change produce the longest solution times and in the initial phase for the experimental group, analogies false by 2 DD' value changes are also solved more slowly than true Type II analogies. This suggests that the training procedure may have made the experimental subjects more cautious so that they perform a checking response prior to pressing the response key, but after having solved the analogy.

For Control Group[1], solution times also show some decline in slope over attribute changes from the 0 to 2 cue condition (Figures 6.5(a)-(b)) but this is not as great as for the Experimental Group. They also show little evidence of a reduction in intercept from the 0 to 2 cue condition in comparison to the Experimental Group. However, like the Experimental Group and the below average and retarded subjects in Experiments 1 and 2, this is probably due to the nonuse of the precued figures rather than to their not using self-terminating processes. Referring to Figure 6.6, it can be seen that the two remaining points suggesting use of self-terminating processes, are met, that is, true Type II analogies produce the longest solution times and solution times to false analogies decrease with increasing degree of falsity (i.e. from 1 to 4 DD' value changes). This suggests that the finding of Type II analogies false by 1 DD' value change producing longer solution times than true Type II analogies is related to having received additional practice and instruction with the task prior to testing. It may also be related to having two rather than four cue conditions since the nonretarded and retarded subjects in Experiment 4 produced similar results.

For the Type I analogies for both groups, results are consistent with the inclusion of dual processing as in all previous experiments. Solution times to these analogies show very little decline across slopes or across cue conditions. The degenerate analogies are again solved more quickly than the semidegenerate analogies. There is also some evidence, especially for the Experimental Group that false 1 DD' value change Type I analogies are being solved more slowly than all other Type I analogies. This suggests that the alternative model fitting procedure, that is, dual processing in 1 DD' value change only, may provide a better fit to the data for this group. For Control Group 1, Type I analogies false by 1 and 2 DD' value changes are solved more slowly than the other Type I analogies. This alternative fitting procedure is also tested subsequently.

Tables 6.5 to 6.7 present the results of the model fitting procedure, incorporating dual processing for the Experimental Group (initial and maintenance phases) and Control Group[1], respectively. Model II provided the best fit to the data in the initial phase for the Experimental Group, accounting for 60.4% of the variance. This was followed by Model III, which accounted for 58.9% of the variance. Model I accounted for 58.4% of the variance and Model IV for 54.9% of the variance. Thus, for the initial phase the results obtained from the Experimental Group suggest that these subjects are using more exhaustive processes due possibly to the training received as will be discussed below. For the experimental group, in the maintenance phase, Model III provided the best fit, accounting for 64.3% of the variance. This was followed by Model II which accounted for 61.3% of the variance. Model IV accounted for 60.9% of the variance and Model I for 58.2% of the variance. Thus, in the maintenance phase of the experiment, conducted four months after the initial training and testing period, the Experimental Group has become more self-terminating in its processing. In

TABLE 6.5

MODEL FITS AND PARAMETER ESTIMATES, MODELS I TO IV
EXPERIMENTAL GROUP, INITIAL PHASE

Parameter Dropouts Dual Processing

				Parameter Estimates				
	% Variance	Freg	df	a	x x'	y y'	z z'	c
MODEL I	58.4%	51	4,145	166	416	741	473	1517
*MODEL II	60.4%	55	4,145	124	540	851	681	1505
MODEL III	58.9%	52	4,145	62	727	1279	239	2118
MODEL IV	54.7%	44	4,145	108	134	983	1286	2081

TABLE 6.6

MODEL FITS AND PARAMETER ESTIMATES, MODELS I TO IV
EXPERIMENTAL GROUP, MAINTENANCE PHASE

Parameter Dropouts Dual Processing

				Parameter Estimates				
	% variance	Freg	df	a	x x'	y y'	z z'	c
MODEL I	58.2%	51	4,145	80	389	726	354	1648
MODEL II	61.3%	57	4,145	57	457	820	621	1522
*MODEL III	64.3%	85	4,145	8	604	1340	179	2067
MODEL IV	60.9%	57	4,145	65	831	1342	67	2045

* Best Fitting Model

TABLE 6.7

MODEL FITS AND PARAMETER ESTIMATES
MODELS I TO IV, CONTROL GROUP 1

Paramater Dropouts Dual Processing

				Parameter Estimates				
	% variance	Freg	df	a	x x'	y y'	z z'	c
MODEL I	42.0%	26	4,145	-88	221	601	596	2851
MODEL II	46.7%	32	4,145	-135	362	747	931	2761
*MODEL III	47.0%	32	4,145	-185	512	1168	536	3281
MODEL IV	44.1%	29	4,145	-118	596	1201	471	3189

TABLE 6.8

MODEL FITS AND PARAMETER ESTIMATES, MODELS I TO IV
EXPERIMENTAL GROUP, INITIAL PHASE

No Parameter Dropouts Dual Processing

				Parameter Estimates				
	% variance	Freg	df	a	x x'	y y'	z z'	c
MODEL I	56.9%	48	4,145	304	317	700	367	1176
MODEL II	59.6%	53	4,145	304	430	747	580	1011
*MODEL III	60.4%	55	4,145	304	615	1081	142	1372
MODEL IV	55.5%	45	4,145	304	1038	976	-191	1734

* Best Fitting Model

TABLE 6.9

MODEL FITS AND PARAMETER ESTIMATES, MODELS I TO IV
EXPERIMENTAL GROUP, MAINTENANCE PHASE

No Parameter Dropouts Dual Processing

	% variance	Freg	df	a	Parameter Estimates x x'	y y'	z z'	c
MODEL I	57.6%	49	4,145	210	453	631	103	1437
MODEL II	60.9%	56	4,145	210	376	725	527	1109
*MODEL III	65.8%	70	4,145	210	517	1171	97	1447
MODEL IV	62.9%	62	4,145	210	985	1019	-244	1785

TABLE 6.10

MODEL FITS AND PARAMETER ESTIMATES, MODELS I TO IV
CONTROL GROUP 1

No Parameter Dropouts Dual Processing

	% variance	Freg	df	a	Parameter Estimates x x'	y y'	z z'	c
MODEL I	41.4%	26	4,145	-14	-52	661	753	2519
MODEL II	46.1%	31	4,145	-14	274	687	872	2427
*MODEL III	47.8%	33	4,145	-14	433	1028	468	2755
MODEL IV	44.3%	29	4,145	-14	615	1020	297	2975

* Best Fitting Model

addition, for the Experimental Group encoding was more reliably predicted as can be seen in Tables 6.5 and 6.6 for the initial and maintenance phases, respectively. Training was useful in helping them to master the task and improved encoding of the analogy terms. However, having mastered the task, they move towards more self-terminating processing as used by the nonretarded in previous experiments and time spent on encoding declines. Even more interesting is the finding that slightly more of the variance is accounted for in this phase when compared to the initial phase.

These results suggest that the training procedure has had the effect of making the Experimental Group more exhaustive in their processing at least, initially. This is not really surprising given the training procedure they received which in the first session encouraged them to find all the changes and nonchanges for each of the four attributes. However, over time, they have adopted the use of more self-terminating processes. Unlike the results for previous experiments, the percentage of variance accounted for has not declined with this use of self-terminating processes and has in fact marginally increased. This suggests that the training procedure has been successful in improving performance in terms of the amount of variance accounted for and in maintaining this level of performance over time.

One other point can be made here, that is, that the componential method appears to be sensitive to introduced changes in the experimental design. This is suggested, for example, by the fact that Model II became the best fitting model for the Experimental Group in the initial phase of the experiment i.e. that training had produced more exhaustive processing. This sensitivity was also present in Experiment 4, for the retarded group, where Model II rather than Model IV was found to follow Model III as the best fitting model, suggesting that the modified method of precueing also induced slightly more exhaustive processing for these subjects.

The validity of these conclusions is further supported by the results of the model fitting procedure obtained for Control Group 1 (Table 6.7). For this group, Model III was found to provide the best fit to the data, accounting for 47.0% of the variance. This was followed by Model II which accounted for 46.7% of the variance. Model IV accounted for 44.1% of the variance and Model I for 42.0% of the variance. These results are very similar to those obtained for the retarded subjects in Experiment 2, both in the amount of variance accounted for and in the ordering of models (although Model IV provided a slightly better fit than Model II in this earlier experiment). In addition, as in Experiment 2, the encoding parameter is poorly estimated by all four models for this group. This would tend to confirm the findings for the interval scores, that these subjects are making less use of the precued figures than the subjects in the Experimental Group.

Model fits were also obtained using the alternative model fitting procedure used in Experiments 1 and 2. As mentioned in Chapter 4, this method assumed that the inference and mapping processes were being carried out in the second rather than the first half of the trial in the 2 and 3 cue conditions. Encoding was still assumed to dropout over cue conditions. It was found that the alternative model fitting procedure provided a much better fit to the data for both groups of subjects in Experiments 1 and 2, but especially for the nonretarded subjects in each experiment. As the original method of stimulus presentation was used here, as in those experiments, this model fitting procedure was performed for both groups. As there were only two rather than four cue conditions in this experiment, only inference and not mapping is affected. It is assumed that this process does not drop out in the 2 cue condition but occurs in the second half of the trial along with mapping and application.

The results using this alternative procedure are presented in Tables 6.8 to

6.10, for the Experimental Group (initial and maintenance phases) and Control Group 1, respectively. Model III provided the best fit to the data for the Experimental Group (initial phase), accounting for 60.4% of the variance. Model II followed, accounting for 59.6% of the variance. Model I accounted for 56.9% of the variance and Model IV for 55.5% of the variance. Thus the same amount of variance is accounted for using this procedure although this time, Model III provides a slightly better fit than Model II. Model IV is still the model providing the worse fit to the data. Thus, both procedures appear to favour more exhaustive processing for this phase of the experiment for the Experimental Group.

For the Experiment Group, in the maintenance phase, Model III remained the model providing the best fit to the data, accounting for 65.8% of the variance. This was followed by Model IV (rather than Model II using the original model fitting procedure), which accounted for 62.9% of the variance. Model II accounted for 60.9% of the variance and Model I for 57.6% of the variance. Thus, for this phase of the experiment, the alternative model fitting procedure provides a slight improvement in the amount of variance accounted for by the original method. It also shows a slight reversal in the ordering of models with Model IV becoming the model providing the next best fit rather than Model II. This suggests that the alternative model fitting procedure may favour the more self-terminating models over the more exhaustive ones. However, this type of result has only occurred in this instance and in none of the previous experiments where the alternative model fitting procedure has been used (i.e. Experiments 1 and 2).

For Control Group 1, Model III remained the best fitting model, accounting for slightly more of the variance (47.8%), than the same model using the original model fitting procedure. Model II followed, accounting for 46.1% of the

variance, followed by Model IV which accounted for 44.3% of the variance and finally Model I, which accounted for 41.4% of the variance. Thus, for this group, the ordering of models remains unchanged. However, it should be mentioned that in previous experiments, Model IV has tended to follow Model III as the best fitting model for the below average and retarded subjects, given similar amounts of instruction. It is puzzling as to why Model II should become the next best fitting model over Model IV in this instance. It may be due to the fact that Control Group 1 received two sessions of practice rather than one. Alternatively, it may be due to the use of only two rather than four cue conditions, since a similar result was also found in Experiment 4 using only two cue conditions but no training.

The finding that the original and alternative model fitting procedures accounted for similar amounts of the variance requires consideration. The most probable explanation is due to the use of only two rather than four cue conditions. When four cue conditions are used parameter dropouts affect two cue conditions, the 2 and 3 cue conditions and also two parameters, inference and mapping. When only two cue condition are used, parameter dropouts affect only the 2 cue condition and only one process, inference. In this latter case therefore, the difference between the original and alternative model fitting procedures is reduced.

However, the same general conclusion can be made using the alternative model fitting procedure as opposed to the original method. The training procedure appears to have initially caused the use of more exhaustive processing but over time, more self-terminating processing has been adopted. Training has also been successful in improving and maintaining the percentage of variance accounted for by retarded subjects. It appears that two initial

sessions providing just practice and minimal instructions concerning the task are not sufficient to improve performance over only one session of practice as received by the retarded subjects in Experiment 2 although these factors may make processing more exhaustive.

The finding that approximately 65% of the data was accounted for by the Experimental Group here and the retarded group in Experiment 4 suggests that the training procedure and modified method of precueing combined with a simpler task (plus additional practice and more explicit instructions) have both been successful in increasing the amount of variance accounted for by the data obtained from retarded subjects. Comparison of the Experimental Group's interval scores in both experimental phases to those of the retarded subjects in Experiment 2, and Control Group 1, also indicate that training has improved the use of the precued figures by this group and, in addition, has reduced their overall solution time. (Comparison with the retarded group in Experiment 4 is not really valid because this latter group received, in effect, a much more difficult task).

However, neither training nor the simplified task and modified method of precueing have raised the amount of variance accounted for by the retarded groups' data to that, or even close to that, obtained using nonretarded subjects. The similarity of the amount of variance accounted for by both the Experimental Group here and the retarded subjects in Experiment 4 suggests that there may be a level (around 65%) above which it will become increasingly difficult to account for more of the retarded subjects' data. This may be due to their using different processes to those suggested here or to their lack of consistency in responding. If the latter is the case, it is unlikely that the amount of variance can be improved upon using these types of subjects, except by including a large number of practice sessions prior to testing (as did Phillips and Nettelbeck, 1984) or by constructing the

experimental situation in such a way as to induce more consistent performance (for example by including the modified cueing method of stimulus presentation in a training experiment).

Finally, one further result is of interest. This is that like the retarded subjects in Experiment 4, the Experimental Group here are spending more time on encoding than Control Group[1]. However, as in Experiment 4, this appears to have only resulted in a saving in application time and not in the more difficult processes, inference and mapping. However, the greater time spend on encoding by the Experimental Group is not as great as for the retarded group in Experiment 4, especially in the maintenance phase. This suggests as mentioned in the previous chapter, that the altered method of precueing is more effective in forcing retarded subjects to spend longer on encoding than explicit instructions used in conjunction with the original method of precueing.

As the alternative model fitting procedure provided slightly better fits to the data for the Experimental Group (maintenance phase) and Control Group 1, the F regression tables are presented using this method. Table 6.11 presents the F regression table for the Experimental Group in the initial phase of the experiment (F regression tables for other models and groups are presented in Appendices 5.3 and 5.4 for the original and alternative model fitting procedures respectively). All parameters were quite reliably predicted except for the application parameter which obtained a standard error higher than its parameter estimate and was not statistically significant. The stepwise multiple regression data presented in the lower half of Table 6.11 indicate that all parameters with the exception of application, made a significant contribution to the amount of variance accounted for.

Table 6.12 presents the F regression table for Model III for the Experimental

TABLE 6.11

F REGRESSION TABLE FOR ALTERNATIVE MODEL III
EXPERIMENTAL GROUP (INITIAL PHASE)

Parameter	Time(msecs)	Standard Error	B	Freg	df
a	304	75	.21	16	1,145
x	615	97	.40	40	1,145
y'	1081	152	.44	50	1,145
z'	142	156	.05	0.8	1,145
c	1372				

Stepwise Multiple Regression

Parameter	Cumulative R2	r	Cumulative Freg	Cumulative df
y'	.43	.66	113	1,148
x	.56	.65	93	2,147
a	.60	.21	74	3,146
z'	.60	.26	55	4,145

TABLE 6.12

F REGRESSION TABLE FOR ALTERNATIVE MODEL III
EXPERIMENTAL GROUP (MAINTENANCE PHASE)

Parameter	Time (msecs)	Standard Error	B	Freg	df
a	210	64	.16	11	1,145
x	517	82	.37	40	1,145
y'	1171	129	.52	83	1,145
z'	97	132	.04	0.6	1,145
c	1447				

Stepwise Multiple Regression

Parameter	Cumulative R2	r	Culative Freg	Cumulative df
y'	.53	.72	164	1,148
x	.63	.66	126	2,147
a	.66	.16	93	3,146
z'	.66	.25	70	4,145

Group in the maintenance phase of the experiment. Again, all parameters were quite reliably predicted except for the application parameter. The standard error for this parameter was greater than its estimate and it was not statistically significant. In the stepwise multiple regression table, it can be seen that all parameters make a statistically significant contribution to the amount of variance accounted for apart from the application parameter.

Finally, Table 6.13 presents the F regression table for Model III for Control Group 1. All parameter estimates are reliable except for the encoding parameter, regression Fs being significant for the inference, mapping and application parameter estimates but not for encoding. A similar result was obtained in Experiment 2 for the retarded subjects, and tends to confirm the suggestion made previously that these subjects are making little use of the precued figures. The stepwise multiple regression table also indicates that inference, mapping and application are making a statistically significant contribution to the amount of variance accounted for. However, the encoding parameter correlates poorly with solution times and makes little contribution to the amount of variance accounted for. The finding that application is a valuable predictor here suggests that it may be the training procedure received by the experimental group or the more explicit instructions received in previous experiments that has caused this parameter to be poorly predicted and to add little to the amount of variance accounted for these instances. It may be, as suggested previously, that training and instructions produces more thorough and cautious responding on the part of the retarded subjects. Thus they are checking their response choice before making it.

As in all previous experiments, separate analyses for each cue condition,

TABLE 6.13

F REGRESSION TABLE FOR ALTERNATIVE MODEL III

CONTROL GROUP I

Parameter	Time (msecs)	Standard Error	B	Freg	df
a	-14	85	.01	0.3	1,145
x	433	109	.29	16	1,145
y'	1028	172	.42	36	1,145
z'	468	176	.17	7	1,145
c	2755				

Stepwise Multiple Regression

Parameter	Cumulative R2	r	Cumulative Freg	Cumulative df
y'	.37	.61	87	1,148
x	.45	.56	61	2,147
a	.45	-.01	40	3,146
z'	.48	.34	33	4,145

nondegenerate analogies only, and for each session separately were conducted, to examine whether these analyses produced results different from those produced using the full set of data. In addition, model fitting for dual processing in 1DD' value change was also carried out. All additional analyses are again presented in a single table (Table 6.14), with in most cases, only the best fitting model being presented in the text. All analyses were conducted using the alternative model fitting procedure with no attribute-comparison process dropouts across cue conditions. (F regression tables for each model in each analysis and for both groups, are presented in Appendices 5.5 to 5.11).

Model fits for Each Cue Condition Separately: For the Experimental Group in the 0 cue condition, initial phase, Model III remained the best fitting model accounting for 63.1% of the variance. Model II followed, accounting for 62.3% of the variance. A similar result was obtained in the 2 cue condition with Model III accounting for 58.1% of the variance and Model II for 57.1% of the variance. For the Experimental Group, maintenance phase, Model III remained the best fitting Model in the 0 cue condition, accounting for 68.0% of the variance. This time, however, Model IV followed, accounting for 65.4% of the variance. In the 2 cue condition, Model III was again the model providing the best fit to the data, accounting for 64.3% of the variance. Model IV followed accounting for 61.4% of the variance. Thus, while the ordering of models does not change across cue conditions, it does change across experimental phases. The subjects show a trend towards becoming more self-terminating from the initial to the maintenance phase, a result also obtained using the full set of data.

For the Control Group, Model III was also the best fitting model in the 0 cue condition, accounting for 52.2% of the variance. For this group , Model II

TABLE 6.14

MODEL FITS FOR ALL ANALYSES, EXPERIMENTAL GROUP (INITIAL AND MAINTENANCE PHASE) AND CONTROL GROUP 1

Analyses	MODELS			
Experimental Group (Initial Phase)	MODEL I	MODEL II	MODEL III	MODEL IV
Analysis of each cue condition separately				
0 cue	60.0%	62.3%	63.1%*	58.0%
2 cue	53.9%	57.1%	58.1%*	52.4%
Analysis of Type II analogies only	57.0%	60.0%	60.4%*	55.5%
Analysis of Session 1 only	55.1%	56.3%*	55.8%	50.0%
Analysis of session 2 only	41.3%	44.8%	45.5%*	42.3%
Analysis dual processing in 1 DD' value change only	56.8%	58.7%	60.7%*	55.3%
Experimental Group (Maintenance Phase)				
Analysis of each cue condition seperately				
0 cue	62.4%	64.1%	68.0%*	65.4%
2 cue	52.2%	57.8%	64.3%*	61.4%
Analysis of Type II analogies only	20.5%	40.8%	49.3%*	49.1%
Analysis of session 1 only	50.6%	52.1%	54.1%*	49.6%
Analysis of session 2 only	49.4%	53.6%	59.5%*	58.8%
Analysis dual processing in 1 DD' value change only	57.9%	61.1%	66.5%*	62.6%
Control Group 1				
Analysis of each cue condition seperately				
0 cue	47.5%	51.7%	52.2%*	48.0%
2 cue	36.0%	41.3%	44.2%*	41.9%
Analysis of Type II analogies only	6.0%	30.0%	39.4%*	39.1%
Analysis of session 1 only	32.7%	35.8%	37.4%*	34.3%
Analysis of session 2 only	27.1%	30.8%	31.4%*	29.6%
Analysis dual processing				
in 1 DD' value change only	44.1%	47.8%	48.6%*	47.7%
in 1&2 DD' value changes	47.2%	50.8%	52.1%*	49.8%

* Best Fitting Model

followed accounting for 51.7% of the variance. In the 2 cue condition, Model III was again the best fitting model, accounting for 44.2% of the variance. Little separated Models IV and II as providing the next best fit, the former accounting for 41.9% of the variance and the latter for 41.3% of the variance.

Thus, all 3 groups reveal results similar to those obtained for the below average and retarded groups in Experiments 1,2, and 4 and the nonretarded group in Experiment 2. The same model best fitting the data for the full analysis remains the best fitting model when the cue conditions are analysed separately suggesting that the initial practice sessions have produced this result.

Model Fits for the Type II, nondegenerage analogies only: Results for the initial phase of the Experimental Group, for Type II nondegenerate analogies were again consistent with the results obtained for the full analysis. Model III accounted for 60.4% of the variance, followed by and almost indistinguishable from Model II which accounted for 60.0% of the variance.

This was also true for the Experimental Group in the maintenance phase of the experiment, with Model III being the best fitting model and accounting for 49.3% of the variance. However, Model IV followed as the next best fitting model (in fact it was almost indistinguishable from Model III) accounting for 49.1% of the variance. This tends to confirm the trend towards more self-terminating processing over time. These model fits do not, however, account for as much of the variance as that accounted for in the initial phase of the experiment, suggesting that the Type II analogies are being less well predicted by the models in this latter phase of the experiment.

For Control Group 1, Model III remained the best fitting model accounting for 39.4% of the variance, and Model IV rather than Model II followed as the next best fitting model (and was almost indistinguishable from it), accounting for 39.1% of the variance. The results for this group, therefore, are more similar to those obtained for the maintenance phase of the Experimental Group. This supports the earlier suggestion that the training procedure initially produces more exhaustive processing as well as improves the amount of variance accounted for but that subjects move towards more self-terminating processing over time.

Model fits for each session separately: In Session 1, for the Experimental Group (initial phase), Model II became the best fitting model, accounting for 56.3% of the variance. Thus, there is a change from Model III for the full set of data to Model II for the data from the first session. The use of more exhaustive processing in Session 1 (i.e. Model II rather than Model III) is probably due to the training procedure used in the initial two training sessions. In Session 2 however, Model III became the model accounting for the greatest percentage of the variance, 45.5% although Model II followed closely, accounting for 44.8% of the variance. Thus, there is a move towards more self-terminating processing from the first to the second session, a result found for the other analyses and in Experiments 1,2 and 3 where four experimental sessions rather than only two were used.

In the maintenance phase for the Experimental Group, Model III provided the best fit to the data for both Sessions 1 and 2 accounting for 54.1% and 59.5% of the variance, respectively. A similar result was obtained for Control Group 1, where Model III remained the best fitting model in both sessions, accounting for 37.4% of the variance in Session 1 and 31.4% of the variance in Session 2.

These results are consistent with those obtained in Experiment 4, where it was found that the same model accounted for the data in both sessions and where subjects also participated in two sessions prior to their experimental sessions.

Model fits for dual processing in 1 DD' value change only: Again, this alternative model fitting procedure accounted for marginally more of the variance than the previous model fitting procedure for both groups and application was more reliably predicted. For the Experimental Group, initial phase, Model III accounted for 60.7% of the variance, followed by Model II which accounted for 58.7% of the variance. For the Experimental Group, maintenance phase, Model III accounted for 66.5% of the variance and Model IV for 62.6% of the variance. Thus, there was a similar change from Model II to Model IV being the next best fitting model in the initial and maintenance phases as for the original analysis.

For Control Group 1, Model III became the best fitting model, accounting for 48.6% of the variance. However, for this group, Type 1 analogies false by both 1 and 2 DD' value changes were responded to more slowly than just the 1 DD' value change Type 1 analogies (see Figure 6.6). If both these analogy types were included in the additional analysis, Model III remained the best fitting model, accounting for 52.1% of the variance. Thus, the ordering of the models does not change but more of the variance is accounted for, and it is slightly better than the amount of variance accounted for using the original model fitting procedure with no parameter dropouts for this group.

6.3.3 ERROR RATES

The mean error rate for both sessions for the Experimental Group in the initial

phase of the experiment was 8.29%, with a rate of 9.14% in the first session and 7.43% in the second session. Thus, there was a slight drop in errors from the first to the second session (See Table 6.15, errors are presented in a similar fashion to all previous experiments for retarded groups). These results were similar to those obtained in Experiment 2 by the retarded group and were lower than those obtained by the retarded group in Experiment 4. This suggests that the task where the modified method of precueing was used was a more difficult task for the retarded subjects. It also suggests that the training procedure has not improved the Experimental Group's error rate compared to the retarded group in Experiment 2. Improvement might have been expected given that they received training plus two rather than four cue conditions. As mentioned previously, this suggests that the tasks using two or four cue conditions are of comparable difficulty if the original method of stimulus presentation is used.

Mean error rates for the Experimental Group in the maintenance phase of the experiment are presented in Table 6.16. As can be seen, the mean error rate for this phase of the experiment was slightly lower than that for the initial phase. This is most likely due to the subjects being familiar with the task in the maintenance phase and indicates that a good understanding of the task has been maintained over the four month interval between the initial training and testing period and maintenance testing.

For Control Group 1, error rates were much greater in comparison to the Experimental Group and retarded groups in all previous experiments. A mean rate of 18.56% was obtained. Both errors made prior to any repetitions and those remaining after one repetition were affected as can be seen in Table 6.17. The most likely explanation for this result is that these subjects did not receive immediate positive feedback after each correct response, as did the

TABLE 6.15

MEAN ERROR RATES, EXPERIMENTAL GROUP (INITIAL PHASE)

ERRORS	SESSION 1	SESSION 2	ALL SESSIONS
1. % of errors produced at the end of each block	7.10%	6.20%	6.65%
2. % of errors remaining after one repetition	2.13%	1.23%	1.68%
3. Total % of errors	9.23%	7.43%	8.33%

TABLE 16.16

MEAN ERROR RATES, EXPERIMENTAL GROUP (MAINTENANCE PHASE)

1. % of errors produced at the end of each block	5.92%	5.87%	5.90%
2. % of errors remaining after one repetition	1.42%	1.14%	1.28%
3. Total % of errors	7.34%	7.01%	7.18%

TABLE 6.17

MEAN ERROR RATES, EXPERIMENTAL GROUP (MAINTENANCE PHASE)

1. % errors produced at the end of each block	14.30%	12.36%	13.33%
2. % errors remaining after one repetition	6.01%	4.45%	5.23%
3. Total % of errors	20.31%	16.81%	18.56%

retarded subjects in all previous experiments. It appears that the retarded subjects are very dependent on feedback for adequate performance on this task.

6.3.4 RAVENS PROGRESSIVE MATRICES

Administration of the coloured form of the Ravens Progressive Matrices was carried out after each subject in the Experimental Group had participated in their final session involving the People Piece Analogies. It was found that there was no significant difference between the Experimental Group's and Control Group 2's scores on the Ravens Progressive Matrices ($F(1,22) = .57$, $p = .46$) (See Appendix 5.12). The Experimental Group obtained an overall mean score of 26.5 (out of a possible total of 36) and Control Group 2, a mean score of 24.8. Thus, it must be concluded that the experimental subjects have not used the information available to them concerning solution of the People Piece Analogies, to solve the items in the Ravens Progressive Matrices test, even though they were informed that the training they had received might be useful in this situation.

6.4 CONCLUSION

A number of conclusions can be drawn from the results of this experiment. Firstly, training appears to have been partially successful in decreasing the solution times of the Experimental Group (both initial and maintenance phases) in comparison to Control Groups 1's solution times. Training also appears to have improved the consistency of the Experimental Group (again in both experimental phases) compared to Control Group 1, in that the standard deviations for solution times are lower for the former group. Training has not, however, reduced solution times and standard deviations to the level obtained

using nonretarded subjects in Experiments 1, 2, 3 and 4. This finding is contrary to the results of many previous experiments (Brown, Campione , Bray and Wilcox, 1973; Butterfield, Wambold & Belmont, 1973). In addition, Phillips & Nettelbeck (1984) found that with extremely high levels of practice, the performance of retarded subjects on S. Sternberg's memory scaning task may be equated with that of nonretarded subjects of similar chronological age.

The fact that training has not reduced the retarded subjects performance level to that of the nonretarded subjects in terms of speed and consistency may be due to a number of factors. Firstly, the training procedure may still require refinements that will improve the results it produces and secondly, more practice sessions might also produce improved performance. Thirdly, it is likely that the complexity of the analogy task is greater than that of the memory tasks used by Brown et al (1973) and Butterfield et al, (1973) and the memory scanning task used by Phillips and Nettelbeck (1984). As mentioned in Chapter 2, Bray (1979) conducted a series of experiments with retarded subjects using a complex directed-forgetting task. He found that retarded subjects could be trained to perform adequately on the task but that they used a simpler strategy than that used by the nonretarded subjects and as a consequence, their performance level was not quite the same as these latter subjects. More research taking all these three factors into consideration needs to be undertaken.

Error rates were not greatly different from those obtained by a similarly retarded group in Experiment 2, although they were better than the rates obtained for Control Group 1. This suggests two things, firstly that training has not improved performance in terms of accuracy and secondly, that immediate positive feedback is very important to the level of accuracy obtained using retarded subjects.

Model III was again confirmed as the best fitting model for both groups of subjects. The Experimental Group was more exhaustive in its processing initially, as a result of the training procedure they participated in but became more self-terminating over time. This was also true for the cue conditions and nondegenerate, Type II analogies, when analysed separately. The use of more exhaustive processes initially is consistent with the training procedure used which encouraged the subjects to verbalise all the changes and nonchanges in the attributes in Training Session 1 and for the first block of trials in Training Session 2. The fact that they became more self-terminating in the maintenance phase suggests that the use of more self-terminating processes is the preferred method of analogical reasoning for retarded (and nonretarded) subjects because it produces the least load on memory but that this preference can be modified by experimental variables. However, the use of self-terminating processes by younger (Sternberg and Rifkin, 1979) and less able (Experiment 1, below average group) subjects is usually less efficient than their use by nonretarded adults, coupled as it is, with higher solution times and error rates. The experimental subjects in this experiment have adopted a more self-terminating style of processing, four months after the initial training period but significantly, the amount of variance accounted for has remained at the higher level obtained when they were using more exhaustive processes (in fact, it has slightly improved). As this is coupled with slightly lower solution times and error rates, it suggests that the training procedure and further practice on the task during the experimental sessions, has produced the more efficient use of self-terminating strategies.

In addition, the Experimental Group was found to be spending more time on encoding in both phases of the experiment (although less so in the maintenance than the initial phase) compared with Control Group 1. This suggests that the

training procedure, like the modified method of precueing used in Experiment 4, has encouraged more thorough encoding of the presented figures, although not to the same extent. As in Experiment 4, this has resulted in a saving in application time and a greatly reduced regression constant in comparison to the control group. However, there is no saving in the inference and mapping processes. The large differences in estimates of encoding time for the Experimental and Control groups may also be in part, attributable to the fact that Control Group 1 was not using the precued figures to the same extent as the Experimental Group.

The original and alternative model fitting procedures both accounted for similar amounts of the variance for both the Experimental and Control Groups. As mentioned previously, this is most probably due to there being only two rather than four cue conditions (as was the case in Experiments 1 and 2, where the alternative procedure provided a better fit to all the groups' data). As there was little evidence that this method (including only two cue conditions rather than four) induced greater use of the precued figures for the retarded subjects and accounted for little more of the variance, it seems that further investigations using this task would achieve more reliable results with the modified method of precueing, which forces the use of the precued figures.

Finally, the training procedure appears to have been successful in improving the performance of the experimental subjects and in maintaining this level of performance over a four month period. Practice and minimal instructions, however, were insufficient to produce the same high level of variance accounted for or even to improve the variance accounted for over that of one practice session, similar instructions, and immediate feedback (Experiment 2, retarded group). Feedback, therefore, would appear to be one of the crucial factors here.

The training procedure, however, was not successful in improving the performance of the Experimental Group on a different analogical reasoning task, namely the coloured form of the Ravens Progressive Matrices. This result is probably not surprising if one accepts, as Campione et al (1982) do, that transfer of performance will only be obtained if training in self-regulatory skills is provided or as Belmont et al (1978) suggest training on two task-specific strategies is provided. This experiment made little attempt to provide training in such skills. Another factor which might also have contributed to the lack of transfer is the use of a "far" generalisation task. If a task more similar to the People Piece Analogies had been used, evidence of generalisation may have been obtained.

In addition, the training procedure was no more successful in terms of percentage of variance accounted for than the explicit instructions, two practice sessions and modified method of precueing used in Experiment 4 for the retarded subjects. As suggested previously, this may be due to there being a level beyond which it is difficult to account for more of the variance using retarded subjects. Even with training, practice and/or explicit instructions, the retarded subjects produce high standard deviations which affect the ability of the mathematical modelling procedure to account for their data.

A further experiment could proceed in two directions, one direction would be to use both the modified method of precueing and the training procedure. It is possible that these two factors, used in combination, will produce an increase in the amount of variance accounted for by the retarded subjects. Alternatively, a number of sessions of just practice might

be used. If differences were still found it would suggest firstly that the task required the use of strategies too complex for the retarded to use adequately and/or secondly that the retarded subjects' high level of random variability limits the usefulness of using a mathematical modelling procedure to investigate their performance. Of the two options mentioned above it was decided to take the former course in the following experiment. This was mainly due to the fact that subjects were from a work and production type setting, where it was not always possible to obtain subjects for long periods of time or on a number of separate occasions. Subjects were also of mainly borderline and mildly retarded ability. Phillips and Nettelbeck (1984) obtained their subjects from an Activity Therapy Centre where less emphasis is placed on work and production and subjects were of mild and moderate intelligence. In their situation, it was possible to obtain subjects for a number of occasions. Phillips and Nettelbeck also saw their subjects on seven consecutive days, another feature that would prove difficult in the setting used by this author. The next experiment, therefore, examined the effect of two sessions of training and the modified method of precueing on the performance of retarded subjects.

CHAPTER 7

THE EFFECTS OF STRATEGY TRAINING AND THE MODIFIED METHOD OF PRECUEING ON THE PERFORMANCE LEVEL OF MENTALLY RETARDED SUBJECTS

7.1 INTRODUCTION TO EXPERIMENT 6

The results of Experiments 4 and 5 suggest firstly, that the use of two rather than four cue conditions is more likely to provide reliable data from retarded subjects. This is probably due to the reduction in the complexity of the task and the reduced load on memory. In addition, if the modified method of precueing is used, greater use of the precued figures can be obtained. Using the original precueing method in Experiment 5, it was found that performance could be improved (in that a larger percentage of the variance was accounted for, solution times were faster and fewer errors were made) but use of this method did not encourage use of the precued figures even with a simplified task.

In addition, both Experiments 4 and 5 found that Model III provided the best fit to the data when all analogies were used and for the nondegenerate analogies when analysed separately for retarded subjects. (In this latter case, Models III and IV were virtually indistinguishable in Experiment 4). This result has been consistent throughout this series of experiments except for Experiment 1, where Model IV was slightly favoured over Model III for the below average group. Parameter estimates for encoding were increased in Experiment 4 compared to all other experiments for retarded subjects and in Experiment 5 for the Experimental Group compared to the control group. It was thought that this was due to the use of the modified method of precueing in the case of the former experiment and to the training procedure in the latter experiment. This resulted in some saving in the application process in both experiments but the inference and mapping processes remained unaffected.

In addition, in both experiments, a similar amount of the variance was accounted for. Thus, while both experiments were successful in producing data from retarded subjects that accounted for a greater percentage of the variance, neither experiment was more successful than the other. There is still a large difference between the amount of variance accounted for by the nonretarded subjects in previous experiments and the retarded subjects in these two experiments. This may be due to the retarded subjects using different processes from those tested by the models, and/or their greater inconsistancy in processing. Before it can be accepted that one or both of these factors is operating, the conditions required to account for a higher level of variance using retarded subjects' data need to be investigated.

The results of Experiments 4 and 5 suggest that the ideal conditions for retarded subjects to perform well and consistently on this task are explicit instructions and training, at least two sessions of practice, use of the simplified task (i.e. two rather than four cue conditions) and the modified method of precueing. It was therefore decided to include all these factors in the one experiment, to examine whether combining these would account for a greater percentage of the variance than when used separately. This experiment would therefore be similar to Experiment 4, in that two initial nonexperimental sessions would precede the two experimental sessions and the modified method of precueing would be used, together with the simplified task.

It would also resemble Experiment 5, in that the two initial sessions would include training and practice, and in that a maintenance phase would be included to examine whether improved performance was maintained over time. Thus, this experiment would consist of two initial training sessions; the simplified task with only the 0 and 2 cue conditions being used; the modified

precueing method so that the two precued figures in the 2 cue condition were removed after the end of the first half of the trial and two further sessions conducted after a time lapse of some months.

It might be assumed, therefore, that the task will be more difficult than that presented in Experiment 5, because of the disappearance of the precued figures in the second half of the trial, in the 2 cue condition. It is probable that it will prove of a similar level of difficulty as the task in Experiment 4. However, the training procedure may improve performance on the task in comparison to the two initial sessions of practice and explicit instructions received by the retarded subjects in Experiment 4. If this is the case, one might expect a reduction in the solution times for the analogies and a reduction in all attribute-comparison parameter estimates in the model fitting procedure. Training may also initially produce more exhaustive processing as it did in Experiment 5 for the Experimental Group in the initial phase of the experiment.

It will also be of interest to examine whether a greater amount of the variance is accounted for in the maintenance phase of the experiment as was found for the Experimental Group in Experiment 5. As mentioned in the previous chapter it would generally be expected that performance would either remain stable or decline over time. It would not be expected to show an improvement. Although, the improvement in the amount of variance accounted for was very slight in Experiment 5, the experimental subjects' overall performance suggested that they found the task much simpler in the maintenance phase. It is possible, as Chi (1981) has suggested, that development of a knowledge base concerning this task, has taken place during training and the experimental sessions that followed. In which case, the retarded subjects approach the task with a knowledge base already intact rather than, as in their initial sessions, with the need to develop such a base.

Ravens Progressive Matrices scores were not obtained for the subjects in this experiment as there were insufficient numbers of subjects with IQ levels that could be matched with the subjects in Experiment 5. Indeed, because of the limitation of the available subjects, a group made up of predominantly mildly retarded individuals was used rather than predominantly borderline individuals as in previous experiments. This may, in itself lower the percentage of variance accounted for in this experiment compared with the amount of variance accounted for by the retarded groups in previous experiments.

Therefore, the aim of Experiment 6 was to examine whether a comparatively greater percentage of the variance could be accounted for in comparison to previous experiments using retarded subjects if the modified method of precueing and simplified task used in Experiment 4 were used in conjunction with the training procedure developed in Experiment 5.

7.2 METHOD

7.2.1 SUBJECTS

Twelve subjects participated in this experiment. They were all employees of Bedford Industries Rehabilitation Centre. Their mean age was 22.8 years and ranged from 17 to 32 years. Actual IQ scores were not available for all subjects, however, classification of the subjects using the system developed by the AAMD indicated that three subjects were within the borderline range of intellectual ability (70-85) and nine subjects were within the mildly retarded range (55-70). All subjects had no known organic cause of intellectual impairment and had no associated physical disability. They were also not taking medically prescribed drugs. All subjects remained naive to the aims of the experiment.

7.2.2 APPARATUS

The apparatus was identical to that used in all previous experiments.

7.2.3 DESIGN

The design of Experiment 6 was identical to that of Experiment 5. Only two cue conditions were used, the 0 and 2 cue conditions. These two conditions combined with the 15 AB, AC attribute change combinations and the 5 DD' value changes to produce 150 different kinds of analogies.

7.2.4 PROCEDURE

Subjects participated in a total of six sessions. The first two sessions consisted of the presentation of the training procedure and practice with the task. The following two sessions were experimental sessions presented in the following week to the subjects. The final two sessions were also experimental sessions but presented three months after the initial training period. (It was not possible to conduct this phase of the Experiment four months after the initial training sessions due to the closure of Bedford Industries for almost a month over the Christmas period).

During the initial practice session, each subject was introduced to the task using the set of 16 cards on which were drawn each of the figures which make up the People Piece Analogies. Subjects were instructed to sort the cards by each attribute (height, weight, sex and colour), separately. The nature of the task was then explained using the second set of 16 cards in conjunction with the 48 practice computer trials, showing true and false examples of each analogy type (degenerate, semidegenerate and nondegenerate). The 0 and 2 cue conditions were also explained using the cards while the computer practice

trials were all presented in the 2 cue condition only, as in Experiments 4 and 5.

Firstly, the nature of the degenerate analogies was explained using the cards. Then the practice computer trials corresponding to this type of analogy were presented. The experimenter solved the first computer trial and then asked the subjects to solve the remaining trials. The cards were then used to explain both forms of semidegenerate analogies, those with the form A:A::B:B being explained first. The computer trials corresponding to this form of semidegerate analogy were then presented. On completion of these trials, the semidegenerate analogies in the form A:B::A:B were explained using the cards followed by the computer trials. In addition, the subjects were told that they would have to take particular notice of the B term for this form, as this figure would also appear at the end of the analogy if it were true but would disappear when they terminated the first half of the trial.

The experimenter solved the first two practice analogies of this type. The nature of the nondegenerate analogies was then explained to the subjects using the cards. The subjects were told that unlike the previous sets of figures they had seen, all four figures in this type would be different from each other. Thus, they would have to look for the relationship between the first two figures with regard to the four attributes they had previously sorted the cards with, then see if the last two figures had the same relationship between them. The subjects were told that if the relationships between the first two figures and the second two figures were identical then the analogy was true, but if the relationships were different, then the analogy was false. The computer trials concerned with the nondegenerate analogies were then presented via the computer, the experimenter solving the first two trials. During solution, the experimenter elaborated the attribute changes and nonchanges between the

first and second two figures and decided if the analogy was true or false. This was the basis of the training procedure, to be used in the next block of trials. Subjects were instructed to state verbally whether they thought the analogy was true or false during all practice computer trials, before pressing the appropriate response key. In this way, errors could be immediately corrected and correct solutions praised.

All subjects were then presented with the first block of 88 trials in the 2 cue condition, from the practice set of 176 analogies. It was here that the training procedure was introduced for the nondegenerate analogies only. The procedure, as for the experimental group in Experiment 5, did not include the Type I analogies.

Subjects were instructed to elaborate the attribute changes and nonchanges between the first and second two figures. For example, to say "tall/short", "fat/skinny", but "male/male" and "coloured in/coloured in", for an analogy where height and weight changed in the first two figures but sex and colour did not. The subjects were told they would have to remember these changes and nonchanges as these two figures would disappear after the end of the first half of the trial, when they pressed the central key. They were then instructed to compare the attribute changes and nonchanges in the C and D analogy terms (the last two figures) with those they had elaborated during the first half of the trial for the first two figures (the A and B analogy terms). If the same pattern of changes and nonchanges was observed, the subjects were told that this was a true analogy while if the pattern was different, the analogy was false. The subjects were told to take as long as they required on both parts of the trial, the most important aspect of the task being to correctly solve the analogies.

The second block of analogies was then presented using the 0 cue condition, again starting with the degenerate analogies and finishing with the nondegenerate analogies. Subjects were told that this time, only a "dot" would be presented in the first half of the trial and that as soon as they saw the dot they should press the central key and all four figures in the analogy would appear. Subjects were again instructed to verbalise the attribute changes and nonchanges between the first two figures for the nondegenerate analogies and to compare this pattern with that in the second two figures, as they had done before.

Subjects were instructed to respond verbally true or false before pressing the appropriate response key so that errors could be immediately corrected and explained. Any errors remaining at the end of each block were not replayed. Positive feedback was provided immediately following the correct solution of an analogy.

During the second training session, the subjects were asked to state the strategy they had been trained to use in the previous session. If the subject was unsure, the experimeter explained that the subject should identify the attribute changes and nonchanges between the first two figures and then compare these to the pattern of changes and nonchanges in the second two figures. The subjects were again instructed to elaborate these attribute changes and nonchanges for the nondegenerate analogies. If the subject only verbalised one attribute change when more than one was present, this was pointed out and she/he was reminded that sometimes two or three attributes might change between the first two figures and that the second two figures must have all these changes but no others.

The subjects began with the 0 cue condition and the degenerate analogies in the first block of 88 trials from the practice set. Again, errors were not

replayed at the end of this block, subjects responding verbally before making the appropriate response. In this way, errors could be immediately corrected. Positive feedback was provided immediately after the correct solution of an analogy.

During the second block in this session, subjects received the remaining 88 trials in the 2 cue condition. Subjects were told to no longer say the attribute changes and nonchanges out loud but to continue this practice silently to themselves, as it would help them solve the nondegenerate analogies. Positive feedback, after each response continued to be given. Since subjects no longer verbalised their response prior to pressing the response key of their choice, errors were replayed at the end of the block and explained.

The subjects then commenced the initial experimental phase of the experiment. This generally occurred one or two days after they had completed their second training session. The alternative set of 176 analogies was used as in Experiments 4 and 5 and no mention was made of the training procedure previously instructed. In the first experimental session, the cue conditions were presented balanced for order, six subjects receiving the 0 cue condition in the first block followed by the 2 cue condition in the second block. The remaining six subjects started with the 2 cue condition followed by the 0 cue condition. The order of presentation was reversed in the following session. Form order was not balanced, all subjects receiving the degenerate analogies at the start of each block and finishing with the nondegenerate analogies. Subjects were instructed to respond as quickly and as accurately as possible. They were told to go as fast as they could without making too many errors but that it was more important to get the analogies right. Immediate positive feedback was provided after each correctly solved analogy and errors were replayed until correctly solved, at the end of each block.

During the maintenance phase of the experiment, conducted three months later, the same subjects participated in two further experimental sessions. In the first of these sessions, the subjects were reminded of the analogy task and the training procedure they had previously received. All subjects remembered the task and training well. They were reminded of the different analogy types (degenerate, semidegenerate and nondegenerate) using the cards and then received the 48 practice computer trials all in the 2 cue condition, in which examples of each analogy type were included. The first block of the experimental set of 176 analogies was then presented. Those subjects who had previously started the first experimental session (in the initial phase of the experiment) with the 0 cue condition, began this session with the 2 cue condition and vice versa for those originally beginning with the 2 cue condition. Cue order was reversed in the second session. Subjects were again instructed to go as fast as possible without making too many errors but that it was more important to correctly solve the analogies. Errors were replayed at the end of each block until correctly solved. Immediate positive feedback was given after each correct response was made.

7.3 RESULTS AND DISCUSSION

As in previous chapters, this section is divided into three subsections: Interval scores, Component scores, and Error rates.

7.3.1 INTERVAL SCORES

Interval scores for the subjects in this experiment are presented in Tables 7.1-7.3. Table 7.1 presents the interval scores for the subjects over all sessions, in both the initial and maintenance phases of the experiment. Table 7.2 presents the interval scores for Type I and Type II analogies, respectively,

TABLE 7.1

INTERVAL SCORES FOR RETARDED SUBJECTS, INITIAL AND MAINTENCE PHASES

Overall Means (For Both Analogy Types)

	Cue Condition	
Initial Phase	0	2
Cue Time	1157	2997
SD	1011	2501
No of Observations	2112	2112
Underflow Trials	23	7
Solution Times	4042	2465
SD	3188	1962
No of Observations	2112	2112
Overflow Trials	2	0
Maintenance Phase		
Cue Time	1108	2840
SD	834	2193
No of Observations	2112	2112
Underflow Trials	7	4
Solution Time	3855	2162
SD	2743	1511
No of Observations	2112	2112
Overflow Trials	0	0

TABLE 7.2

INTERVAL SCORES FOR TYPE I AND TYPE II ANALOGIES
INITIAL PHASE - RETARDED SUBJECTS

	Cue Condition	
	0	2
Type I Analogies		
All Sessions		
Cue Time	1174	2083
SD	987	1860
No of Observations	960	960
Underflow Trials	8	7
Solution Time	2619	2089
SD	1993	1644
No of Observations	960	960
Overflow Trials	0	0
Session 1		
Cue Time	1295	2256
SD	1167	2101
No of Observations	480	480
Underflow Trials	1	3
Solution Time	2704	2127
SD	2009	1752
No of Observations	480	480
Overflow Trials	0	0
Session 2		
Cue Time	1052	1911
SD	745	1564
No of Observations	480	480
Underflow Trials	7	4
Solution Time	2535	2051
SD	1973	1528
No of Observations	480	480
Overflow Trials	0	0
Type II Analogies		
All Sessions		
Cue Time	1139	3911
SD	1034	3009
No of Observations	1152	1152
Underflow Trials	15	0
Solution Time	5465	2841
SD	4044	2236
No of Observations	1152	1152
Overflow Trials	2	0
Session 1		
Cue Time	1301	4241
SD	1197	3332
No of Observations	576	576
Underflow Trials	1	0
Solution Time	5729	2858
SD	4416	2321
No of Observations	576	576
Overflow Trials	2	0
Session 2		
Cue Time	978	3581
SD	808	2607
No of Observations	576	576
Underflow Trials	14	0
Solution Time	5202	2825
SD	3615	2147
No of Observations	576	576
Overflow Trials	0	0

TABLE 7.3

INTERVAL SCORES FOR TYPE I AND TYPE II ANALOGIES

RETARDED SUBJECTS - MAINTENANCE PHASE

Type I Analogies	Cue Condition	
All Sessions	0	2
Cue Time	1110	2180
SD	824	1938
No of Observations	960	960
Underflow Trials	4	4
Solution Time	2665	1780
SD	1983	1148
No of Observations	960	960
Overflow Trials	0	0
Session 1		
Cue Time	1235	2298
SD	832	1907
No of Observations	480	480
Underflow Trials	2	2
Solution Time	2805	1870
SD	1998	1189
No of Observations	480	480
Overflow Trials	0	0
Session 2		
Cue Time	986	2062
SD	796	1962
No of Observations	480	480
Underflow Trials	2	2
Solution Time	2524	1689
SD	1958	1098
No of Observations	480	480
Overflow Trials	0	0
Type II Analogies		
All Sessions		
Cue Time	1105	3499
SD	843	2421
No of Observations	1152	1152
Underflow Trials	3	0
Solution Time	5045	2543
SD	3334	1802
No of Observations	1152	1152
Overflow Trials	0	0
Session 1		
Cue Time	1248	3674
SD	886	2572
No of Observations	576	576
Underflow Trials	2	0
Solution Time	5177	2647
SD	3260	1815
No of Observations	576	576
Overflow Trials	0	0
Session 2		
Cue Time	962	3325
SD	771	2245
No of Observations	576	576
Underflow Trials	1	0
Solution Time	4914	2448
SD	3402	1784
No of Observations	576	576
Overflow Trials	0	0

for both sessions and for Sessions 1 and 2 separately, in the initial phase of the experiment. Table 7.3 presents the interval scores for the two types of analogies for both sessions and for Sessions 1 and 2 separately, in the maintenance phase of the experiment.

Results obtained from both phases of the experiment are very similar and consistent with those obtained for the retarded group in Experiment 4 in terms of use of the precued figures. Cue times show a marked increase from the 0 to 2 cue condition while solution times show a marked decrease. The solution times for the maintenance phase of this experiment are, in addition, slightly faster than those obtained for the initial phase and for the comparable group in Experiment 4. This is probably due to these subjects having participated in four previous experimental and training sessions. It also suggests that they have maintained a good understanding of the task over time, a similar result to that found in Experiment 5 for the Experimental Group.

The longer solution and cue times obtained by the retarded groups in Experiment 4 and in this experiment, in comparison to the Experimental Group in Experiment 5, suggest that the modified method of precueing received by these groups makes the analogy task more difficult. However, the fact that the former groups also produce relatively shorter solution times and longer cue times in the 2 cue condition than the latter group indicates that much better use is being made of the precued figures in this cue condition.

A three way analysis of variance (Group x Type x Cue) using the solution times, revealed significant main effects for Cue ($F(1,88) = 68.45$, $p < .01$) and Type ($F(1,88) = 72.95$, $p < .01$) (See Appendix 6.1). A significant interaction between Cue and Type was also obtained ($F(1,88) = 22.01$, $p < .01$). The

significant main effect for Cue confirms the results reflected in Tables 7.1-7.3 that the modified method of precueing is successful in producing use of the precued figures and suggests that solution times for cue conditions are additive. The significant main effect for Type again confirms the results obtained in Experiments 4 and 5 and reflected in Tables 7.2 and 7.3, that the Type I analogies are solved much more quickly than the Type II analogies. This result tends to support use of dual processing in the model fitting analysis. The significant Cue by Type interaction indicates (and this can be observed in Tables 7.2 and 7.3 for both experimental phases) that the difference between the solution times for the Type II analogies in the 0 and 2 cue conditions is greater than the difference between the Type I analogies in these conditions. This tends to suggest that the Type I analogies are less affected by the method of precueing than the Type II analogies, a result also obtained in Experiments 4 and 5. Again, this finding tends to support use of dual processing, the Type I analogies being less affected by the number of attribute changes between the AB, AC and DD' analogy terms and the cue conditions.

Finally, there was no significant difference between the solution times obtained by the subjects in the initial and maintenance phases of the experiment. Thus, while the solution times obtained in the maintenance phase of the experiment are slightly faster than those obtained in the initial phase, expecially in the 2 cue condition, the difference is not large enough to produce a statistically significant result.

A four way analysis of variance (Goup x Session x Type x Cue with repeated measures for Session) was also conducted to examine whether performance improved from the first to the second session, and if so was this for a particular group, analogy type or cue condition (See Appendix 6.2). A

significant main effect for Session was obtained ($F = (1,22) = 14.44$, $p<.01$) and also for Type ($F = (1,22) = 132.99$, $p<.01$) and Cue ($F = (1,22) = 191.74$, $p < .01$) these latter two mirroring the previous analysis using all the data. The session effect revealed that the retarded group significantly improved their performance even across two sessions and inspite of the fact that they had already received two practice and training sessions. There was no significant interactions between Session and the other three variables, suggesting the practice effect was equivalent for both analogy types, both groups and the practice effect was equivalent for both analogy types, both groups and across cue conditions.

7.3.2 COMPONENT SCORES

The component scores were derived in an identical manner to that used in all previous experiments. In addition, as in Experiments 4 and 5, model fitting was based on 150 rather than 300 data points due to there being only two rather than four cue conditions (15 AB/AC change combinations x 5 DD' value changes x two cue conditions). All four models were tested, each incorporating dual processing, using linear multiple regression. The same mathematical equations for the models as presented in Chapter 5 for Experiment 4 (Table 5.12) were used here.

Figures 7.1 (a)-(b) and 7.3 (a)-(b) present the solution times obtained for the 15 AB/AC attribute change combinations for the true analogies in the 0 and 2 cue conditions, for the initial and maintenance phases of the experiment, respectively. Figures 7.2 and 7.4 present the solution times for true and false analogies for both Type I and Type II analogies collapsed across cue conditions. All four points indicating use of self-terminating processes when solving Type II analogies (i.e. Models II to IV) receive general support. Slopes

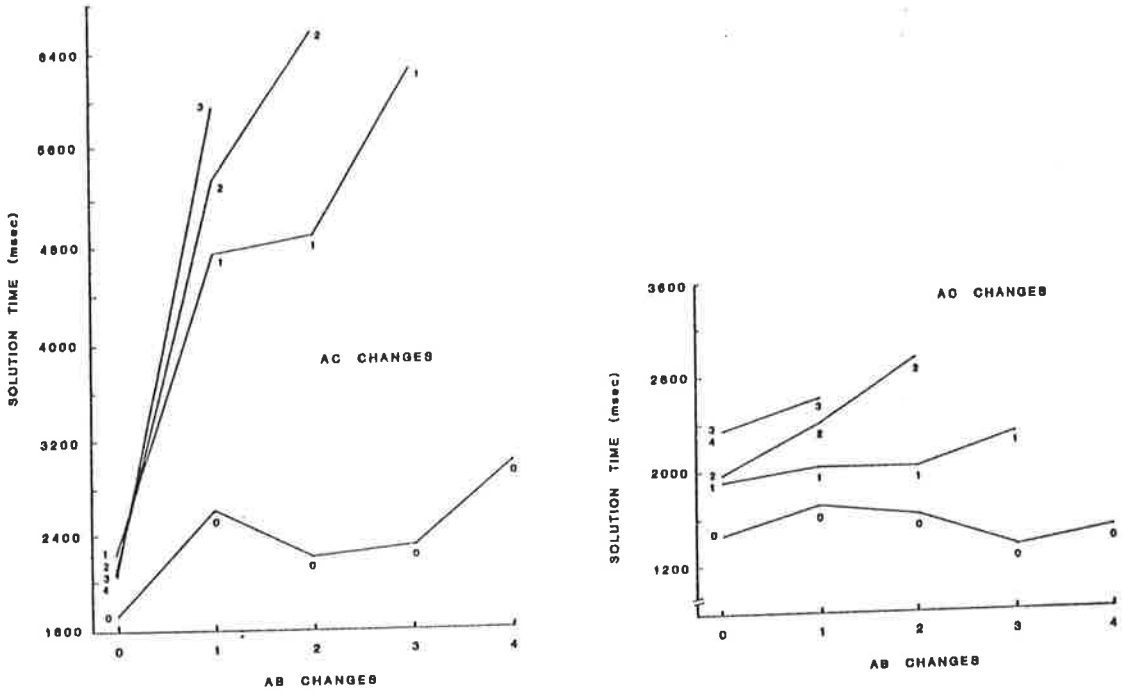


Figure 7.1 Mean solution times for 15 AB/AC attribute change combinations for true Type I and II analogies in each condition, retarded subjects, initial phase
(a) 0 cue condition
(b) 2 cue condition.

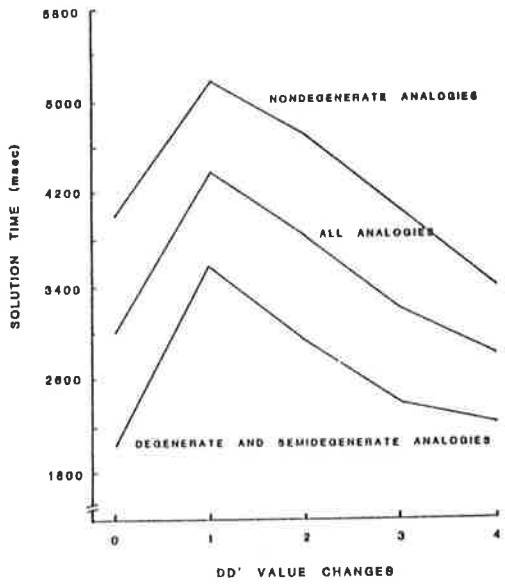


Figure 7.2 Mean solution times for true and false Type I and II analogies, retarded subjects, initial phase.

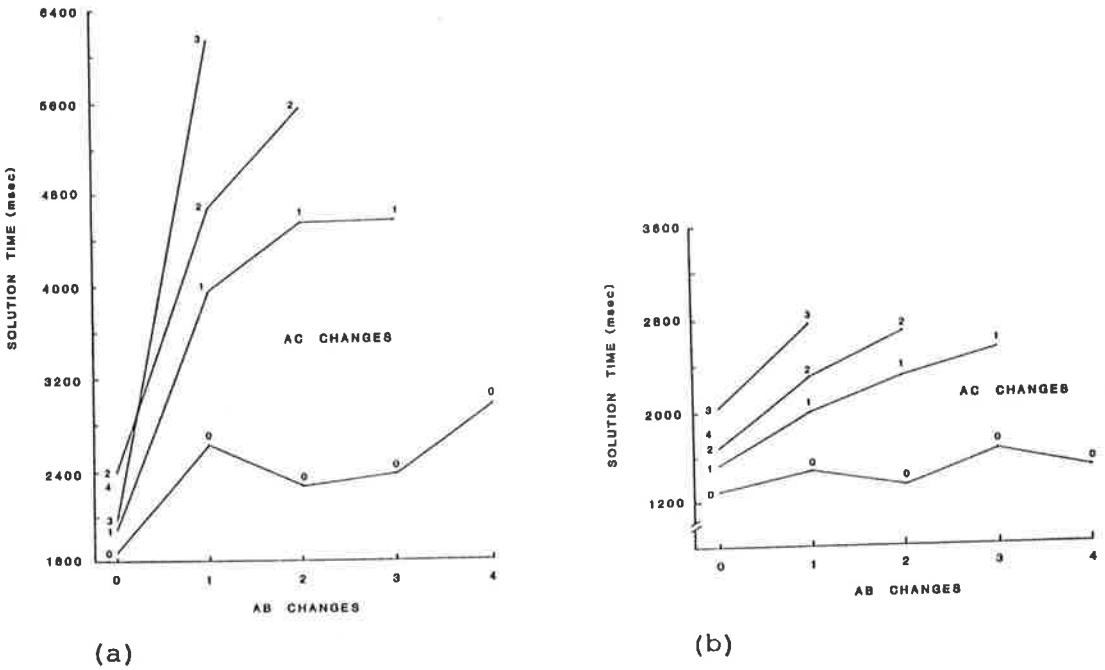


Figure 7.3 Mean solution times for 15 AB/AC attribute change combinations for true Type I and II analogies in each cue condition, retarded subjects, maintenance phase
(a) 0 cue condition
(b) 2 cue condition.

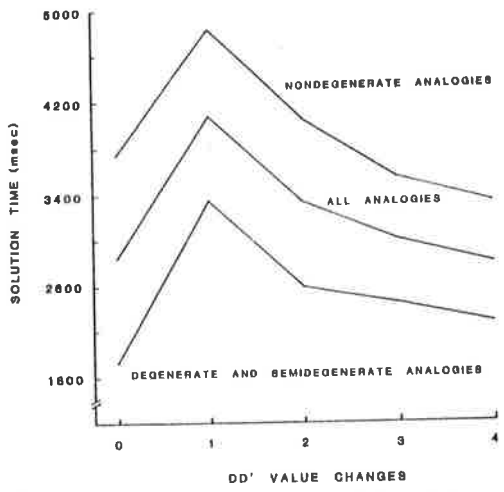


Figure 7.4 Mean solution times for true and false Type I and II analogies, retarded subjects, maintenance phase.

decline across attribute change combinations from the 0 to 2 cue condition and curves are displaced downwards dramatically from the 0 to 2 cue condition. (Figures 7.1 (a)-(b) and 7.3(a)-(b)). Solution times decline with increasing degree of falsity for false analogies (Figures 7.2 and 7.4). However, as in Experiment 4, true Type II analogies are not solved more slowly than all false analogies. Both false analogies with 1 and 2 DD' value changes are solved more slowly than true analogies. As suggested in Experiment 4, this tends to support the use of a checking procedure for these false analogy types.

With regard to the Type I analogies, results are again similar to those found in all experiments, using retarded subjects. These subjects show more variability in their responding to these analogies than the nonretarded subjects but there is still less variability than that found for the Type II analogies. In addition, false Type I analogies false by 1 DD' value change are solved more slowly than all other true and false Type I analogies. However, the general results support use of dual processing in the model fitting procedures.

Tables 7.4 and 7.5 present the results of the model fitting procedure for the subjects in both experimental phases. As in Experiment 5, for the experimental group in their initial phase using the same model fitting procedure, Model II provided the best fit to the data, for the subjects in this experiment in the initial experimental phase. This model accounted for 62.7% of the variance. This result tends to confirm that the training procedure induces more exhaustive processing in the retarded subjects. In fact, the finding tends to be even stronger in this experiment in that Model I follows as the next best fitting model, accounting for 61.8% of the variance. Model III followed, accounting for 61.3% of the variance (as in Experiment 5,

TABLE 7.4

MODEL FITS AND PARAMETER ESTIMATES, MODELS I TO IV

RETARDED SUBJECTS, INITIAL PHASE

Parameter Dropouts Dual Processing

	% variance	Freg	df	a	Parameter Estimates x' x	y' y	z' z	c
MODEL I	61.8%	59	4,145	397	763	420	229	1285
*MODEL II	62.7%	61	4,145	381	811	479	384	1223
MODEL III	61.3%	57	4,145	341	930	675	141	1588
MODEL IV	56.9%	48	4,145	400	1448	630	-78	1668

TABLE 7.5

MODEL FITS AND PARAMETER ESTIMATES, MODELS I TO IV

RETARDED SUBJECTS, MAINTENANCE PHASE

Parameter Dropouts Dual Processing

	% variance	Freg	df	a	Parameter Estimates x' x	y' y	z' z	c
MODEL I	66.1%	71	4,145	629	567	388	211	458
*MODEL II	67.4%	75	4,145	617	602	446	394	359
MODEL III	66.2%	71	4,145	581	711	637	167	695
MODEL IV	61.6%	58	4,145	652	958	645	40	656

* Best Fitting Model

it is virtually indistinguishable from Model I). Finally, Model IV accounted for 56.9% of the variance. These results again suggest that the training procedure produces more exhaustive processing and this is not surprising given the type of training provided (i.e. subjects were asked to state all the attribute changes and nonchanges between the figures).

It also reinforces the point made in Experiment 5, that the componential method appears to be sensitive to changes introduced in the experimental procedure. This tends to provide some reliability to Sternberg's componential method, in terms of each of the models measuring the types of processes (i.e. exhaustive or self-terminating) they purport to measure.

One finding from the initial phase of the experiment which is consistent with both Experiments 4 and 5 is that the estimate for encoding is greatly increased compared to the comparable group in Experiment 2. This appears to have resulted in a saving in both the mapping and application processes and not just in the application process as found in earlier experiments.

In the maintenance phase of the experiment (Table 7.5), Model II remained the best fitting model, accounting for 67.4% of the variance. This adds further weight to the suggestion that training produces more exhaustive processing. Models III and I were virtually indistinguishable as the next best fitting models, Model III accounting for 66.2% of the variance and Model I for 66.1% of the variance. Model IV accounted for 61.6% of the variance. These results are very similar to those obtained in the previous experimental phase and Experiment 5 in the initial experimental phase for the Experimental Group. The fact that Model II rather than Model III has continued to be the best fitting model may in part be due to these subjects being remeasured

three rather than four months later (as opposed to Experiment 5 where Model III became the best fitting model in the maintenance phase). It may also be due to these subjects being a predominantly mildly retarded group (as opposed to the predominantly borderline subjects use in previous experiments). They may, therefore, have been more dependent on the trained strategy and showed less change to the more efficient self-terminating strategy over time.

Another explanation is that the training procedure and modified method of precueing used in combination, have contributed this result. As mentioned previously, the training procedure produces more exhaustive processing. In addition, it is likely that the modified method of precueing has a similar effect, because the subjects must hold in memory the results of encoding and inferring the relationship between the first two figures in the 2 cue condition, when these two figures disappear after the end of the first half of the trial. This together with the emphasis on accurate performance, may make subjects more cautious and thorough in their processing of the nonprecued figures. Evidence for this comes form the results of Experiment 4, where Model II rather than Model IV was found to follow Model III as the next best fitting model, for retarded subjects (Experiment 4 used the modified method of precueing). Of further interest, is the finding that in the maintenance phase, the greatest amount of variance has been accounted for by any retarded group in these experiments. This together with the slight reduction in solution times for this phase of the experiment, suggests that performance over time has slightly improved, although it has not resulted in the greater use of self-terminating processes. This is most likely due to the fact that the subjects have now participated in four previous sessions and thus are highly familar with the task and its requirements. However, the slightly lower ability level of this group may have continued to make them more cautious in their responding, even in the maintenance phase.

Related to these findings, are the results for the parameter estimates. The encoding parameter estimate is greatly increased in this phase of the experiment in contrast to Experiment 5, where the precues remained present in the second half of the trial and the encoding parameter declined in time from the initial to the maintenance phase. In addition, and even more significantly, this appears to have been transferred to a saving in all other parameter estimates. As in the initial phase of the experiment, parameter estimates for both mapping and application are reduced. In addition, the estimates for inference and preparation-response are also reduced in comparison to the initial phase of the experiment and in comparison to Experiment 4.

The estimate for the preparation-response processes especially, is greatly reduced in comparison to the results obtained for all retarded groups used previously. This suggests that the retarded subjects have been able to carry out the preparation-response processes more quickly than previously. It is however, surprising that this result was not obtained in the initial phase of the experiment, immediately after training. It suggests that the long-term effects of the training procedure, using the modified method of precueing are of more significant value than the short-term effects. More will be said concerning this finding in the conclusion.

Table 7.6 presents the F regression tables for the retarded subjects in the initial phase of the experiment using the best fitting model, Model II (F regression tables for other models are presented in Appendix 6.3 for both experimental phases). Parameter estimates are all reliable and all regression Fs are significant, including the estimate for self-terminating application, although this is the least significant of the four parameters. It may be remembered that self-terminating application was poorly predicted in both

TABLE 7.6

F REGRESSION TABLES FOR MODEL II,

RETARDED GROUP, INITIAL PHASE

Parameter	Time(msec)	Standard Error	B	Freg	df
a	381	81	.27	22	1,145
x	811	122	.44	44	1,145
y	479	85	.33	32	1,145
z'	384	144	.14	7	1,145
c	1223				

Stepwise Multiple Regression

Parameter	Cumulative R^2	r	Cumulative Freg	Cumulative df
y	.24	.49	46	1,148
x	.56	.71	94	2,147
a	.61	.47	76	3,146
z'	.63	.20	61	4,145

TABLE 7.7

F REGRESSION TABLES FOR MODEL II,

RETARDED GROUP, MAINTENANCE PHASE

Parameter	Time (msecs)	Standard Error	B	Freg	df
a	617	74	.46	70	1,145
x	602	111	.33	30	1,145
y	446	77	.31	34	1,145
z'	394	131	.15	9	1,145
c	359				

Stepwise Multiple Regression

Parameter	Cumulative R^2	r	Cumulative Freg	Cumulative df
y	.19	.44	35	1,148
x	.51	.69	76	2,147
a	.65	.61	92	3,146
z'	.67	.19	75	4,145

Experiments 4 and 5 for retarded subjects. It might be suggested that the predictability of this process by the models has been improved by the combination of the modified method of precueing and the training procedure.

The stepwise multiple regression data shown in the lower half of Table 7.6, indicate that each parameter estimate is reliable. Also, inference, mapping and encoding make valuable contributions to the amount of variance accounted for, while the contribution of self-terminating application is less valuable. This may be, in part, due to the Type II analogies false by 1 and 2 DD' value changes being solved more slowly than the true Type II analogies (Figure 7.2).

Table 7.7 presents the F regression Table for the retarded subjects in the maintenance phase of the experiment. All parameter estimates are again quite reliable, although the self-terminating application process is less well predicted than the other processes. All parameter estimates are statistically significant. The stepwise multiple regression table presented in the lower half of the table indicates that all parameters make a significant contribution to the amount of variance accounted for, although again, the value of the application process is less than that of the other processes.

As in all previous experiments, separate analyses were performed using each of the cue conditions (0 and 2), the nondegenerate analogies only and Sessions 1 and 2. The reason for performing these additional analyses was to examine whether the best fitting model for the full set of data remained the best fitting model across cue conditions (suggesting that separate cue conditions were being treated as subsets of the same task rather than as different tasks); for the "real" nondegenerate analogies and across sessions (thus, examining the

existence of a practice effect). These analyses have in previous experiments revealed results which have been at variance with those obtained by Sternberg and have also revealed differences between nonretarded, below average and retarded groups, between retarded groups in different experimental phases (initial versus maintenance) and between experiments where different experimental designs have been used. These results are again presented in table form (Table 7.8) with only the best fitting model for each analysis being presented in the text in most cases. F regression tables for these analyses are presented in Appendices 6.4 to 6.8 for both experimental phases.

Model fits for each Cue Condition Separately: Since encoding has become a constant, model fitting is based on three parameters only, inference, mapping and application. In addition, as in Experiment 4, only two parameters can be predicted in the 2 cue condition - mapping and application. As a consequence of this, Models III and IV become indistinguishable, Model III previously including exhaustive inference and Model IV, self-terminating inference. Thus it would be expected that there would be a reduction in the amount of variance accounted for in the 2 cue condition.

In the 0 cue condition, Model II remained the best fitting model for the initial phase of the experiment, accounting for 63.0% of the variance. Model III, however, followed (rather than Model I) as the model providing the next best fit, accounting for 62.2% of the variance. Thus, as was found for the full analysis, there is a shift towards more exhaustive processing with Model IV consistently providing a much worse fit than the other three more exhaustive models. The fact that Model III rather than Model I is the model providing the second best fit here, suggests that it is the 2 cue condition that produces more exhaustive processing as has been found in previous experiments. This was indeed the case, with Model I becoming the best

TABLE 7.8

MODEL FITS FOR ALL ADDITIONAL ANALYSES, RETARDED SUBJECTS
INITIAL AND MAINTENANCE PHASES

Analyses	MODELS			
Initial Phase	MODEL I	MODEL II	MODEL III	MODEL IV
Analysis of each cue condition separately				
0 cue	60.5%	63.0%*	62.2%	54.3%
2 cue	23.2%*	21.1%	14.1%	
Analysis of Type II analogies	63.2%	63.6%	64.4%	67.1%*
Analysis of Session 1	54.3%	55.0%*	54.0%	51.2%
Analysis of Session 2	54.4%	55.1%*	53.5%	48.5%
Maintenance Phase				
Analysis of each cue condition separately				
0 cue	54.1%	54.7%*	52.5%	43.5%
2 cue	26.4%	28.4%*	23.7%	
Analysis of Type II analogies	75.2%	76.1%	77.3%*	77.0%
Analysis of Session 1	56.9%	57.7%*	56.8%	52.9%
Analysis of Session 2	55.3%	56.7%*	55.6%	51.7%

* Best Fitting Model

fitting model in the 2 cue condition, accounting for 23.3% of the variance.

In the maintenance phase of the experiment, in the 0 cue condition, Model II remained the best fitting model, accounting for 54.7% of the variance. Model I rather than Model III however, followed very closely, accounting for 54.1% of the variance. It is difficult to explain why Model I and not Model III follows Model II as the best fitting model in this case, when for the full set of data more self-terminating processing is favoured in the maintenance phase of the experiment. As can be seen in Table 7.8, again Model IV does worse than the more exhaustive models. In the 2 cue condition, a similar ordering of models was obtained. Model II was the best fitting model accounting for 28.4% of the variance followed by Model I, with 26.8% of the variance. Thus, processing is slightly less exhaustive in the 2 cue condition in the maintenance phase of the experiment with Model II rather than Model I as in the initial experimental phase, providing the best fit.

The subjects in this experiment appear to be more exhaustive in their processing than the retarded subjects in Experiments 4 and 5 (Experimental Group) where Model III was the best fitting model in the 0 cue condition. Model II became the best fitting model in the 2 cue condition for the retarded group in Experiment 4, but Model III remained the best fitting model for the Experimental Group in Experiment 5. It therefore seems likely that this is due to the modified method of precueing and training and the lower ability level of this group.

Model Fits for the Type II, Nondegenerate Analogies only: The results of this analysis for both phases of the experiment were more consistent with those obtained for the retarded group in Experiment 4 and differed from those

obtained for the Experimental Group in Experiment 5. Model IV became the best fitting model for the nondegenerate analogies, accounting for 67.1% of the variance in the initial phase of the experiment.

In the maintenance phase of the experiment, Models III and IV were virtually indistinguishable as the best fitting model, the former accounting for 77.3% of the variance and the latter for 77.0% of the variance. Thus, there is a reversal of the best fitting model from the full analysis to that using nondegenerate analogies only. For this latter type of analogy, processing appears to be more self-terminating. Again, however, little separates the amount of variance accounted for by all four models, for the nondegenerate (Type II) analogies, (See Table 7.8). This is especially the case in the maintenance phase of the experiment where 77.3% of the variance is accounted for by Model III and only 2% separates it from the model providing the worst fit, Model I. The results for these analogies are therefore, very similar to those previously obtained with Models III and IV providing the best fits. In addition, the high percentage of variance accounted for, in the maintenance phase, for this type of analogy, is greater than that obtained for any retarded group previously in any analysis.

Model Fits for Each Session Separately: As in Experiments 4 and 5 there was no difference between the best fitting model for each of the sessions analysed separately and for the full analysis using sessions combined. This is unlike Experiments 1,2 and 3 (where four cue conditions were used) and Experiment 5, Experimental Group, initial phase where a trend towards more self-terminating processing across sessions was found.

Model II was the best fitting model in Session 1 of the initial phase of the experiment, accounting for 55.0% of the variance. Models I and III were

virtually indistinguishable as the model providing the next best fit, the former accounting for 54.3% of the variance and the latter for 54.0% of the variance. In Session 2 of the initial experimental phase, Model II was the best fitting model and accounted for 55.1% of the variance followed by Model I which accounted for for 54.4% of the variance. In the maintenance phase of the experiment, Model II remained the best fitting model, in Session 1, accounting for 57.7% of the variance. Models I and III were again virtually indistinguishable as the next best fitting model, accounting for 56.9% and 56.8% of the variance, respectively. In Session 2 of this experimental phase, Model II accounted for 56.7% of the variance and Models III and I were again virtually indistinguishable accounting for 55.6% and 55.3% of the variance, respectively.

As in Experiments 4 and 5 (Experimental Group, maintenance phase), it appears that there is no change in the type of processing when only two sessions are used. If four sessions had been included a change from more exhaustive to more self-terminating processing may have been observed. In addition, as processing remained more exhaustive even though the two experimental phases corresponded to the third, fourth fifth and sixth sessions the subjects had participated in, it adds further support to the suggestion that the training procedure produces more exhaustive processing, at least initially, although it is difficult to reconcile this with the results of the nondegenerate analogies analysed separately, where Model IV was favoured. More shall be said on this subsequently.

Finally, all these analyses tend to highlight the indistinguishability of the models, especially Models I, II and III in this experiment. Again, this suggests that subjects may be varying the type of process they use whether self-terminating or exhaustive depending on the particular

analogy. Support for this suggestion comes from the finding that Model IV tends to do worse in this experiment for most analyses compared with the other three more exhaustive models.

Model Fits for Each Individual in Each Phase of the Experiment Separately: Individual model fits evidenced similar results to those obtained in Experiments 1, 3 and 4, in that the percentage of variance accounted for was greatly reduced for most subjects. (These results are presented in Table 7.9. Two models gave equivalent fits to one decimal place. In these cases, two decimal places were used to separate them). This was especially so in the initial phase of the experiment. Most subjects showed an increase in the amount of variance accounted for by the models in the maintenance phase of the experiment.

In addition, the use of a particular model is less consistent across subjects in the maintenance phase of the experiment. In the initial experimental phase, Model II is the best fitting model for the greatest proportion of subjects (six of the twelve subjects). Model I followed, being the best fitting model for three subjects. Model III was the best fitting model for two subjects and Model IV, the best fitting model for one subject only. In the maintenance phase, Model II remained the best fitting model for the greatest proportions of subjects (five out of the twelve subjects). However, Models III and IV both now account for the greatest percentage of the variance for three subjects. Model I remained the best fitting model for only two subjects. Thus, the overall trend is towards more self-terminating processing over time. If the best fitting model has changed for any subjects, it is most often in the direction of a more self-terminating model. This tends to confirm the results obtained using the nondegenerate analogies in the maintenance phase of the experiment, where Models III and IV were found to account for the greatest percentage of the variance.

TABLE 7.9

MODEL FITS FOR EACH INDIVIDUAL SEPARATELY
RETARDED SUBJECTS
INITIAL AND MAINTENANCE PHASE

Initial Phase	MODEL I	MODEL II	MODEL III	MODEL IV
S_1	38.8%	38.9%*	38.4%	36.8%
S_2	21.4%*	21.4%	20.7%	16.8%
S_3	36.4%	36.4%*	36.1%	31.1%
S_4	37.1%*	37.1%	36.0%	30.8%
S_5	8.2%	8.8%	9.1%*	8.6%
S_6	55.1%	55.2%*	54.3%	47.3%
S_7	49.8%	50.4%*	49.1%	43.4%
S_8	20.7%*	19.9%	18.1%	15.8%
S_9	29.4%	31.3%*	29.2%	29.2%
S_{10}	34.8%	37.1%*	36.0%	33.6%
S_{11}	25.1%	27.6%	29.2%	31.2%*
S_{12}	19.7%	21.1%	21.5%*	21.0%
Maintenance Phase				
S_1	48.2%	48.2%*	45.5%	42.0%
S_2	25.9%	26.4%*	22.0%	18.2%
S_3	30.2%	30.0%	30.4%	30.9%*
S_4	27.8%	29.0%	29.6%	30.6%*
S_5	17.6%	19.3%	19.7%*	19.0%
S_6	42.3%	45.2%	46.6%	47.3%*
S_7	54.0%	54.5%*	53.6%	48.8%
S_8	39.3%*	39.3%*	38.5%	32.9%
S_9	33.7%	35.6%	35.6%*	35.3%
S_{10}	63.6%	64.6%*	62.0%	55.2%
S_{11}	28.1%*	27.2%	26.7%	25.3%
S_{12}	7.1%	8.6%	9.1%*	8.9%

* Best Fitting Model

Again, as in Experiments, 1, 3 and 4, all models account for very similar proportions of the variance, in most cases. The best fitting model is usually only the best fitting model by less than 1% of the variance (See Table 7.9). Thus, the indistinguishability of the models tends to be reflected in the individual analyses. This again suggests that subjects are flexible in their use of the particular methods tested here as strategies for responding. As mentioned previously it appears likely that subjects alter the type of model or strategy used depending on the particular analogy item.

7.3.3 ERROR RATES

Table 7.10 presents the mean error rates for the retarded subjects in the initial experimental phase. These are divided into 1) the percentage of errors produced at the end of a block, 2) the percentage of errors remaining after one repetition, 3) the total percentage of errors, 4) the percentage of errors made in the 0 cue condition, and 5) the percentage of errors made in the 2 cue condition. These are also presented for Sessions 1 and 2 separately and for both sessions together. A mean error rate of 12.98% was obtained for both sessions with a mean of 13.45% in Session 1 and 12.5% in Session 2. Thus, errors remained stable over sessions as they had in Experiment 4, and this is probably due to the subjects having participated in two prior training and practice sessions.

Mean error rates for the maintenance phase of the experiment are presented in Table 7.11. They are very similar to those obtained in the initial phase with an overall mean rate of 13.12%. The mean for Session 1 was 13.45% and for Session 2 was 12.78%. Thus, errors were slightly higher in this experimental phase but only marginally so.

Error rates in both experimental phases were very similar to those obtained

TABLE 7.10

MEAN ERROR RATES, RETARDED SUBJECTS,

INITIAL PHASE

ERRORS	SESSION 1	SESSION 2	ALL SESSIONS
1. % errors produced at the end of each block	10.04%	8.95%	9.50%
2. % errors remaining after one repetition	3.41%	3.55%	3.48%
3. Total % errors	13.45%	12.50%	12.98%
4. Errors made in 0 cue condition	5.68%	4.59%	5.14%
5. Errors made in 2 cue condition	7.77%	7.91%	7.84%

TABLE 7.11

MEAN ERROR RATES, RETARDED SUBJECTS

MAINTENANCE PHASE

ERRORS	SESSION 1	SESSION 2	ALL SESSIONS
1. % errors produced at the end of each block	10.04%	9.52%	9.78%
2. % errors remaining after one repetition	3.41%	3.27%	3.34%
3. Total % errors	13.45%	12.78%	13.12%
4. Errors made in 0 cue condition	5.49%	5.35%	5.42%
5. Errors made in 2 cue condition	7.95%	7.43%	7.69%

from the retarded subjects in Experiment 4 and greater than those obtained in Experiment 5, by the Experimental Group. One might have expected the training procedure to produce a reduction in error rates compared to the retarded subjects in Experiment 4. However, one explanation for this lack of reduction in error rates is that the retarded subjects in Experiment 4 received the equivalent of two sessions of explicit instructions and practice with the task. It may also be partially due to these subjects being of slightly lower overall intelligence than the retarded subjects in Experiment 4. A higher error rate would have been expected from the subjects in this experiment compared to the Experimental Subjects in Experiment 5 because they received, in effect, a more difficult task with the introduction of the modified method of precueing in which the precues disappeared in the second half of the trial.

One difference between the error rates for the retarded subjects in Experiment 4 and this experiment was the percentage of errors made in each cue condition. In Experiment 4, the error rates obtained for the 2 cue condition were much greater than those obtained for the 0 cue condition (9.19% compared to 4.52%). However, in this experiment and for both experimental phases, the difference between the error rates for each cue condition, while still present, was greatly reduced. This was due to slightly more errors being made in the 0 cue condition and slightly less errors being made in the 2 cue condition, compared to Experiment 4. This suggests that the training procedure has at least been effective in reducing the error rates obtained for the 2 as opposed to the 0 cue condition.

7.4 CONCLUSION

A number of conclusions can be drawn from the results of this experiment. Firstly, Model II became the best fitting model for the retarded subjects in the

initial phase of the experiment and remained so in the maintenance phase. This suggested that the training procedure and modified method of precueing together with the lower ability level of the group, produced more exhaustive processing of the analogies.

However, only approximately 1% of the variance accounted for, separated Models II and III in the analysis of the full set of data. In addition, analysis of the nondegenerate analogies separately, revealed that the best fitting model for these analogies was Model IV in the initial phase of the experiment and Models III and IV in the maintenance phase. Added to this, is the finding that Model III accounted for 77.3% of the variance in the maintenance phase for these analogies, a similar amount of variance to that accounted for by the nonretarded subjects in Experiments 3 and 4 for these analogies (82.4% and 79.4% respectively). This suggests that the inclusion of the Type I analogies in the full analysis is causing Model II to appear as the best fitting model. Why this should be the case is difficult to explain since the Type I analogies are predicted to be solved, by all the models, in a match-mismatch fashion and not in a self-terminating or exhaustive manner. This tends to highlight the difficulties encountered in drawing apparently meaningful conclusions from small changes in the amount of variance accounted for by each of the models.

Secondly, slightly more of the variance is accounted for by Model II, for the full set of data, than in previous experiments using retarded subjects. This suggests that the modified method of precueing and the training procedure have together, improved the amount of variance accounted for. This is the case even though this group was made up of a majority of mildly retarded subjects while the subjects in Experiments 4 and 5 were mainly of a borderline level of intellectual ability. It would be of interest to examine whether a retarded (and nonretarded) group trained using the modified method of

precueing (where the precued figures disappeared after the end of the first half of the trial) would continue to use these figures in a maintenance phase where the precued figures remained present in the second half of the trial.

The variance accounted for is still not nearly as much as that accounted for by the nonretarded subjects or the subjects in Sternberg's original experiment. One promising finding in this regard, is the large amount of variance accounted for by the nondegenerate (Type II) analogies for these subjects. This is even more so when one considers the improvement obtained in mapping and application in the initial experimental phase and the improvement in all attribute-comparison processes in the maintenance phase of the experiment. However, these findings need to be replicated before firm conclusions can be drawn.

These results lead on to a third point, the finding that as in Experiment 5, the maintenance phase of the experiment tends to produce more consistent and better performance than the initial experimental phase, conducted directly after training. This result is surprising. The expectation in most experiments and the most frequent finding is that performance remains stable over time or shows evidence of a decline (See Chapter 2). This is not the case here. Performance appears to have actually improved or at least become more stable, during the interval between the initial and maintenance phases of the experiment.

This finding may be due, as Chi (1981) has suggested, to the development of a knowledge base concerning the task such as familiarity with the analogies and the trained strategy, by the retarded subjects. For example, by the maintenance phase of the experiment they had participated in four previous sessions with the task. It is not, however, the case that the subjects

remembered the answers to the analogies. They received 176 analogies per session and seemed genuinely surprised when told at the end of the final session, that the analogies they had been solving were the same in all experimental sessions but presented in a different cue condition each time. (This was also the case for the nonretarded below average and retarded subjects in Experiments 1, 2, 3, 4 and 5.)

It would be interesting to examine whether nonretarded subjects retested after a number of months also showed a similar increase in the percentage of variance accounted for. If not, it might suggest that retarded subjects build up a knowledge base more slowly than nonretarded subjects. That is, they take longer to build up familiarity with the figures and use of the strategy. As mentioned previously, the results of Phillips and Nettelbeck's (1980) experiment using extensive practice on S. Sternberg's memory scanning task would tend to support this. Their result may have been primarily due to the retarded subjects slowly building up a more detailed knowledge base concerning this task, something nonretarded subjects are able to do in one session.

Fourthly, it must be remembered that even though a greater percentage of the variance was accounted for, and the parameter estimates for mapping, inference, application and preparation-response were reduced due to a lengthening of the encoding parameter, solution times and standard deviations are still much greater than those obtained from nonretarded subjects. In addition, there is only a slight reduction in the solution times obtained in the maintenance phase of the experiment compared to the initial phase and the retarded group in Experiment 4. Standard deviations are still very high. This suggests that one is redirecting the processing of the retarded subjects so that more of the variance is accounted for by the models tested, a suggestion

made in Experiment 4 using the modified method of precueing. It is also possible that this is not due to a reduction in variability but to the training causing the retarded subjects to alter the processes they have been using to fit the models.

Finally, as in all previous experiments, there is the problem of the indistinguishability of the models, a problem also relevant to Sternberg's experiment. In the initial experimental phase, .9% separates Models II and I as the best fitting models for the full set of data, and only .5% separates Models I and III. In the maintenance phase, 1.2% of the variance separates Models II and III but only .1% separates Models III and I. Thus, these three models account for very similar amounts of the variance in both experimental phases. Also the best fitting model changed from the full set of data to the Type II analogies analysed separately. There is little evidence that with increased practice the difference between the amount of variance accounted for by the models would be increased. In both Sessions 1 and 2 of the initial and maintenance phases, all models provide similar fits to the variance. While the difference between models for the nonretarded subjects tended to be greater than for the retarded subjects this appears to be due to factors other than practice. This may be due to both nonretarded and to a lesser extent, retarded subjects being flexible in their use of exhaustive and self-terminating forms of the same process, this being dependent on the task situation at any one time,and the analogy being solved and for the retarded subjects, to taking longer to adopt the most efficient strategy.

CHAPTER 8

R.J. STERNBERG'S COMPONENTIAL METHOD : SUMMARY AND CONCLUSIONS

8.1 INTRODUCTION

The purpose of this thesis has been to investigate the validity of the componential method developed by R.J. Sternberg (1977a, 1980a) as a means of examining analogical reasoning processes in nonretarded and retarded persons. Section 8.2 is concerned with a brief summary of the experimental procedures used in each of the experiments in this thesis. Section 8.3 deals with a discussion of the results of the four experiments which included nonretarded subjects. Each experiment is discussed and the results obtained are considered in relation to those obtained by Sternberg. Section 8.4 considers the results obtained using the below average and retarded subjects in all six experiments. Section 8.5 considers the componential method as a subtractive method in terms of some of the criticisms made of the subtractive technique in Chapter 1. Section 8.6 discusses the componential method as an explanation of analogical reasoning and cognitive processing in general. Finally, Section 8.7 provides an overall conclusion to this thesis and a direction for future research.

8.2 A SUMMARY OF EXPERIMENTAL PROCEDURES

In Experiments 1 and 2, an attempt was made to replicate the original results obtained by Sternberg (1977a) when he first tested the componential method using the People Piece Analogy Task. As in his experiment, analogies were presented in each of four cue conditions, the 0, 1, 2 and 3 cue conditions. The cue conditions differed from each other in how much information was presented in the first half of the trial, the assumption being that information presented and thus processed in this first half, would not need to

be reprocessed subsequently, in the second half of the trial. In the 0 cue condition, no information was presented in the first half of the trial. In the 1 cue condition, the first figure or term in the analogy was presented. In the 2 cue condition, the first two figures in the analogy were presented, and in the three cue condition, the first 3 figures were presented. The full analogy appeared in the second half of the trial in all cue conditions.

In Experiment 1, groups of above and below average intelligence were used. The below average group received an additional practice session as it appeared after the initial practice trials that these subjects did not have an adequate understanding of the task. This was not unexpected given the results of Bray, (1972, 1973, 1979) and Bray, Justice and Simon, (1978) who found that the minimal instructions provided by the experimenter to nonretarded subjects were not sufficient for retarded subjects to understand the complex task used in their experiments. In Experiment 2, an above average intelligence and retarded group were used, the latter group being used after it was found that below average subjects could perform the task adequately. So that both these groups had quantitatively equivalent amounts of practice on the task, they each received an initial session of 176 practice trials. In addition, instructions concerning the nature of the analogies and use of the precued figures were made more explicit than they had been in Experiment 1, to examine whether this would improve both groups' use of these figures.

In Experiment 3, the presentation of the analogies was altered so that the full analogy no longer remained present in the second half of the trial. This was done because of the failure in Experiment 2 to obtain use of the precued figures by the nonretarded and especially the retarded subjects, even though these groups had received explicit instructions to do so. Instead, only the

nonprecued figures were presented in this half of the trial. The first half of the trial remained the same as in previous experiments. Because of this change in the method of stimulus presentation, it was acknowledged that a greater load might be placed on short-term memory, a factor that might especially affect retarded subjects (Detterman, 1979; Ellis, 1970, 1978). Again, a nonretarded and retarded group were used as had been the case in Experiment 2. An extra practice session was provided for the retarded group but not the nonretarded group, as it had been found in Experiment 2 that an additional practice session for this latter group did not reduce solution times or error rates. It was found that after one practice session, the retarded subjects did not understand the nature of the task sufficiently well to continue with the experiment. These subjects did not therefore, complete the experiment.

In Experiment 4, the same method of stimulus presentation used in Experiment 3 was used. However, the number of cue conditions was reduced from four to two, in an attempt to simplify the task so that retarded subjects could understand it in one or two practice sessions and to reduce the load on short-term memory, a procedure used successfully by Bray et al, (1978). The two cue conditions remaining in the task were those using 0 and 2 precues. In the 0 cue condition, no figures were presented in the first half of the trial, and the full analogy was presented in the second half of the trial. In the 2 cue condition, the first two figures in the analogy were presented in the first half of the trial and the second two figures were presented in the second half of the trial. This task would therefore place less load on memory than the task used in Experiment 3, as only one, rather than three cue conditions required the use of memory for analogy solution. A nonretarded and retarded group were used, the retarded group being the same group that

had participated in one practice session in Experiment 3. This group received a further practice session prior to the first experimental session in Experiment 4.

In Experiments 5 and 6 only retarded subjects were used and the simplified task described in Experiment 4, above, was retained. In addition, in both Experiments 5 and 6, a training procedure was introduced which required the elaboration of the relationships between the first two figures in the analogy and the second two figures and then a comparison of these two relationships to evaluate whether they were the same. This training procedure was based on a study by Kendall, Borkowski and Cavanaugh (1980) who found an interrogative, elaborative training strategy to be successful in obtaining maintenance and transfer of that strategy. The two experiments here differed in that in Experiment 5, the original method of precueing was used, where the full analogy was presented in the second half of the trial, irrespective of the number of figures precued in the first half of the trial. A control group was also included to examine whether the training procedure improved performance over two sessions of practice with minimal instructions. A maintenance phase examined performance after a four month lapse in training. A second control group was also included to examine whether there was any transfer of improved performance from the People Piece Analogy task to another task requiring the use of similar processes. In Experiment 6, however, the modified method of precueing was used, where only the nonprecued figures were presented in the second half of the trial, a maintenance phase was also included, conducted three months later.

8.3 THE VALIDITY OF THE COMPONENTIAL METHOD AS A MEANS OF STUDYING ANALOGICAL REASONING

Experiments 1,2,3 and 4 were concerned with determining the validity of

componential analysis as a means of investigating how nonretarded subjects solve analogies. Primarily, these experiments were interested in replicating and expanding on the results Sternberg (1977a) obtained in his original People Piece Analogy experiment, using subjects of above average intellectual ability.

8.3.1 INTERVAL SCORES AND NONRETARDED SUBJECTS

Results with regard to the interval scores were remarkably consistent across all experiments using nonretarded subjects (These results are presented in Table 8.1 for all nonretarded groups and Sternberg's subjects). Thus, while interval scores and standard deviations were much larger than those obtained by Sternberg, they were consistent within this series of experiments. There was some decline in solution times in the 0 cue condition (the composite task) when the modified method of precueing was used, but this was not great. The greater reduction in solution times in Experiment 4 compared to Experiment 3 is probably due to the use of two rather than four cue conditions, thus producing a slightly simpler task. Mean solution time varied from approximately 2500 msecs in Experiment 1 to 2100 msecs in Experiment 4 for the 0 cue condition, the composite analogy task. This is compared to a mean solution time of 1423 msecs obtained by Sternberg (1977a) in the 0 cue condition. Comparisons across other cue conditions are not really valid due to the variation in the method of precueing.

There was evidence that the nonretarded subjects in Experiments 1 and 2 were making some use of the precued figures. This was apparant from analyses using the simplex model, which indicated simplical structure for the solution scores, from an analysis of variance which found a significant main effect and significant linear trend for cue condition, and finally, from the similar differences between mean solution times across cue conditions. However, the

TABLE 8.1

INTERNAL SCORES , NONRETARDED SUBJECTS

ALL EXPERIMENTS

EXPERIMENT	CUE CONDITION			
	0	1	2	3
Experiment 1				
Cue Time	649	711	1023	1551
Solution Time	2506	2418	2081	1732
+				
Experiment 2				
Cue Time	611	676	1171	1748
Solution Time	2366	2212	1807	1581
+				
Experiment 3				
Cue Time	644	2117	2644	3260
Solution Time	2317	2194	1372	938
++				
Experiment 4				
Cue Time	619		2247	
Solution Time	2163		1314	
++				
Sternberg's Subjects				
Cue Time	530	755	952	1147
Solution Time	1423	1328	947	681
+				

\+ Original Method of Precueing

++ Modified Method of Precueing

experimenter consistently found that subjects in the actual task tended to press the central key terminating the end of the first half of the trial before closely inspecting the precued figures. This was the case even when subjects were instructed to make as much use as possible of the precued figures in the first half of the trial, in Experiment 2. As mentioned previously, it was not known what instructions Sternberg provided to obtain use of the precued figures, but it does appear that his subjects made greater use of the precued figures than the nonretarded subjects in Experiments 1 and 2.

Mean solution times were decreased and mean cue times were increased using the modified method of precueing, although the difference in overall interval scores was not greatly different from that obtained using nonretarded subjects in Experiments 1 and 2. Standard deviations were also slightly reduced. However, the interval scores were still much longer and the standard deviations much higher than those obtained by Sternberg using above average subjects. Some factors which may have affected these results are discussed subsequently.

Type II analogies were solved significantly more slowly than Type I analogies. It is not possible to examine whether it is the Type II or the Type I analogies (or both) which are being solved more slowly by the nonretarded subjects in Sternberg's experiment as Sternberg did not separate mean solution times by analogy type. The Type I analogies were less affected by the type of cue condition even when the modified method of precueing was used. This is probably due to the simplicity of these analogies compared to the Type II analogies, their requiring only a brief holistic scan for solution. As suggested by Sternberg's inclusion of dual processing, the Type I analogies are solved using a same-different, match-mismatch process rather than by searching for individual attribute changes between analogy terms.

The difference in interval scores and standard deviations between the nonretarded subjects in this series of experiments and the above average group in Sternberg's original experiment may be caused by a number of factors.

Firstly, Sternberg's subjects received more analogies overall than the subjects in this experiment, 288 compared to 176 analogies. In addition, there was more than double the amount of observations made (for each analogy in each cue condition because of this greater number of analogies used). The mean solution times for Sternberg's data are based on 4608 observations in each cue condition. This is compared to 2112 observations in this series of experiments. As a consequence, each session in Sternberg's original experiment lasted approximately one hour and fifteen minutes while for the subjects in this series of experiments, each session lasted between 25 and 35 minutes. As mentioned in Experiment 1, it was originally decided to reduce the number of analogies to reduce the length of the sessions because of the detrimental effects a session of one hour and fifteen minutes might have on the performance level of the retarded subjects, especially given that for these subjects, sessions were likely to be of a longer duration than for the nonretarded subjects. In addition it was not possible to remove these subjects from their work for long periods of time.

As the subjects in Sternberg's experiment received a greater number of overall analogies and longer sessions it might be expected that they should become more highly practiced with the task. However, Sternberg's subjects were still faster in their first session than the nonretarded subjects in this series of experiments were in their last. Both Sternberg's subjects and the nonretarded subjects in Experiments 1, 3 and 4 received only 48 practice trials on the task prior to commencing the experimental sessions. The nonretarded subjects in

Experiment 2 received a full session of practice but this made little difference to the length of their interval scores, their standard deviations or their error rates. They were slightly faster than the nonretarded subjects in Experiment 1, equal in speed to the subjects in Experiment 3 and slightly slower than the nonretarded subjects in Experiment 4. (About 200 msecs in all cases, see Table 8.1).

Two further factors can not be discounted as causing this discrepancy between the interval scores and standard deviations produced by Sternberg's subjects and the nonretarded subjects in this experiment. Firstly, it could be suggested that Sternberg's subjects were more intelligent than the subjects used here. However, this seems unlikely. Both were drawn from Psychology I subject pools from recognised universities.

Secondly, the method of stimulus presentation and the actual stimuli used may have produced a difference. Sternberg used tachistoscopic stimulus presentation and figures taken from the Elementary Science Study (ESS) People Pieces which are more idyosyncratic in shape (Examples of these figures are presented in Figure 3.7, Chapter 3). The stimuli used here were presented via a computer graphics package and were consequently more geometric in shape (see Figure 4.1 (a)-(d), Chapter 4). However, both figures consisted of the same four attribute dimensions - height, sex, weight and colour and the experimental design used in these experiments replicated as closely as possible, that used by Sternberg. No firm conclusion regarding the differences in stimulus type can be made here. An experiment comparing both types of stimuli might resolve this issue.

8.3.2 MODEL FITTING, PARAMETER ESTIMATES AND NONRETARDED SUBJECTS

In all experiments, the nonretarded groups' data were best fitted by Model III,

the partially exhaustive, partially self-terminating model. This is a result identical to that obtained by Sternberg (1977a) and Sternberg and Rifkin (1979) using similar subjects. Table 8.2 presents the percentage of variance accounted for by each model for all groups in each experiment.

In Experiments 1 and 2, 66% and 63% of the variance was accounted for by Model III for the nonretarded groups compared to 92% of the variance accounted for by Model III using Sternberg's subjects. The amount of variance accounted for by these subjects was increased to 74% and 73% respectively, when an alternatively model fitting procedure was used. This alternative model fitting procedure took into account the apparent reduced use of the precued figures made by these subjects compared to Sternberg's subjects.

Introduction of the modified method of precueing in Experiments 3 and 4 greatly improved the percentage of variance accounted for. Model III, the best fitting model, accounted for 84% and 80% of the variance in Experiments 3 and 4 respectively.

In Model III, encoding and inference are exhaustive, but mapping and application are self-terminating. Parameter estimates were quite reliable for all four processes, although application tended to be less well predicted than the other three processes. However, this result is similar to that obtained by Sternberg, who found that encoding and application contributed least to the amount of variance accounted for. The actual parameter estimate for application obtained by Sternberg was more reliable, having a lower standard error and higher beta weight than was generally found here. As for Sternberg's subjects, the nonretarded subject's data were better fitted by inclusion of dual processing.

The self-terminating encoding model fitting procedure, where encoding

TABLE 8.2

MODEL FITS FOR ALL GROUPS IN ALL EXPERIMENTS

	MODEL I	MODEL II	MODEL III	MODEL IV
Nonretarded Subjects				
Experiment 1 + Experiment 2 + Experiment 3 ++ Experiment 4 ++	61.6%	69.5%	74.4%*	73.6%
	60.5%	67.2%	73.0%*	73.1%
	77.1%	79.7%	84.1%*	83.6%
	73.5%	76.5%	80.3%*	79.6%
Retarded Subjects				
Experiment 1 + Experiment 2 + Experiment 4 ++ Experiment 5 Initial Phase + Maintenance Phase + Control Group 1 + Experiment 6 Initial Phase ++ Maintenance Phase ++	32.6%	42.6%	50.4%	51.3%*
	40.5%	46.2%	49.3%*	47.7%
	60.7%	62.9%	64.5%*	61.1%
	56.9%	59.6%	60.4%*	55.5%
	57.6%	60.9%	65.8%*	62.9%
	41.4%	46.1%	47.8%*	44.3%
	61.8%	62.7%*	61.3%	56.9%
	66.1%	67.4%*	66.2%	61.6%

* Best Fitting Model

\+ No Parameter Dropouts alternative model fitting procedure

++ Parameter Dropouts original model fitting procedure

became self-terminating just prior to the first self-terminating attribute comparison process (i.e. inference, mapping and application), provided as good a fit to the data in all experiments even though changes were made to the method of stimulus presentation. This was also the case with the alternative modelling fitting procedure, dual processing in 1 DD' value change only. In both cases, Model III remained the best fitting model.

The fact that both alternative model fitting procedures mentioned above provided similar fits to the data as the original model fitting procedure, is related to another finding from this series of experiments - that there was little to distinguish Models III and IV and often Models II, III and IV and sometimes all four models. Not only was this the case for group data but also for individual analyses for each subject. Nevertheless, when the alternative model fitting procedures with no mapping or dual processing in application only were analysed, these clearly provided worse fits to the data in that much less of the variance was accounted for. It appears that it is only when exhaustive or self-terminating forms of the processes are considered such as in the case of self-terminating encoding or when considering the differences between attribute-comparison processes in Models I, II, III and IV that the problem occurs.

As suggested previously, this may be due to the nonretarded subjects being more flexible in their use of exhaustive and self-terminating forms of the processes in the models. It is quite possible that subjects alternate between exhaustive and self-terminating inference or encoding, depending on the experimental situation and the difficulty of the analogies. Support for this suggestion comes from a recent study by Bethell-Fox, Lohman and Snow (1984) (discussed in Chapter 1). They obtained evidence which suggested that more difficult items within the same task were solved using a more thorough

strategy than that used to solve simpler items. They also found that the best fitting model tended to vary across subjects and that the percentage of variance accounted for varied from subject to subject. It would be possible to examine this for the data received in this series of Experiments by examining solution times for each analogy type separately. One might expect that the more difficult Type II analogies with a number of AB and AC attribute changes would produce the longest times compared to Type II analogies with fewer AB/AC changes, and the Type I analogies. Model fits could then be conducted for each of these difficulty levels.

In general terms then, the results of model fitting are very similar to those obtained by Sternberg. Model III, incorporating dual processing provides the best fit to the data for the nonretarded subjects. In Experiments 3 and 4 where the modified method of precueing was used, considerable amounts of the variance were accounted for, as was the case for Sternberg. However, more detailed analyses revealed certain differences between the results obtained by Sternberg and those obtained here.

While Sternberg found that Model III remained the best fitting model in the 0 cue condition and for the nondegenerate analogies analysed separately (although Model IV was best for Sessions 1 and 4 analysed separately, the one instance where the best fitting model for a more specific analysis varied from that for the full analysis in Sternberg's results) this was not always the case here. Nonretarded subjects in this series of experiments tended to show a trend towards more exhaustive processing across cue conditions (Table 8.3), to use either Model III or IV in Experiments 1 and 2 (where the original method of precueing was used) to solve the nondegenerate analogies, and to use Model IV when solving these analogies in Experiments 3 and 4 (where the modified method of precueing was used) (Table 8.4). Finally, they also tended to

TABLE 8.3

CUE CONDITIONS BEST FITTING MODEL

	CUE CONDITIONS			
	0	1	2	3
Nonretarded Subjects				
Experiment 1	MODEL IV	MODEL III	MODEL III	MODEL II
+	72.6%	78.0%	65.8%	75.8%
Experiment 2	MODEL IV	MODEL IV	MODEL IV	MODEL
+	69.0%	76.5%	64.6%	73.0%
Experiment 3	MODEL IV	MODEL III	MODEL II	all models
+	88.5%	86.3%	52.6%	the same
Experiment 4	MODEL III		MODEL II	
++	86.3%	-	52.5%	-
Retarded Subjects				
Experiment 1	MODEL IV	MODEL IV	MODEL IV	MODEL IV
+	59.0%	39.5%	50.0%	59.1%
Experiment 2	MODEL III	MODEL III	MODEL III	MODEL III
+	39.8%	49.8%	53.5%	55.3%
Exeriment 4	MODEL III	-	MODEL II	-
++	62.9%		35.4%	
Experiment 5 Experimental Group				
Initial Phase	MODEL III	-	MODEL III	-
+	63.1%		58.1%	
Maintenance Phase				
+	MODEL III 68.0%	-	MODEL III 64.3%	-
Control Group 1	MODEL III	-	MODEL III	-
+	52.2%		44.2%	
Experiment 6 Initial Phase	MODEL II		MODEL II	
++	62.7%		67.4%	
Maintenance Phase				
++				

\+ No Parameter Dropouts alternative model fitting procedure

++ Parameter Dropouts original model fitting procedure

TABLE 8.4

NONDEGENERATE ANALOGIES BEST FITTING MODEL

Experiment	Nonretarded Subjects	Below Average /Retarded
Experiment 1 +	MODELS III AND IV 71.4%	MODEL III 68.0%
Experiment 2 +	MODELS III AND IV 67.3%	MODEL III 42.5%
Experiment 3 ++	MODEL IV 82.4%	-
Experiment 4 ++	MODEL IV 79.4%	MODEL IV 67.9%
Experiment 5 Initial Phase +		MODEL III 60.4%
Maintenance Phase +	-	MODEL III 49.3%
Control Group 1 +	-	MODEL III 39.4%
Experiment 6 Initial Phase ++	-	MODEL IV 67.1%
Maintenance Phase ++	-	MODEL III 77.3%

\+ No Parameter Dropouts alternative model fitting procedure
++ Parameter Dropouts Original Model fitting procedure

become more self-terminating across sessions when four sessions were used (Table 8.5 Experiments 1, 2 and 3). Model IV tended to be favoured over Model III in later sessions while Model III was favoured in the earlier sessions. One might have expected a similar practice effect for Sternberg's subjects given that they had received a similar level of initial practice. However, it may be that their change from Model III to Model IV occurred in the first session, and thus they used Model IV thereafter. It is therefore surprising that Model IV does not produce the best fit to the data for the full analysis in Sternberg's experiment. This again illustrates the difficulty of making conclusions about which model provides the best fit to the data when so little separates them.

As Sternberg had found, Models III and IV were often virtually indistinguishable in the full analysis. Individual difference analyses revealed that this was the case for the individual data as well as the group data. It was not, therefore a case of some subjects obviously using Model III over Model IV or vice versa. Another finding, although one that tended to occur far more in the retarded subjects' data was that Model IV appeared as the best fitting model over Model III (favoured in the group data) for a slightly greater proportion of the subjects when analysed separately. This suggested that in the componential method the group data favoured Model III while individual data favoured Model IV.

Thus, more detailed analyses of the obtained data reveal a number of differences from those obtained by Sternberg. The model used to solve the nondegenerate analogies differed from the model used to solve the Type I analogies, a not unexpected result. Also, there appeared to be practice effects in the type of model used across sessions, changes in the model used across cue conditions, and alterations in the best fitting model and amount of variance accounted for by individual subjects.

TABLE 8.5

SESSIONS ANALYSIS BEST FITTING MODEL

	Session 1 (two or four cue conditions)	Session 2 (two cue conditions)	Session 4 (four cue conditions)
Nonretarded Subjects			
Experiment 1 +	MODEL III 50.4%		MODEL IV 60.4%
Experiment 2 +	MODEL III 56.3%		MODEL IV 66.5%
Experiment 3 ++	MODEL III (77.7%)		MODEL IV (72.3%)
Experiment 4 ++	MODEL III (74.7%)	MODEL III (77.0%)	
Retarded Subjects			
Experiment 1 +	MODEL III (21.2%)		MODEL IV 43.8%
Experiment 2 +	MODEL III 40.8%		MODEL III (27.6%)
Experiment 4 ++	MODEL III (59.5%)	MODEL III (56.0%)	
Experiment 5 Initial Phase + Maintenance Phase + Control Group 1 + Experiment 6 Initial Phase ++	MODEL II (55.0%)	MODEL II (55.1%)	
Maintenance Phase ++	MODEL II (57.7%)	MODEL II (56.7%)	

\+ No Parameter Dropouts Alternative Model Fitting Procedure

++ Parameter Dropouts original model fitting procedure

8.3.3 CONCLUSIONS CONCERNING THE NONRETARDED SUBJECTS AND THE COMPONENTIAL METHOD

Firstly, interval scores were much longer overall and standard deviations were much higher than those obtained by Sternberg. In the model fitting analyses regressions Fs were usually lower than those obtained by Sternberg and the standard errors of the estimate were higher. The subjects appeared to make less use of the precued figures in the actual experimental situation when the original method of precueing was used but made more use of these figures (even more than Sternberg's subjects) when the modified method of precueing was introduced. Cue scores here showed evidence of a memory factor in that there was a dramatic increase in these times from the 0 to 1 cue condition (See Table 8.6), although this did not appear to be transferred on to the solution scores. Secondly, different models were favoured when different aspects of the data were analysed separately. While this may indicate that the componential method is to some extent sensitive to changes in the type of model or strategy used by the subject it also makes the validity of basing conclusions on a single analysis of the group data more tenuous. Thirdly, while it can explain quite well the processes a group of nonretarded subjects use to solve People Piece Analogies, it may not be able to be easily adapted to different tasks. In other words, it may be task-specific. Sternberg (1977a) has used the method to study geometric and verbal analogies with less success than People Piece Analogies. This is partly because the method was unable to take into account the complexity of the situation, especially with regard to verbal analogies. As mentioned previously, Sternberg has himself suggested that as the complexity of a given task is increased the ability of mathematical models to account for that task is decreased. Nevertheless with modifications in combination with other approaches, it may be possible to make the componential method more flexible so that it is able to take these factors into account. Some of these modifications and other approaches

will be discussed in subsequent sections.

8.4 THE APPLICABILITY OF THE COMPONENTIAL METHOD TO THE INVESTIGATION OF MENTAL RETARDATION

All the experiments in this thesis included either intellectually below average or mentally retarded groups of subjects and a number of interesting results were obtained. The below average group tended to produce results that were midway between those obtained for the retarded and nonretarded groups . This suggests that at least for the range of intellectual abilities studied here the ability to reason analogically exists on a continuum.

8.4.1 INTERVAL SCORES AND BELOW AVERAGE AND RETARDED SUBJECTS

Interval scores obtained by the below average and retarded groups in Experiments 1 to 6 are presented in Table 8.6. As can be seen, the modified method of precueing used in Experiments 4 and 6 produced longer cue times, especially in the 2 cue condition, indicating use of the precued figures. The below average group in Experiment 1 where the original method of precueing was used, show some evidence of having used the precued figures, however, it is much less than that obtained in Experiments 4, 5 and 6, for the retarded subjects.

The results for the retarded group in Experiment 2 and the Control Group in Experiment 5, as one might expect, were similar in that both groups showed little evidence of having used the precued figures. These two groups received the same method of precueing as that used in Experiment 1 (and as originally used by Sternberg (1977a)). However, the control group in Experiment 5 received the simplified task with two rather than four cue conditions, two sessions of practice rather than one, and no feedback.

TABLE 8.6

INTERVAL SCORES BELOW AVERAGE AND RETARDED SUBJECTS ALL EXPERIMENTS

Experiment	Cue Condition 0	1	2	3
Experiment 1				
Cue Time	894	839	875	1040
Solution Time	3720	3624	3498	3412
+				
Experiment 2	894	852	893	968
Solution Time Cue Time	3812	3760	3841	3678
+				
Experiment 4	1195		3370	
Initial Phase Cue Time	4008		2528	
Solution Time				
++				
Experiment 5	866		1657	
Initial Phase Cue Time	3575		2939	
Solution Time				
+				
Cue Time Maintenance Phase	954		1992	
Solution Time	3370		2868	
+				
Control Group	762		907	
Solution Time Cue Time	3870		3849	
+				
Experiment 6	1157		2997	
Initial Phase Cue Time	4042		2465	
Solution Time				
++				
Maintenance Phase	1108		2840	
Cue Time	3855		2162	
Solution Time				
++				

\+ Original Method of Precueing
++ Modified Method of Precueing

The retarded group in Experiment 2 received the more complex task with four rather than two cue conditions, one session of practice, and feedback. The main difference between these two groups was in the mean error rates, Control Group making significantly more errors (18.56% compared to 8.73% for the retarded group in Experiment 2). This appears to be directly related to the presence or absense of feedback. Cue times for all cue conditions in both groups are very similar and much shorter than those obtained for the comparable subjects in Experiments 4 and 6 in the 0 cue condition. Conversely, solution times in the 2 cue condition are much longer.

Results for the Experimental Group in Experiment 5 were part way between those obtained in Experiments 4 and 6 and those in Experiments 2 and 5 (Control Group). Their solution times were longer in the 0 cue condition than the 2 cue condition and the reverse was true of their cue scores suggesting some use of the precued figures in the 2 cue condition. However, the change in cue and solution scores across cue conditions was less dramatic than that obtained in Experiments 4 and 6 using the modified precueing method. This suggests that they were making more use of the precued figures than the subjects in Experiments 1, 2 and 5 (Control Group) where the original precueing method was used, but less use of these figures than the subjects in Experiments 4 and 6 where the modified method of precueing (with the precued figures disappearing after the end of the first half of the trial) was used.

Thus, the use of a simplified task may have been partially successful in producing use of the precued figures in the 2 cue condition by the Experimental Group in Experiment 5. It would be interesting to examine the results obtained by a nonretarded group using this task. It might be expected that they would make more use of the precued figures which may in turn make it unnecessary to use the modified method of precueing.

From examination of the solution scores in all experiments in the 0 cue condition (the composite task), it appears that the task presented in Experiments 4 and 6 where the precued figures disappeared after the first half of the trial, was the most difficult and the task presented in Experiment 5 to the Experimental Group where the precued figures remained present in the second half of the trial, was the simplest. This latter finding is probably due to the training procedure used and the presence of the full analogy in the second half of the trial. The finding that mean solution times have not increased in both cue conditions from the initial to the maintenance phase in Experiments 5 and 6 also suggests that a good knowledge of the task has been maintained over time, a similar result to that obtained by Brown, Campione and Barclay (1979) and Kendall, Borkowski and Cavanaugh (1980). The fact that solution times have slightly decreased in the maintenance phase strongly suggests that, as mentioned previously, knowledge base factors (Chi, 1981) play a major role in this type of task when performed by retarded subjects. It appears that retarded subjects may take longer to build up an adequate knowledge base but once they have done so, this knowledge is retained for a long period of time.

8.4.2 MODEL FITTING, PARAMETER ESTIMATES AND BELOW AVERAGE AND RETARDED SUBJECTS

The results obtained in Experiments 1 and 2 for the below average and retarded groups revealed contradictory findings. In Experiment 1, the below average group was best fitted by Model IV (51.3%), the fully self-terminating model, while the retarded group in Experiment 2 was best fitted by Model III (49.3%) (Table 8.2). These results were obtained using the alternative model fitting procedure which took into account the fact that these subjects were not using the precued figures. Model III was the best fitting model for the

subjects in Experiment 4. In addition, a greater percentage of the variance was accounted for, 64.5% compared to 49.3%, in Experiment 2 for the comparable group. This was probably due to the modified method of precueing forcing the retarded subjects to use the precued figures and to the fact that the subjects participated in two practice sessions rather than one.

The results of Experiment 5 were similar to those obtained in Experiment 4. Model III remained the best fitting model and accounted for 60.4% of the variance in the initial phase of the experiment, again an improvement compared to the similar group in Experiment 2 (Table 8.2). This was maintained over time, Model III accounting for 65.8% of the variance in the maintenance phase of the experiment. It should be remembered that this was using the alternative model fitting procedure used in Experiments 1 and 2, which took into account the fact that subjects were making less use of the precued figures than the retarded subjects in Experiment 4. Thus, even though only one cue condition required use of the precued figures, the original method of precueing was unsuccessful in getting the subjects to use the precued figures. Although training produced faster solution times, and more variance accounted for, it was unsuccessful in generalizing performance to a task (the Ravens Progressive Matrices) requiring the use of similar processes.

Experiment 6 combined the precueing method used in Experiment 4 with the training procedure from Experiment 5. This experiment resulted in the greatest amount of variance accounted for by retarded subjects - again in the maintenance phase of the experiment (67.4%, Table 8.2). It also resulted in a change in the best fitting model from Model III to Model II. Of interest also, was the finding that for the nondegenerate (Type II) analogies in the maintenance phase of the experiment, 77.3% of the variance was accounted for (Table 8.4). This was similar to the amount of variance accounted for by

the nonretarded subjects in Experiments 3 and 4 for these types of analogies.

As has been mentioned previously, the below average group in Experiment 1 was the only instance in which a result was obtained similar to that which might have been expected given Sternberg and Rifkin's (1979) results using young children. As the retarded groups in all subsequent experiments were best fitted by Models III and II, this suggests that the initial result was either due to chance (Model III was only .9% behind Model IV as the next best fitting model in Experiment 1 and provided a slightly better fit to the data for the nondegenerate analogies when analysed separately, Table 8.4) or as mentioned previously, to the more detailed instructions and training received by the retarded groups in later experiments. The below average group received the least amount of instruction on the task, although they also received an additional initial session of practice. In all subsequent experiments, the retarded subjects received progressively greater amounts of instruction and direction on how to solve the analogies successfully. It is true that the form of training used encouraged the use of more exhaustive processing, at least initially. This is probably why in Experiment 6, Model II became the best fitting model for the full set of data, these subjects receiving the greatest degree of instruction because of the modified method of precueing and the training procedure used, both of which appeared to produced more exhaustive processing (although Model IV provided the best fit to the nondegenerate analogies when analysed separately. More will be said on this subsequently). It may also be due to their being of mildly rather than borderline intelligence as in previous experiments. Thus, they were more dependent on the trained strategy than the other retarded groups. As has been mentioned previously, increased instruction was required to ensure the retarded subjects had an adequate understanding of the task, thus improving the amount of variance accounted for and reducing error rates.

Without mastery of the task, self-terminating processing is associated with long solution times and high error rates. With mastery of the task self-terminating processing is associated with decreased solution times and lower error rates. More exhaustive processing means a more thorough analysis of the task producing longer solution times but lower error rates. It seems that retarded subjects need to be trained to use this interim step to progress from inefficient to efficient self-terminating processing.

The retarded subjects produced results similar to those obtained by Sternberg in so far as model fits remained unchanged across cue conditions (Table 8.3) and when the nondegenerate analogies were analysed separately, in Experiments 2 and 5 (Table 8.4). In addition, the best fitting model for the full analysis also remained the best fitting model across sessions in Experiments 2, 4, 5 and 6 (Table 8.5). This excludes the below average group in Experiment 1 whose trend towards self-terminating processing across sessions was similar to that of the nonretarded subjects in all experiments. The retarded groups in Experiments 4 and 6 appeared to use more self-terminating processes when solving the nondegenerate analogies, a trend that had been observed in the case of the nonretarded subjects (Table 8.4). As this effect was observed only in these two experiments for the retarded subjects, it suggests that this was due to the modified method of precueing where the precued figures were removed in the second half of the trial together with the additional practice sessions received by these groups. More exhaustive encoding of the precued figures and practice may have produced more self-terminating inference, mapping and application processes as Sternberg (1977a, 1980a) has suggested occurs for better reasoners.

One reason why the below average and retarded subjects in most experiments produced results similar to Sternberg's original results but different from those

obtained for the nonretarded subjects in these experiments (in terms of the best fitting model for the full analysis often remaining the best model for the additional analyses by session, cue condition and analogy type) may be due to their having received, in general, one or two sessions of practice prior to performing on the People Piece Analogy task, thus making their data more stable. Alternatively, it may be due to their being less flexible in changing from an exhaustive to a self-terminating form of a particular process. For example, it has been suggested that the variability of the best fitting model for nonretarded subjects may be due to flexibility both between and within subjects in the use of exhaustive or self-terminating processes, exhaustive on more difficult items and self-terminating on simpler items. The retarded subjects may be less efficient at alternating between exhaustive and self-terminating forms of each process.

Finally, the amount of variance accounted for by the data for these subjects is much smaller compared to that accounted for by Sternberg and the nonretarded subjects in this series of experiments. In addition, their parameter estimates were generally less reliable. Analyses using their data tended to produce lower regression Fs, higher standard errors of the estimate and lower beta weights compared to both Sternberg's results and the nonretarded subjects in this series of experiments. While estimates for inference and mapping were generally quite reliable, the estimates for encoding and application were less so and these estimates also contributed less to the amount of variance accounted for. Encoding was poorly predicted in Experiments 2 and 5 (Control Group) where less instruction on the task was provided and the original method of precueing was used. This was probably due to the nonuse of the precued figures by the retarded subjects in these experiments (as can be seen in the solution times for each cue condition in Table 8.6). Application was poorly predicted in Experiments 4

and 5 (Experimental Group) where it was not even statistically significant and to a lesser extent in Experiments 1, 2, 5 (Control Group) and 6. It is difficult to understand why this occured since it was especially evident when using the modified method of precueing (Experiment 4) or training (Experiment 5) but not when both of these were used in the same experiment (Experiment 6).

8.4.3 CONCLUSIONS CONCERNING THE BELOW AVERAGE AND RETARDED SUBJECTS AND THE COMPONENTIAL METHOD

From this series of experiments it can be concluded that apart from a few exceptions, retarded subjects tended to use Model III, the partially exhaustive, partially self-terminating model and the same model that accounted for most of the variance for the nonretarded subjects. It might, therefore, be concluded that the retarded subjects were solving the analogies in the same way as the nonretarded subjects, but that they were slower and more variable in their response rate. However, the exceptions, (Experiment 1, Model IV and Experiment 6, Model II) tend to suggest that Model IV might be favoured by the retarded subjects if left to their own devices but that this is altered by the high level of instruction and training received. Individual difference analyses tended to support this, (as did analysis using the Type II analogies only) in that in most cases, Model IV appeared as the best fitting model for the retarded subjects when model fits were conducted for each individual separately. However, without the additional instructions or training it is doubtful that the retarded subjects would have produced data as reliable as those obtained. Support for this suggestion comes from Experiments 2 and 5 (Control Group) where minimal instructions and in the latter case, no immediate feedback were provided, and much less of the variance was accounted for.

It seems likely that their use of more self-terminating processing is due to a short-term memory overload when solving the Type II, nondegenerate analogies (with training, retarded subjects can be forced to make greater use of short-term memory but overtime they appear to revert back to a more self-terminating mode of processing). Interestingly, this does not result in a drop in overall performance (in terms of speed of processing, error rates or percentage of variance accounted for, see Tables 8.2 and 8.6). This suggests that the retarded subjects have built up a knowledge base for the task so they are not as dependent on the trained strategy as in the experimental sessions following training. This suggests that training retarded subjects to use a more difficult but also more thorough strategy initially, may result in their being able to use the more efficient self-terminating strategy successfully later.

Training or instruction did not appear to reduce analogy solution times greatly. But then, confounded here was the degree of instruction or training received and the difficulty level of the task. The task used in Experiments 4 and 6 (and 3 which the retarded subjects could not perform) with the modified method of precueing was a more difficult task than that used in Experiments 1, 2 and 5. This was reflected in the error rates obtained from the retarded subjects in Experiments 4 and 6 where the precued figures disappeared after the end of the first half of the trial. These error rates were much higher than for the below average and retarded subjects in Experiments 1, 2 and 5, where the precued figures remained present in the second half of the trial. The Experimental Group in Experiment 5 did show a decline in solution times and error rates compared to the retarded groups in Experiments 1, 2 and 5 (Control Group) suggesting that training did improve performance to a certain degree. However, the difference between the Experimental and Control Groups in

Experiment 5 is less significant than the difference between retarded and nonretarded groups. The retarded subjects at no time produced solution times or error rates comparable to the nonretarded subjects. It would be interesting to examine whether with increased practice following training, the retarded subjects became faster and more consistent and accurate in their solutions and also, if this had any effect on the model used and the amount of variance accounted for. As mentioned previously, Phillips and Nettelbeck (1984) conducted a series of experiments using retarded subjects similar to those used in this thesis. They examined performance on the S. Sternberg (1969, a, b) memory scanning task and the effect extended practice had on level of performance. They found that after seven practice sessions the performance level of the retarded subjects had improved dramatically. In comparison to the nonretarded group given no practice, the retarded groups performance was very similar although they were still slightly slower overall. In addition, Phillips and Nettelbeck (1984) found that the individual differences between the retarded subjects were reduced after extended practice and that after a three month period of no practice, performance on the task by the retarded subjects was still high. (It had declined in the first session after the three month time lapse but rose to a high level in the second session).

Retarded subjects in this series of experiments using R.J. Sternberg's (1977 a, b) task also became faster and more accurate over sessions. Improvement in the amount of variance accounted for by the models from the first to the last session was however, much less evident. More evident was a change in the best fitting model from a more exhaustive to a more self-terminating one (see Table 8.5). It was also the case that the retarded subjects participated in at least five sessions using the People Piece Analogy task in all experiments and as many as six sessions in Experiments 5 and 6. In these latter two

experiments, the last two sessions were conducted 3 to 4 months after the presentation of the first four sessions. These last two sessions accounted for slightly more of the variance than in the earlier experimental sessions. Solution times were also slightly faster and error rates were slightly lower. This result is similar to that obtained by Phillips and Nettelbeck (1984) although their subjects showed an initial decline in performance after a three month time lapse, whereas the subjects in these experiments performed at a slightly improved level in both maintenance sessions.

These results tend to suggest that extended practice together with training may improve performance even more than that observed in Experiments 5 and 6 in terms of decreased solution times and error rates and an increased percentage of the variance accounted for by the retarded subjects. It may also show the increased and more efficient use of self-terminating processes. It is the opinion of this author however, that extended practice without training as provided by Phillips and Nettelbeck (1984) would not improve performance on the People Piece Analogy task or at least not in seven practice sessions. The People Piece Analogy task is a more difficult task, especially when the modifed method of precueing (where the precued figures disappear at the end of the first half of trial) is used. In addition, at least two experimental sessions are required to obtain task results as opposed to only one session being required using the S. Sternberg (1969, a,b) memory scanning task. If just practice were to be used, a very large number of practice sessions would be required which might cause problems in terms of other factors such as interest and motivation to continue the task.

One important result of the training and practice received by the the retarded subjects in Experiments 5 and 6 and the method of precueing in Experiment 6 was that they spent more time on encoding. In Experiment 6, this was

transferred to a saving in the application and mapping processes in the initial experimental phase and to all processes in the maintenance phase. This also appears to have resulted in a greater percentage of variance being accounted for especially for the nondegenerate analogies. However, this improvement only occured under these ideal conditions. It would be interesting to examine whether transfer to other tasks occurred under these ideal conditions. Given the results obtained in Experiment 5 for the experimental group this may be unlikely. An increased probability of success might be found if training on at least two analogy tasks was provided as Belmont, Ferretti and Mitchell (1978) found using two similar verbal learning memory tasks.

8.4.4 THE BROADER IMPLICATIONS FOR TRAINING THE MENTALLY RETARDED

What are the broader implications of the results in terms of training the mentally retarded to perform other experimental tasks?

Firstly, it appears that training can improve the performance of retarded subjects on cognitive tasks and this improvement can be maintained over time, a result also found by other researchers (Belmont and Butterfield, 1977; Campione, Brown and Ferretti, 1982). More importantly, this is the case even on difficult tasks such as the one used in Experiment 6, where the precued figures disappeared after the end of the first part of the trial, thus requiring the greater use of short term memory when solving the analogies. What appears to be required, if possible, is the simplification of the task. For example, it was found in Experiment 3 that after one practice session, the retarded subjects were unable to perform the People Piece Analogy task when the precued figures disappeared after the end of the first half of the trial, in conjunction with four cue conditions. Contrast this with the nonretarded

subjects who performed the task adequately after only 48 initial practice trials. Included in this high level of task complexity was the need to use memory in three of the four cue conditions, with each of these cue conditions placing different loads on short-term memory, and to understand the nature of the nondegenerate (Type II) analogies.

The results of this series of experiments suggest that to achieve more consistent and efficient performance on a difficult task it may be better to concentrate on developing the use of effective strategies and delay large improvements in speed. This would be particularly the case if the strategy would subsequently be useful for a range of tasks. As noted previously, it is possible that with extended practice, speed and accuracy could be improved upon. In addition, training on a more thorough (exhaustive) strategy may eventually lead to the adoption of a quicker (self-terminating) strategy by retarded subjects which they can then use more efficiently.

The importance of positive feedback must also be considered. In Experiments 2, 4, 5 (Experimental group) and 6, immediate positive feedback was provided to the retarded subjects. This consisted of a verbal reinforcement, the word "good", stated after each trial in which the subject correctly solved the analogy. Zigler (1973; Zigler and Balla, 1981) has strongly advocated the importance of motivational aspects and feelings of self-worth in retarded subjects and their performance on many sorts of tasks. He has suggested that the retarded subjects' history of failure in academic settings leads to a lack of motivation when placed in a learning situation. If the subjects had some tangible evidence that they were progressing well, their motivation to continue with the task might be increased and this would result in further improvements in task performance. This appeared to be the case in the series

of experiments here. In the one experiment where retarded subjects received no feedback (Experiment 5, Control Group), solution times, standard deviations and error rates were higher than an Experimental Group matched for IQ who received feedback. Waters (1979) examined the impact of positive feedback on the performance of retarded subjects in a sheltered workshop setting on an industrial sewing task. She also found that feedback significantly improved performance. In addition, she found that the more consistent and regular the feedback, the more the performance level of the subjects improved. Feedback therefore, appears to be an important factor in maximising the performance level of retarded individuals.

8.5 THE COMPONENTIAL METHOD AND CRITISICMS MADE OF THE SUBTRACTIVE METHOD.

In Chapter 1, the advantages and disadvantages of the subtractive method were discussed. Sternberg (1977a) suggested that his componential method avoided the problems of the subtractive method. This section is concerned with examining whether this has been the case, in this series of experiments.

Firstly, the conceptualisation of the method is an extremely sophisticated one. Certain processes are proposed to occur when reasoning by analogy and four models are constructed to test the validity of these processes. However, all four models are very similar and include the same processes, these processes just occuring in either of two forms, exhaustive or self-terminating. Models which include very different processes are not investigated but these may account for as much or more of the variance than the models tested, as was found with investigations of Clark and Chase (1972) and Carptenter and Just's (1975) models of the sentence verification task. Also, Mulholland, Pellegrino and Glaser (1980) used a slightly different model to measure

processes used in geometric analogy solution, which accounted for 97% of the variance. Bethell-Fox, Lohman and Snow (1984) in testing Sternberg's models have suggested that Model 1 may be a better model to adopt since it accounts for a similar amount of the variance as the self-terminating models and is more parsimonious in terms of obtaining parameter estimates.

Pachella (1974) has suggested that a sophisticated conceptualisation of a method tends to be similar to a self-fulfilling prophecy, in that the data obtained support the model tested because the task is so arranged that the model will be supported. This same criticism can be made of the nonretarded and retarded subjects in terms of using the modified method of precueing and can even be made of Sternberg's subjects and their having received the original method of precueing. It is likely that both methods of precueing direct the subjects to solve the analogies in a particular way, and in a way that they might not normally use. The hope is that the redirection does not alter too markedly the way in which the subjects solve the analogies. In most experimental work in cognitive psychology it is difficult to design techniques which make it possible to measure processes quantitatively without changing the processes themselves in a way that would only occur under experimental circumstances and it may be the case that Sternberg's method suffers from the same problem, especially when used with retarded subjects.

Secondly, the assumptions of pure insertion and additivity, which are part of any subtractive method, are also incorporated into the componential method. As noted previously, it is assumed that cue times increase and solution times decrease across cue conditions, because of the increase in processing taking place in the first half of the trial, as the number of precued figures increases. If the assumption of pure insertion is actually being met, one might expect the

cue and solution times in each cue condition when added together to give an overall similar total response time.

Table 8.7 presents these data for Sternberg's nonretarded subjects and for the subjects in Experiment 3.

TABLE 8.7

Total Mean Response Times Across Cue Conditions

Sternberg's subjects and Experiment 3 Nonretarded Subjects

SUBJECT GROUP	CUE CONDITION			
Sternberg's Subjects	0	1	2	3
Cue Time	530	755	952	1147
Solution Time	1423	1328	947	681
Total Mean Response Time	1953	2083	1899	1828
Experiment 3 Nonretarded Subjects				
Cue Time	644	2117	2644	3260
Solution Time	2317	2194	1372	938
Total Mean Response Time	2961	4311	4016	4198

Data from the remaining experiments are not presented because in Experiments 4, and 6 only two cue conditions can be compared. In Experiments 1, 2 and 5 also, solution times were very similar across cue conditions suggesting that the same processes were being used irrespective of the number of precues presented. The results from Experiment 3 are those most comparable to those obtained by Sternberg (1977a).

As can be seen in the top half of the table, the assumption of pure insertion

appears to have been met according to this criteria for Sternberg's data. Total response times for all four cue conditions are approximately equivalent for Sternberg's subjects, while cue times increase and solution times decrease across cue conditions. For the data in Experiment 3, a slightly different pattern is obtained. If only the 1, 2 and 3 cue conditions are considered, total response times across cue conditions are approximately equivalent. However, the mean response time to the 0 cue condition is much shorter than those obtained for the other three cue conditions. This does not invalidate the assumption of pure insertion since as mentioned in the discussion of the results of Experiment 3, this is probably due to the addition of a memory load to the cue times in the 1, 2 and 3 cue conditions caused by the disappearance of the precued figures in the second half of the trial. Subjects are spending longer encoding the figures in these cue conditions and storing them in short-term memory. This suggestion is supported by the fact that there is a dramatic increase in the cue times from the 0 to 1 cue condition but only a slight increase thereafter. Indeed this suggests that memory load as a process could be measured in this instance, and tends to validate the assumption of pure insertion for the subjects in this experiment.

The assumption of additivity was tested using the simplex model and analysis of variance for cue condition. From these results it appeared that the nonretarded subjects in Experiments 1, 2 and 3 (where the test for simplical structure could be made) were making use of the precued figures. However, it was the observation of the author that the nonretarded subjects in Experiments 1 and 2 appeared to be making little use of the precued figures since they pressed the central key after only a brief examination of these figures compared to the nonretarded subjects in Experiment 3. For the below average and retarded groups in Experiments 1 and 2, the results were even less

consistent, both groups evidencing a number of break downs in simplical structure. Evidence from examination of actual cue and solution scores also tended to support these conclusions for these subjects.

The results of the analyses of variance must be dealt with separately in Experiments 1, 2 and 3 where four cues were used and Experiments 4, 5 and 6 where only two cues were used. In the former group of experiments it was possible to test for a significant linear trend, in addition to a main effect for cue. In Experiments 1 and 3 a significant main effect for cue and a significant linear trend were obtained. In Experiment 2, only a significant main effect for cue was obtained because of the nonuse of the precued figures by the retarded subjects. In Experiments 4 and 6 a significant main effect for cue was obtained but no significant effect for cue was obtained in Experiment 5. Thus, the general trend is for the assumption of additivity, as measured by the simplex model and analysis of variance to be upheld in two instances; namely, in all experiments where nonretarded subjects were used and, for the retarded subjects where the simplified task and modified method of precueing were used together.

Thirdly, the lack of difference between the models tested must be considered. Throughout all the experiments in this thesis for nonretarded, below average and retarded groups, the lack of difference between the models and particularly Models III and IV has been a major problem. This is true also of Sternberg's original findings where only 1% of the variance separated Model III from Model IV. It is also evident in the study by Bethell-Fox, Lohman and Snow (1984) who used Sternberg's method and is thus a strong criticism that can be made of the componential method. As has been discussed a number of

times previously, the lack of difference between the models appears at least in part to be due to flexibility between and within subjects as to the form of each process used i.e. whether exhaustive or self-terminating. In addition, Sternberg (1977a) has himself suggested that an unusually large parameter estimate for a particular process may indicate a confounded parameter which could in turn lead to a lack of difference between alternative models. The preparation-response parameter estimate (regression constant) is large in all experiments using retarded subjects except for the retarded subjects in the maintenance phase of Experiment 6. This may be due to the encoding parameter being partially confounded in the regression constant in those experiments where the retarded subjects have not used the precued figures or have used them minimally (i.e. Experiments 1, 2 and 5). The same can also be said of the nonretarded subjects in Experiments 1 and 2. The size of the regression constant may also be related to the lack of consistency in performance of the retarded subjects.

The componential method therefore, appears to suffer from a number of the problems faced by other subtractive methods. Firstly, the experimental task is designed in such a way that it is likely to support the models tested. Secondly, while there is support for the assumptions of pure insertion and additivity this was less so for the latter for the retarded subjects, and when the original method of precueing was used, for both nonretarded and retarded groups. Much more obvious use of the precued figures was obtained when the modified method of precueing (where the precued figures were removed in the second half of the trial) was included. Thirdly, it was difficult to distinguish between alternative models due possibly to between and within subject differences. Fourthly, the estimate for the preparation-response process was large for all model fits and especially for the retarded subjects in all experiments, excluding the final phase of Experiment 6. This suggests a

confounded parameter hidden within the regression constant or at least poor consistency of performance where below average and retarded subjects are concerned. Finally, mathematical modelling requires consistent performance, a result particularly difficult to obtain using retarded subjects on any task.

8.6 THE COMPONENTIAL METHOD, ANALOGICAL REASONING AND COGNITIVE PROCESSING

The results of this series of experiments suggest that the processes involved in analogical reasoning, at least for nonretarded subjects, include those postulated by Sternberg, namely, encoding, inference, mapping, application and preparation response.

However, whether the models tested here provide a better explanation of the processes used in other analogical reasoning tasks is not known. The results obtained here may be very task-specific. Sternberg (1977a) also investigated the applicability of the componential method to the solution of geometric and verbal analogies. The results he obtained in the case of these types of analogies were more equivocal than those obtained using the People Piece Analogy task. In the case of verbal analogies, Model III provided the best fit to the data, accounting for 85.6% of the variance in the case of the verbal analogies. Model IV accounted for 84.8% of the variance, Model II for 84.7% of the variance and Model I for 83.2% of the variance. Thus, the lack of difference between the models here, is much greater than that obtained for the People Piece analogies and is similar to the results obtained in this thesis. For the geometric analogies, Model III again provided the best fit to the data, accounting for 80.4% of the variance. Model IV followed accounting for 80.0% of the variance. Model II accounted for 79.7% of the variance and Model I

for 73.8% of the variance. This analysis included an additional parameter, justification, since the analogies were in a forced choice format i.e. two or more D terms were provided, the subject having to choose the best fitting option given the A, B and C terms. Again Models III and IV were virtually indistinguishable and Model II also followed closely as the model providing the next best fit. As mentioned previously in this chapter, the study by Mulholland, et al (1980) also investigated the processes used in geometric analogy solution. As described in Chapter 1, they proposed the use of two processes, encoding and transformation. Encoding consisted of the encoding and decomposition of the analogy terms into their constituent elements. Transformation consisted of discovering the transformations between the A and B and C and D terms. Using a simple linear model (RT = T (no of transformations)) + E (no of elements to be encoded) they were able to account for 95% of the variance. This was marginally improved (97%) when a more complex model (RT = T + E + TE) was used. Thus, this model actually provides a better fit to the data than Sternberg's models. Since Sternberg's models include encoding, inference, mapping, application, justification and preparation-response, they are also certainly much less parsimonious. Bethell-Fox et al (1984) have advocated the adoption of Model I as the best model because the differences between it and the other more self-terminating models is mariginal and it is more parsimonious in terms of extraction of components. Two processes that occur in both Sternberg's and Mullholland et al's model are encoding and inference/mapping (number of transformations). These two processes might therefore be considered important in a general scheme of analogical reasoning. (It was not possible to apply the model developed by Mulholland et al, 1980 to the People Piece analogy experiment as in these analogies, the number of elements to be encoded is always four and therefore would become a constant in parameter estimation and model fitting).

Are these two processes, encoding and inference/mapping important to a general model of cognitive processing? How information is initially encoded would appear to be very important to how it is further processed. Indeed the results obtained from the nonretarded and retarded subjects, with regard to encoding, would tend to support this. The ability to extract the relationship between items on a larger scale than analogies would also appear to be important to efficient cognitive processing. It is widely considered to be the case that this is a major factor in intellectual ability (Greeno, 1978; Norman, Gentner and Stevens, 1976; Oppenheimer, 1956). And in the case of the intellectually retarded, it would appear that it is an area in which they experience difficulties. The experimental findings indicate a lack of the transfer of knowledge or strategic behaviour from one task to another where it would be relevant. As discussed in Chapter 2, this is a major cause of the failure of the retarded individual to perform cognitive tasks efficiently. This might be considered as a failure to realise the similarity of the relationship between the training and the transfer task.

8.7 OVERALL CONCLUSIONS AND DIRECTIONS FOR FUTURE RESEARCH

The results of this series of experiments suggest firstly, that the componential method developed by RJ Sternberg can provide a reasonable explanation of the data obtained using nonretarded subjects. The results obtained here were however, not always consistent with those obtained by Sternberg in his original experiments. Interval scores and standard deviations were considerably larger and model changes occurred across cue conditions and sessions. In addition, the method in its present form can not be used as efficiently to examine individual differences in strategy usage as some other methods discussed previously.

With regard to the intellectually retarded subjects, results were less supportive of the ability of the componential method to provide reliable and valid results. The amount of variance accounted for was much lower even when the retarded subjects received explicit instructions, a simplified task and training with that task. Their data were generally less consistent compared to the nonretarded subjects, evidencing a high level of variability.

This is a common finding in research using retarded subjects (Baumeister and Kellas, 1968) but becomes particularly difficult when using mathematical modelling procedures which require consistent performance both within and across subjects. Extensive practice (Phillips and Nettelbeck, 1984) may help to overcome this problem, but whether the People Piece Analogy task in its present form is as readily adaptable to many practice sessions as the memory scanning task used by Phillips and Nettelbeck (1984) is questionable given the need for more than one experimental session to obtain a full set of data. Task complexity (Bray, 1979) may also be a factor here and given that the analogy task is a more difficult task than memory scanning, it may require more sessions.

Some interesting results were obtained with regard to the improvement in encoding time for these subjects and the maintenance of improved performance overtime. Solution and cue times were also reduced when the task was not made more difficult by the introduction of the modified precueing method and adequate training was provided (Experiment 5). Standard deviations also were lower in this experiment and in Experiment 6 in the maintenance phase of the experiment. This suggested that training and practice, as Phillips and Nettelbeck, (1984) found, can reduce variability in retarded subjects. In addition, training which produced more exhaustive processing initially appeared to lead to more efficient use of quicker self-terminating processes over time. However, it can always be argued that

the high level of training and instruction received by the retarded subjects to improve the amount of variance accounted for, is significantly altering the way in which they would perform the task and the processes they would use, if left uninstructed. This may not matter if more efficient performance on the particular task is of primary interest, as opposed to interest in what type of processes the retarded use without instruction.

Finally, a number of criticisms can be made of the actual models, and experimental procedure. It was found to be very difficult to obtain use of the precued figures by means of the original method of precueing used by Sternberg. Much more obvious use of these figures was obtained when the modified method of precueing was introduced. The models themselves were often indistinguishable or different from each other by less then 10% of the variance. This result was also present in the analysis of each individual's data separately, where even less of the variance was accounted for. Use of the method appears to be, at least to some extent, task-specific and nonparsimonious in the number of processes proposed to be used. Three processes appear to be of value to a general model of processing, namely encoding, inference and mapping, the latter two of which could be amalgamated into a single process (as done by Mulholland, Pellegrino and Glaser, 1980). Alternatively, an approach used by Bethell-Fox, Lohman and Snow (1984) may be better.

The results of the present series of experiments therefore, indicate that Sternberg's componential method requires modification if it is to be used to further investigate the cognitive processes used in analogical reasoning. For nonretarded subjects, it would be interesting to investigate individual differences in the processes used. This can only be done in a rudimentary fashion in the componential method as it now stands. As Bethell-Fox et al suggest, incorporation of both Sternberg's constructive-matching and

Mulholland et al's response-elimination type strategies in the same experimental procedure appears to be a good direction in which to proceed. This might be done by inclusion of only Type II analogies and the use of geometric rather than People Piece analogies. In this way a wider variety of item difficulty levels could be incorporated which could be quantifiably examined.

One weakness of the People Piece analogies is the fixed nature of the number of elements in each analogy term - it is alway four. Thus, extraction of the encoding parameter is dependent on the use of the precueing method. Use of geometric analogies would avoid this problem, because in these analogies the number of elements can be varied from analogy to analogy. Thus, encoding can be predicted independently of the precueing procedure. The precueing procedure could still be retained, but it would need to be in the modified form used in Experiments 3, 4 and 6 so that obvious use of the figures could be obtained (thus ensuring that parameter dropouts actually occur).

The choice of whether to use four or two cue conditions might depend on the number of sessions the experimenter wishes to include, both procedures tending to give equally reliable results for nonretarded subjects. Retention of the precueing procedure would allow separate estimates of each of the parameters involved in a constructive-matching strategy to be made. It would also allow for the estimation of a memory component using the cue scores, if used with the modified method of precueing. One would expect this memory component to be evident in the 1, 2 and 3 cue conditions and to vary across each of these conditions. For example, the three cue condition might require more memory in terms of the maintenance of three terms and their relationships while processing the last figure. However, this may not be the case. The 2 cue condition may in fact be the most difficult, in that two terms

and their relationship must be maintained in short-term memory while processing of the two remaining terms occurs. Thus, more information must be maintained in short-term memory for a longer period of time.

In terms of retarded subjects, some of the above mentioned proposals might be easily incorporated into an experiment comparing these and nonretarded subjects. However, they may also raise difficulties not encountered using just nonretarded subjects. For example, retarded subjects may find geometric analogies less intuitively interesting and/or more difficult than People Piece Analogies. The People Piece analogies only have changes in terms of the four elements, height, weight, sex and colour and these would be comparatively familiar to retarded subjects. It is conceivable that retarded subjects might find the changes in geometric analogies more difficult, as these and their number could vary from analogy to analogy. Some might also be less familiar to retarded subjects, being changes in size, shape, addition, subtraction and rotation. In addition, removal of the Type I analogies would remove some items that even retarded subject find easy.

Other problems might be that training would still be required before adequate use of the modified method of precueing could be achieved by retarded subjects, especially if four cue conditions were used. It is the case that in this series of experiments the simplified task, using only two cue conditions, tended to produce more reliable results. It also allows the use of more training practice sessions, requiring only two rather than four experimental sessions.

Another problem is that mathematical modelling would still be required, irrespective of which of the methods described was used. It is likely that training and/or practice is not going to improve the consistency of the

retarded subjects performance so that it equals that of nonretarded subjects. However, an experiment providing extensive training and/or practice may be successful given the results obtained by Phillips and Nettelbeck (1984). In relation to using all four or just two cue conditions (the simplified task) it is likely that there would be an interaction between the amount of training and/or practice provided and the type of task used (Bray, 1979). One aspect that might be investigated here is whether after training with the modified method of precueing, the retarded subjects continued to use the precued figures in experimental sessions that presented the analogies using the original method of precueing. A return to nonuse of the precues might be more likely in the four as opposed to the two cue condition design as this requires a greater memory load and therefore more effort on the part of the subject.

Some features worthy of investigation using nonretarded and retarded subjects might be the effect of the introduction of a memory component on the type of strategy used and whether training on a number of analogy tasks would produce transfer. In the case of the former, one might expect retarded subjects to use a response-elimination strategy even on more difficult items because of the additional memory load caused by constructive-matching and also because of the findings of Bray, Dan and Gwartney (1978) that retarded subjects tend to use simpler strategies than nonretarded subjects.

In the case of the latter, training on two or more analogy tasks could be examined by explaining to subjects the differences and similarities between the tasks, as done by Belmont, Ferretti and Mitchell (1978). For example, training could be provided on People Piece and geometric analogies explaining the similarities and differences between these two tasks. Subjects could then be tested on the Ravens Progressive matrices as a test of 'near' transfer (to

geometric analogies) and on verbal analogies as a test of 'far' transfer. The trained strategies would need major modification to be successfully applied to verbal analogies. Use of these types of analogies would also possibly be influenced by other variables such as language and verbal skills possibly making it less likely to obtain transfer.

Another factor that might provide interesting results, is the analysis of eye movements on an analogical reasoning task, for both nonretarded and retarded subjects. Studies by Bethell-Fox et al (1984) in analogical reasoning, Caprenter and Just (1978) in spatial rotation and Nettelbeck et al (unpublished manuscript) in inspection time and mental retardation have all yielded interesting results from the analysis of eye movements. Adoption of this type of analysis might proceed in two ways. Firstly, as a means of examining whether nonretarded and retarded subjects are making use of the precued figures, using both the original and modified method of precueing in the People Piece Analogy task. Secondly, it could be used to examine what type of processing is used to solve items of different levels of difficulty (as Bethell-Fox et al, 1984, did) and if there are any differences between nonretarded and retarded subjects (as done by Nettelbeck et al, unpublished manuscript). It would also give an indication of the overall strategy used to solve particular tasks, for example, a working-forward or working-backwards strategy.

Finally, one troublesome feature of the componential method that is highlighted by the use of retarded subjects, namely the need for error free data for mathematical modelling, could be examined. An analysis that separated those analogies correctly and incorrectly solved from each other might reveal process differences between nonretarded and retarded subjects and between correctly and incorrectly solved analogies. For example, one

might expect more errors to be made on the Type II People Piece analogies and especially the more difficult (those with the largest number of AB/AC attribute changes) of these analogy types, and also for retarded subjects. In addition, it might be the case that processing becomes more exhaustive for the more difficult analogies solved correctly but not for those solved incorrectly. Thus, again, one might expect retarded subjects to use more self-terminating processing and therefore make more errors. It would be possible to test this by dividing the analogies into different difficulty levels based on number of AB/AC changes and conducting model fits for each level.

The general conclusion of this author concerning the componential method is that it is a good starting-off point for further investigations of cognitive processing. It can provide reliable results for group data, although less so in the case of retarded subjects. It can not, however, provide more than general information about individual differences in processing both between and within subjects. It is a good theoretical and methodological base from which to build but it requires significant modifications (some of which have been discussed here) if it is to contribute to and be able to account for, the complexity and diversity of analogical reasoning processes, specifically, and cognitive processes in general, in both nonretarded and retarded populations.

APPENDICES

Significance levels are reported only when significant at the .05 (*) or .01 (**) level. All analyses of variance were caluclated using the Genstat V Statistical Packages Mark 4.01 - 4.03 (1977, 1978, 1979, 198). Analyses of variance tables are reproduced in the same format as the output tables. All model fitting was calculated using the subprogram, Linear Multiple Regression, from the Statistical Package for Social Sciences (SPSS, 2nd Edition, 1975) and SPSS Updates 7-9 (1981).

Key to abbreviations used in the analysis of variance tables:

Df	Degrees of Freedom
SS	Sum of Squares
SS%	Sum of Squares as a percentage of corrected SS of input data
MS	Mean Square
VR	F Ratio

Appendix 1.1 Analysis of variance of solution times for above and below average subjects in each cue condition and for each analogy type.

Source	Df	SS	SS%	MS	VR
Cue.Type.Group. Units Stratum					
Cue	3	8189418	2.17	2729806	2.963*
Lin	1	8034432	2.13	8034432	8.720**
Quad	1	135256	0.04	135256	0.147
Deviations	1	19729	0.01	19729	0.021
Type	1	111224719	29.44	111224719	120.716**
Group	1	89874870	23.79	89874870	97.545**
Cue.Type	3	134074	0.04	44691	0.049
Lin.Dev	1	64518	0.02	64518	0.070
Quad.Dev	1	28082	0.01	28082	0.030
Deviations	1	41475	0.01	41475	0.045
Cue.Group	3	1982326	0.52	660775	0.717
Lin.Dev	1	1642257	0.43	1642257	1.782
Quad.Dev	1	288765	0.08	288765	0.313
Deviations	1	51305	0.01	51305	0.056
Type.Group	1	3016021	0.80	3016021	3.273
Cue.Type.Group	3	1232888	0.33	410963	0.446
Lin.Dev.Dev	1	1038587	0.27	1038587	1.127
Quad.Dev.Dev	1	132090	0.03	132090	0.143
Deviations	1	62210	0.02	62210	0.068
Residual	176	162161351	42.92	921371	
Total	191	377815667	100.00	1978092	

* significant at .05
** significant at .01

Appendix 1.2 Repeated measures analysis of variance of solution times in sessions 1 and 4 for above and below average subjects in each cue condition and for each analogy type.

Source	Df	SS	SS%	MS	VR
Grp.Subject Stratum					
Grp	1	180461988	20.51	180461988	15.610**
Residual	22	254340946	28.91	11560952	48.452
Total	23	434802935	49.42	18904475	79.229
Grp.Subject.Session Stratum					
Session	1	46274540	5.26	46274540	29.626**
Grp.Session	1	168254	0.02	168254	0.108
Residual	22	34363557	3.91	1561980	6.546
Total	24	80806351	9.19	3366931	14.111
Grp.Subject.Type Stratum					
Type	1	226845834	25.79	226845834	161.609**
Grp.Type	1	6346359	0.72	6346359	4.521*
Residual	22	30880684	3.51	1403667	5.883
Total	24	264072877	30.02	11003037	46.114
Grp.Subject.Cue Stratum					
Cue	3	15243615	1.73	5081205	15.648**
Grp.Cue	3	3633654	0.41	1211218	3.730*
Residual	66	21431340	2.44	324717	1.361
Total	72	40308609	4.58	559842	2.346
Grp.Subject.Session.Type Stratum					
Session.Type	1	400158	0.05	400158	1.039
Grp.Session.Type	1	1541280	0.18	1541280	4.002
Residual	22	8472587	0.96	385118	1.614
Total	24	10414026	1.18	433918	1.819
Grp.Subject.Session.Cue Stratum					
Session.Cue	3	363869	0.04	121290	0.452
Grp.Session.Cue	3	986511	0.11	328837	1.224
Residual	66	17726389	2.01	268582	1.126
Total	72	19076770	2.17	264955	1.110
Grp.Subject.Type.Cue Stratum					
Type.Cue	3	516958	0.06	172319	1.060
Grp.Type.Cue	3	1742831	0.20	580944	3.574
Residual	66	10727635	1.22	162540	0.681
Total	72	12987424	1.48	180381	0.756
Grp.Subject.Session.Type.Cue Stratum					
Session.Type.Cue	3	818856	0.09	272952	1.144
Residual	69	16463798	1.87	238606	
Total	72	17282654		240037	
Grand Total	383	879751644	100.00		

* significant at .05
** significant at .01

Appendix 1.3 Linear regression tables for above and below average subjects, Models I to IV.

NONRETARDED Ss

MODEL I

Parameter	Time	Standard Error	β	Freq.	df
y	369	37	.46	102	1,295
x	87	53	.09	3	1,295
a	131	28	.21	22	1,295
z	287	47	.29	37	1,295
c	1169				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.42	.64	212	1,298
x	.49	.57	144	2,297
a	.51	.36	101	3,296
z	.56	.47	94	4,295

MODEL II

Parameter	Time	Standard Error	β	Freq.	df
y	429	35	.53	150	1,295
x	157	44	.17	12	1,295
a	102	25	.16	16	1,295
z'	453	52	.33	75	1,295
c	1144				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.42	.64	212	1,298
x	.49	.57	144	2,297
a	.51	.36	101	3,296
z'	.61	.34	113	4,295

MODEL III

Parameter	Time	Standard Error	β	Freq.	df
y'	744	51	.56	213	1,295
x	210	39	.22	29	1,295
a	95	24	.15	16	1,295
z'	276	48	.20	33	1,295
c	1310				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y'	.53	.73	331	1,298
x	.60	.57	226	2,297
a	.62	.36	159	3,296
z'	.66	.34	140	4,295

MODEL IV

Parameter	Time	Standard Error	β	Freq.	df
y'	709	54	.53	171	1,295
x'	377	72	.24	27	1,295
a	101	23	.16	19	1,295
z'	215	51	.16	17	1,295
c	1357				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y'	.53	.73	331	1,298
x'	.62	.65	239	2,297
a	.63	.36	170	3,296
z'	.65	.34	139	4,295

RETARDED Ss

MODEL I

Parameter	Time	Standard Error	β	Freq.	df
y	422	80	.31	28	1,295
x	- 11	115	-.01	1	1,295
a	40	60	.04	.44	1,295
z	536	104	.32	27	1,295
c	2464				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.17	.41	60	1,298
x	.19	.34	35	2,297
a	.19	.11	23	3,296
z	.26	.41	26	4,295

MODEL II

Parameter	Time	Standard Error	β	Freq.	df
y	536	78	.40	48	1,295
x	117	97	.07	1	1,295
a	- 17	55	-.02	1	1,295
z'	867	116	.37	56	1,295
c	2405				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.17	.41	60	1,298
x	.19	.34	35	2,297
a	.19	.11	23	3,296
z'	.32	.37	35	4,295

MODEL III

Parameter	Time	Standard Error	β	Freq.	df
y'	1029	115	.46	80	1,295
x	153	87	.10	3	1,295
a	- 27	53	-.03	.26	1,295
z'	635	110	.27	33	1,295
c	2609				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y'	.29	.54	124	1,298
x	.31	.34	65	2,297
a	.31	.11	44	3,296
z'	.38	.37	45	4,295

MODEL IV

Parameter	Time	Standard Error	β	Freq.	df
y'	983	122	.44	65	1,295
x'	330	161	.13	4	1,295
a	- 27	52	-.03	.27	1,295
z'	574	117	.25	24	1,295
c	2666				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y'	.29	.54	124	1,298
x'	.33	.45	72	2,297
a	.33	.11	49	3,296
z'	.38	.37	45	4,295

Appendix 1.4 Linear regression tables for above, Models I, II and IV, and below average subjects, Models I, II and III, alternative procedure.

NONRETARDED Ss

MODEL I

Parameter	Time	Standard Error	β	Freq.	df
y	364	38	.49	91	1,295
x	100	68	.13	2	1,295
a	227	23	.36	101	1,295
z	184	76	.19	5	1,295
c	949				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.41	.64	209	1,298
x	.48	.60	136	2,297
a	.61	.36	153	3,296
z	.62	.47	118	4,295

MODEL II

Parameter	Time	Standard Error	β	Freq.	df
y	423	32	.57	170	1,295
x	107	34	.14	10	1,295
a	229	20	.37	130	1,295
z'	452	49	.33	84	1,295
c	740				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.41	.64	209	1,298
x	.48	.60	136	2,297
a	.61	.36	153	3,296
z'	.69	.34	168	4,295

MODEL IV

Parameter	Time	Standard Error	β	Freq.	df
y'	596	50	.50	140	1,295
x'	401	61	.33	43	1,295
a	228	19	.36	146	1,295
z'	62	53	.05	1	1,295
c	1074				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y'	.33	.73	332	1,298
x'	.60	.69	227	2,297
a	.73	.36	273	3,296
z'	.74	.34	205	4,295

RETARDED Ss

MODEL I

Parameter	Time	Standard Error	β	Freq.	df
y	430	85	.34	25	1,295
x	203	154	.16	2	1,295
a	121	50	.11	6	1,295
z	244	171	.15	2	1,295
c	2381				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.25	.50	98	1,298
x	.31	.50	66	2,297
a	.32	.11	47	3,296
z	.33	.41	36	4,295

MODEL II

Parameter	Time	Standard Error	β	Freq.	df
y	562	75	.45	56	1,295
x	142	78	.11	3	1,295
a	121	46	.11	7	1,295
z'	840	114	.36	54	1,295
c	1920				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.25	.50	98	1,298
x	.31	.50	66	2,297
a	.32	.11	47	3,296
z'	.43	.37	55	4,295

MODEL III

Parameter	Time	Standard Error	β	Freq.	df
y'	1031	98	.51	112	1,295
x'	212	62	.17	12	1,295
a	121	43	.11	8	1,295
z'	501	100	.21	25	1,295
c	2170				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y'	.41	.64	208	1,298
x	.45	.50	121	2,297
a	.46	.11	85	3,296
z'	.50	.37	75	4,295

Appendix 1.5 Linear regression tables for above and below average subjects, Models I to IV, 0 cue condition.

NONRETARDED Ss

MODEL I

Parameter	Time	Standard Error	β	Freq.	df
y	363	91	.48	16	1,71
x	202	163	.27	2	1,71
z	61	182	.06	.11	1,71
c	1858				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.44	.66	58	1,73
x	.51	.62	37	2,72
z	.51	.46	24	3,71

MODEL II

Parameter	Time	Standard Error	β	Freq.	df
y	467	76	.61	38	1,71
x	90	79	.12	1	1,71
z'	534	116	.38	21	1,71
c	1491				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.44	.66	58	1,73
x	.51	.62	37	2,72
z'	.62	.37	39	3,71

MODEL III

Parameter	Time	Standard Error	β	Freq.	df
y'	775	94	.63	68	1,71
x'	175	60	.23	9	1,71
z'	256	96	.18	7	1,71
c	1707				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y'	.62	.79	118	1,73
x'	.67	.62	74	2,72
z'	.70	.37	56	3,71

MODEL IV

Parameter	Time	Standard Error	β	Freq.	df
y'	623	108	.51	34	1,71
x'	509	130	.41	15	1,71
z'	44	115	.03	.15	1,71
c	1875				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y'	.62	.79	118	1,73
x'	.73	.77	95	2,72
z'	.73	.37	63	3,71

RETARDED Ss

MODEL I

Parameter	Time	Standard Error	β	Freq.	df
y	498	160	.43	10	1,71
x	133	288	.11	.21	1,71
z	234	321	.15	104	1,71
c	2881				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.30	.55	32	1,73
x	.35	.51	19	2,72
z	.35	.40	13	3,71

MODEL II

Parameter	Time	Standard Error	β	Freq.	df
y	640	137	.55	21	1,71
x	53	143	.05	.14	1,71
z'	877	209	.40	18	1,71
c	2382				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.30	.55	32	1,73
x	.35	.51	19	2,72
z'	.48	.38	22	3,71

MODEL III

Parameter	Time	Standard Error	β	Freq.	df
y'	1148	172	.61	44	1,71
x'	141	109	.12	2	1,71
z'	491	176	.23	8	1,71
c	2670				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y'	.51	.71	76	1,73
x'	.53	.51	41	2,72
z'	.58	.38	33	3,71

MODEL IV

Parameter	Time	Standard Error	β	Freq.	df
y'	999	202	.53	24	1,71
x'	458	245	.24	4	1,71
z'	295	216	.13	2	1,71
c	2820				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y'	.51	.71	76	1,73
x'	.58	.67	49	2,72
z'	.59	.38	34	3,71

Appendix 1.6 Linear regression tables for above and below average subjects, Models I to IV, 1 cue condition.

NONRETARDED Ss

MODEL I

Parameter	Time	Standard Error	β	Freq.	df
y	405	79	.53	26	1,71
x	149	143	.20	1	1,71
z	184	159	.18	1	1,71
c	1657				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.52	.72	79	1,73
x	.61	.69	57	2,72
z	.62	.54	38	3,71

MODEL II

Parameter	Time	Standard Error	β	Freq.	df
y	476	65	.63	53	1,71
x	141	68	.19	4	1,71
z'	506	100	.36	26	1,71
c	1407				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.52	.72	79	1,73
x	.61	.69	57	2,72
z'	.71	.37	59	3,71

MODEL III

Parameter	Time	Standard Error	β	Freq.	df
y'	762	80	.62	90	1,71
x'	235	51	.31	21	1,71
z'	224	83	.16	7	1,71
c	1630				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y'	.67	.82	146	1,73
x'	.76	.69	112	2,72
z'	.78	.37	84	3,71

MODEL IV

Parameter	Time	Standard Error	β	Freq.	df
y'	666	98	.54	46	1,71
x'	496	119	.40	17	1,71
z'	42	104	.03	.16	1,71
c	1799				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y'	.67	.82	146	1,73
x'	.77	.78	121	2,72
z'	.77	.37	80	3,71

RETARDED Ss

MODEL I

Parameter	Time	Standard Error	β	Freq.	df
y	393	205	.29	4	1,71
x	126	368	.09	.12	1,71
z	295	411	.16	.52	1,71
c	2779				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.16	.41	14	1,73
x	.21	.41	9	2,72
z	.21	.34	6	3,71

MODEL II

Parameter	Time	Standard Error	β	Freq.	df
y	537	181	.40	9	1,71
x	73	189	.05	.15	1,71
z'	945	276	.37	12	1,71
c	2275				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.16	.41	14	1,73
x	.21	.41	9	2,72
z'	.32	.36	11	3,71

MODEL III

Parameter	Time	Standard Error	β	Freq.	df
y'	1004	241	.46	17	1,71
x'	134	153	.10	1	1,71
z'	619	247	.24	6	1,71
c	2513				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y'	.31	.56	33	1,73
x'	.33	.41	18	2,72
z'	.38	.36	15	3,71

MODEL IV

Parameter	Time	Standard Error	β	Freq.	df
y'	831	285	.38	9	1,71
x'	490	345	.22	2	1,71
z'	402	304	.16	2	1,71
c	2671				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y'	.31	.56	33	1,73
x'	.38	.57	22	2,72
z'	.39	.36	15	3,71

Appendix 1.7 Linear regression tables for above and below average subjects, Models I to IV, 2 cue condition.

NONRETARDED Ss

MODEL I

Parameter	Time	Standard Error	β	Freq.	df
y	312	78	.48	16	1,71
x	57	140	.09	.17	1,71
z	240	156	.28	2	1,71
c	1441				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.40	.63	49	1,73
x	.49	.62	34	2,72
z	.50	.52	24	3,71

MODEL II

Parameter	Time	Standard Error	β	Freq.	df
y	356	67	.55	28	1,71
x	112	70	.17	3	1,71
z'	439	102	.36	18	1,71
c	1286				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.40	.63	49	1,73
x	.49	.62	34	2,72
z'	.59	.38	34	3,71

MODEL III

Parameter	Time	Standard Error	β	Freq.	df
y'	592	86	.56	47	1,71
x	176	55	.27	10	1,71
z'	227	88	.19	7	1,71
c	1451				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y'	.55	.74	90	1,73
x	.63	.62	60	2,72
z'	.66	.38	46	3,71

MODEL IV

Parameter	Time	Standard Error	β	Freq.	df
y'	549	105	.52	27	1,71
x'	320	127	.30	6	1,71
z'	119	112	.10	1	1,71
c	1561				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y'	.55	.74	90	1,73
x'	.63	.71	63	2,72
z'	.64	.38	42	3,71

RETARDED Ss

MODEL I

Parameter	Time	Standard Error	β	Freq.	df
y	349	169	.29	4	1,71
x	235	304	.20	.60	1,71
z	254	338	.16	.57	1,71
c	2605				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.22	.47	21	1,73
x	.30	.52	16	2,72
z	.31	.43	11	3,71

MODEL II

Parameter	Time	Standard Error	β	Freq.	df
y	470	148	.39	10	1,71
x	193	155	.16	2	1,71
z'	804	227	.36	13	1,71
c	2180				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.22	.47	21	1,73
x	.30	.52	16	2,72
z'	.41	.38	16	3,71

MODEL III

Parameter	Time	Standard Error	β	Freq.	df
y'	933	193	.48	23	1,71
x	229	122	.19	4	1,71
z'	516	198	.23	7	1,71
c	2382				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y'	.40	.63	48	1,73
x	.44	.52	29	2,72
z'	.49	.38	23	3,71

MODEL IV

Parameter	Time	Standard Error	β	Freq.	df
y'	778	228	.40	12	1,71
x'	590	276	.31	5	1,71
z'	281	243	.13	1	1,71
c	2579				

Parameter	Cumulative R_2	r	Cumulative Freq.	Cumulative df
y'	.40	.63	48	1,73
x'	.49	.65	35	2,72
z'	.50	.38	24	3,71

Appendix 1.8 Linear regression tables for above and below average subjects, Models I to IV, 3 cue condition.

NONRETARDED Ss

MODEL I

Parameter	Time	Standard Error	β	Freq.	df
y	379	53	.67	51	1,71
x	- 1	96	-.002	.22	1,71
z	244	107	.32	5	1,71
c	1112				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.61	.78	113	1,73
x	.67	.69	74	2,72
z	.70	.56	54	3,71

MODEL II

Parameter	Time	Standard Error	β	Freq.	df
y	401	45	.70	78	1,71
x	87	47	.15	3	1,71
z'	341	69	.32	24	1,71
c	1037				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.61	.78	113	1,73
x	.67	.69	74	2,72
z'	.76	.32	74	3,71

MODEL III

Parameter	Time	Standard Error	β	Freq.	df
y'	558	64	.61	76	1,71
x	193	41	.34	23	1,71
z'	108	66	.10	3	1,71
c	1233				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y'	.65	.80	134	1,73
x	.74	.69	105	2,72
z'	.75	.32	73	3,71

MODEL IV

Parameter	Time	Standard Error	β	Freq.	df
y'	541	82	.59	43	1,71
x'	297	100	.32	9	1,71
z'	19	88	.02	.47	1,71
c	1337				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y'	.65	.80	134	1,73
x'	.71	.72	89	2,72
z'	.71	.32	58	3,71

RETARDED Ss

MODEL I

Parameter	Time	Standard Error	β	Freq.	df
y	481	156	.39	9	1,71
x	318	281	.26	1	1,71
z	194	313	.12	.38	1,71
c	2470				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.35	.59	40	1,73
x	.44	.60	28	2,72
z	.44	.48	19	3,71

MODEL II

Parameter	Time	Standard Error	β	Freq.	df
y	600	137	.49	19	1,71
x	249	144	.20	3	1,71
z'	734	210	.32	12	1,71
c	2052				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.35	.59	40	1,73
x	.44	.60	28	2,72
z'	.52	.35	26	3,71

MODEL III

Parameter	Time	Standard Error	β	Freq.	df
y'	1039	178	.52	34	1,71
x	343	113	.28	9	1,71
z'	375	183	.16	4	1,71
c	2325				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y'	.49	.70	70	1,73
x	.57	.60	47	2,72
z'	.59	.35	34	3,71

MODEL IV

Parameter	Time	Standard Error	β	Freq.	df
y'	861	212	.43	16	1,71
x'	790	257	.40	9	1,71
z'	73	227	.03	.11	1,71
c	2591				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y'	.49	.70	70	1,73
x'	.59	.70	52	2,72
z'	.59	.35	34	3,71

Appendix 1.9 Linear regression tables for above and below average subjects, Models I to IV, nondegenerate, Type II analogies.

NONRETARDED Ss

MODEL I

Parameter	Time	Standard Error	β	Freq.	df
y	299	76	.34	15	1,116
x	218	76	.25	8	1,116
a	281	44	.48	41	1,116
c	1044				
*					

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.05	.22	6	1,118
x	.09	.08	6	2,117
a	.33	.48	19	3,116

MODEL II

Parameter	Time	Standard Error	β	Freq.	df
y	299	55	.34	30	1,115
x	-175	66	-.20	7	1,115
a	281	32	.48	80	1,115
z'	755	71	.73	113	1,115
c	1044				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.05	.22	6	1,118
x	.09	.08	6	2,117
a	.33	.48	19	3,116
z'	.66	.50	56	4,115

MODEL III

Parameter	Time	Standard Error	β	Freq.	df
y'	520	69	.50	57	1,115
x	14	71	.02	.38	1,115
a	281	29	.48	94	1,115
z'	365	83	.35	19	1,115
c	1115				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y'	.36	.60	65	1,118
x	.43	.08	44	2,117
a	.67	.48	77	3,116
z'	.71	.50	72	4,115

MODEL IV

Parameter	Time	Standard Error	β	Freq.	df
y'	511	53	.50	92	1,116
x'	378	53	.37	50	1,116
a	281	29	.48	95	1,116
c	1134				
*					

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y'	.36	.60	65	1,118
x'	.48	.50	54	2,117
a	.71	.48	96	3,116

RETARDED Ss

MODEL I

Parameter	Time	Standard Error	β	Freq.	df
y	343	143	.25	6	1,116
x	360	143	.26	6	1,116
a	64	82	.07	.60	1,116
c	2829				
*					

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.01	.12	2	1,118
x	.07	.14	4	2,117
a	.07	.07	3	3,116

MODEL II

Parameter	Time	Standard Error	β	Freq.	df
y	343	95	.25	13	1,115
x	-417	115	-.30	13	1,115
a	64	55	.07	1	1,115
z'	1494	124	.91	144	1,115
c	2828				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.01	.12	2	1,118
x	.07	.14	4	2,117
a	.07	.07	3	3,116
z'	.59	.65	41	4,115

MODEL III

Parameter	Time	Standard Error	β	Freq.	df
y'	817	116	.50	50	1,115
x	- 57	119	-.04	.23	1,115
a	64	49	.07	2	1,115
z'	881	140	.54	40	1,115
c	2623				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y'	.44	.66	91	1,118
x	.56	.14	76	2,117
a	.57	.07	51	3,116
z'	.68	.65	61	4,115

MODEL IV

Parameter	Time	Standard Error	β	Freq.	df
y'	852	89	.52	90	1,116
x'	830	89	.51	86	1,116
a	64	48	.07	2	1,116
c	2541				
*					

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y'	.44	.66	91	1,118
x'	.67	.65	121	2,117
a	.68	.07	82	3,116

* F-level or tolerance level insufficient for further computation

Appendix 1.10 Linear regression tables for above and below average subjects, Models I to IV, session 1.

NONRETARDED Ss

MODEL I

Parameter	Time	Standard Error	β	Freq.	df
y	482	59	.45	68	1,295
x	220	66	.21	11	1,295
a	232	36	.27	42	1,295
z	125	92	.07	2	1,295
c	1237				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.37	.61	172	1,298
x	.41	.54	102	2,297
a	.48	.27	91	3,296
z	.48	.32	69	4,295

MODEL II

Parameter	Time	Standard Error	β	Freq.	df
y	477	58	.44	68	1,295
x	219	59	.21	14	1,295
a	232	36	.27	43	1,295
z'	238	96	.11	6	1,295
c	1148				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.37	.61	172	1,298
x	.41	.54	102	2,297
a	.48	.27	92	3,296
z'	.49	.30	71	4,295

MODEL III

Parameter	Time	Standard Error	β	Freq.	df
y'	708	80	.43	77	1,295
x	309	52	.30	36	1,295
a	232	35	.27	44	1,295
z'	81	96	.04	1	1,295
c	1291				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y'	.36	.60	166	1,298
x	.43	.54	112	2,297
a	.50	.27	100	3,296
z'	.50	.30	75	4,295

MODEL IV

Parameter	Time	Standard Error	β	Freq.	df
y'	700	94	.42	55	1,295
x'	427	111	.26	15	1,295
a	232	36	.27	41	1,295
z'	15	113	.01	.17	1,295
c	1405				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y'	.36	.60	166	1,298
x'	.40	.55	98	2,297
a	.47	.27	88	3,296
z'	.47	.30	65	4,295

RETARDED Ss

MODEL I

Parameter	Time	Standard Error	β	Freq.	df
y	405	122	.25	11	1,295
x	10	220	.01	.22	1,295
a	62	72	.05	1	1,295
z	473	245	.22	4	1,295
c	2867				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.11	.34	38	1,298
x	.15	.35	26	2,297
a	.15	.05	17	3,296
z	.16	.32	14	4,295

MODEL II

Parameter	Time	Standard Error	β	Freq.	df
y	450	114	.28	16	1,295
x	176	119	.11	2	1,295
a	62	71	.05	1	1,295
z'	676	174	.23	15	1,295
c	2710				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.11	.34	38	1,298
x	.15	.35	26	2,297
a	.15	.05	17	3,296
z'	.19	.24	17	4,295

MODEL III

Parameter	Time	Standard Error	β	Freq.	df
y'	773	158	.30	24	1,295
x	249	100	.16	6	1,295
a	62	70	.05	1	1,295
z'	406	162	.14	6	1,295
c	2916				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y'	.17	.41	59	1,298
x	.19	.35	36	2,297
a	.20	.05	24	3,296
z'	.21	.24	20	4,295

MODEL IV

Parameter	Time	Standard Error	β	Freq.	df
y'	746	189	.29	16	1,295
x'	394	229	.15	3	1,295
a	62	70	.05	1	1,295
z'	286	202	.10	2	1,295
c	3054				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y'	.17	.41	59	1,298
x'	.20	.40	36	2,297
a	.20	.05	24	3,396
z'	.20	.24	19	4,295

Appendix 1.11 Linear regression tables for above and below average subjects, Models I to IV, session 4.

MODEL I

Parameter	Time	Standard Error	β	Freq.	df
y	317	40	.43	64	1,295
x	57	50	.09	1	1,295
a	211	26	.34	67	1,295
z	236	65	.21	13	1,295
c	687				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.30	.55	130	1,298
x	.34	.49	75	2,297
a	.46	.34	82	3,296
z	.48	.40	68	4,295

MODEL II

Parameter	Time	Standard Error	β	Freq.	df
y	345	39	.47	80	1,295
x	65	41	.09	3	1,295
a	211	25	.34	72	1,295
z'	389	63	.27	38	1,295
c	565				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.30	.55	130	1,298
x	.34	.49	75	2,297
a	.46	.34	82	3,296
z'	.52	.35	79	4,295

MODEL III

Parameter	Time	Standard Error	β	Freq.	df
y'	641	51	.54	155	1,295
x	105	33	.14	10	1,295
a	211	23	.34	87	1,295
z'	217	57	.15	15	1,295
c	698				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y'	.43	.66	228	1,298
x	.46	.49	127	2,297
a	.58	.34	135	3,296
z'	.60	.35	110	4,295

MODEL IV

Parameter	Time	Standard Error	β	Freq.	df
y'	571	59	.48	92	1,295
x'	274	72	.23	14	1,295
a	211	23	.34	88	1,295
z'	113	68	.08	3	1,295
c	789				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y'	.43	.66	228	1,298
x'	.48	.60	138	2,297
a	.60	.34	148	3,296
z'	.60	.35	112	4,295

MODEL I

Parameter	Time	Standard Error	β	Freq.	df
y	365	101	.26	13	1,295
x	499	182	.35	8	1,295
a	117	60	.10	4	1,295
z	- 89	203	-.05	.20	1,295
c	2131				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.21	.46	79	1,298
x	.27	.47	54	2,297
a	.28	.10	38	3,396
z	.28	.34	28	4,295

MODEL II

Parameter	Time	Standard Error	β	Freq.	df
y	550	92	.39	36	1,295
x	208	96	.15	5	1,295
a	117	57	.10	4	1,295
z'	743	140	.28	28	1,295
c	1486				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.21	.46	79	1,298
x	.27	.47	54	2,297
a	.28	.10	37	3,296
z'	.34	.30	38	4,295

MODEL III

Parameter	Time	Standard Error	β	Freq.	df
y'	1067	121	.46	77	1,295
x	258	77	.18	11	1,295
a	117	54	.10	5	1,295
z'	408	125	.15	11	1,295
c	1726				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y'	.35	.59	157	1,298
x	.38	.47	92	2,297
a	.39	.10	63	3,296
z'	.41	.30	52	4,295

MODEL IV

Parameter	Time	Standard Error	β	Freq.	df
y'	783	142	.34	31	1,295
x'	858	171	.37	25	1,295
a	117	52	.10	5	1,295
z'	37	151	.01	1	1,295
c	2005				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y'	.35	.59	157	1,298
x'	.43	.60	111	2,297
a	.44	.10	77	3,396
z'	.44	.30	57	4,295

Appendix 1.12 Linear regression tables for above and below average subjects, Models I to IV, dual processing in application only.

NONRETARDED Ss

MODEL I

Parameter	Time	Standard Error	β	Freq.	df
y	210	28	.37	56	1,295
x	216	30	.38	50	1,295
a	226	26	.36	73	1,295
z	323	47	.33	48	1,295
c	535				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.03	.18	10	1,298
x	.26	.32	53	2,297
a	.39	.36	64	3,396
z	.48	.47	67	4,295

MODEL II

Parameter	Time	Standard Error	β	Freq.	df
y	253	28	.45	84	1,295
x	277	28	.49	97	1,295
a	226	27	.36	72	1,295
z'	377	60	.27	39	1,295
c	453				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.03	.18	10	1,298
x	.26	.32	53	2,297
a	.39	.36	64	3,296
z'	.46	.34	64	4,295

MODEL III

Parameter	Time	Standard Error	β	Freq.	df
y'	388	39	.45	99	1,295
x	253	26	.45	94	1,295
a	226	26	.36	74	1,295
z'	365	59	.26	38	1,295
c	564				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y'	.07	.26	22	1,298
x	.29	.32	60	2,297
a	.42	.36	71	3,296
z'	.48	.34	69	4,295

MODEL IV

Parameter	Time	Standard Error	β	Freq.	df
y'	304	38	.35	65	1,295
x'	336	39	.39	75	1,295
a	226	27	.36	71	1,295
z'	353	61	.25	33	1,295
c	734				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y'	.07	.26	22	1,298
x'	.27	.38	54	2,297
a	.40	.36	65	3,296
z'	.46	.34	62	4,295

RETARDED Ss

MODEL I

Parameter	Time	Standard Error	β	Freq.	df
y	412	53	.44	60	1,295
x	405	58	.43	49	1,295
a	121	50	.11	6	1,295
z	401	88	.24	21	1,295
c	1535				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.05	.22	16	1,298
x	.28	.30	57	2,297
a	.29	.11	41	3,296
z	.34	.41	38	4,295

MODEL II

Parameter	Time	Standard Error	β	Freq.	df
y	463	50	.49	86	1,295
x	460	51	.49	82	1,295
a	121	48	.11	6	1,295
z'	715	109	.31	43	1,295
c	1261				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.05	.22	16	1,298
x	.28	.30	57	2,297
a	.29	.11	41	3,296
z'	.38	.37	46	4,295

MODEL III

Parameter	Time	Standard Error	β	Freq.	df
y'	799	67	.55	141	1,295
x	439	45	.47	96	1,295
a	121	45	.11	7	1,295
z'	686	102	.29	46	1,295
c	1375				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y'	.13	.36	44	1,298
x	.36	.30	85	2,297
a	.38	.11	60	3,296
z'	.46	.37	63	4,295

MODEL IV

Parameter	Time	Standard Error	β	Freq.	df
y'	669	62	.46	117	1,295
x'	667	64	.46	109	1,295
a	121	44	.11	7	1,295
z'	634	101	.27	40	1,295
c	1632				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y'	.13	.36	44	1,298
x'	.40	.43	97	2,297
a	.41	.11	68	3,296
z'	.48	.37	68	4,295

Appendix 1.13 Linear regression tables for above and below average subjects, Models I to IV, self-terminating encoding.

NONRETARDED Ss

MODEL I

Parameter	Time	Standard Error	β	Freq.	df
y	365	38	.49	90	1,295
x	102	69	.14	2	1,295
a	226	23	.36	100	1,295
z	182	77	.18	6	1,295
c	953				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.41	.64	209	1,298
x	.48	.60	136	2,297
a	.61	.36	153	3,396
z	.62	.47	118	4,295

MODEL II

Parameter	Time	Standard Error	β	Freq.	df
y	425	32	.57	171	1,295
x	107	34	.14	10	1,295
a	226	20	.40	126	1,295
z'	229	54	.17	18	1,295
c	967				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.41	.64	209	1,298
x	.48	.60	136	2,297
a	.68	.47	206	3,396
z'	.69	.34	168	4,295

MODEL III

Parameter	Time	Standard Error	β	Freq.	df
y'	404	51	.34	62	1,295
x	195	28	.26	48	1,295
a	268	26	.39	104	1,295
z'	204	45	.15	20	1,295
c	1305				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y'	.53	.73	332	1,298
x	.59	.60	217	2,297
a	.69	.68	224	3,396
z'	.71	.34	184	4,295

MODEL IV

Parameter	Time	Standard Error	β	Freq.	df
y'	595	58	.50	106	1,295
x'	48	89	.04	.29	1,295
a	357	55	.37	42	1,295
z'	56	62	.04	1	1,295
c	1554				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y'	.53	.73	332	1,298
x'	.60	.69	227	2,297
a	.65	.68	186	3,297
z'	.65	.34	140	4,295

RETARDED Ss

MODEL I

Parameter	Time	Standard Error	β	Freq.	df
y	430	85	.34	25	1,295
x	203	154	.16	2	1,295
a	121	50	.11	6	1,295
z	244	171	.15	2	1,295
c	2381				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.25	.50	98	1,298
x	.31	.50	66	2,297
a	.32	.11	47	3,296
z	.33	.41	36	4,295

MODEL II

Parameter	Time	Standard Error	β	Freq.	df
y	562	75	.45	56	1,295
x	142	78	.11	3	1,295
a	121	46	.13	7	1,295
z'	719	123	.31	34	1,295
c	2041				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.25	.50	98	1,298
x	.31	.50	66	2,297
a	.36	.26	56	3,296
z'	.43	.37	55	4,295

MODEL III

Parameter	Time	Standard Error	β	Freq.	df
y'	869	114	.43	59	1,295
x	212	62	.17	12	1,295
a	162	58	.14	8	1,295
z'	501	100	.21	25	1,295
c	2352				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y'	.41	.64	208	1,298
x	.45	.50	121	2,297
a	.46	.46	85	3,296
z'	.50	.37	75	4,295

MODEL IV

Parameter	Time	Standard Error	β	Freq.	df
y'	867	116	.43	56	1,295
x'	337	179	.17	4	1,295
a	245	111	.15	5	1,295
z'	263	124	.11	5	1,295
c	2604				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y'	.41	.64	208	1,298
x'	.49	.64	144	2,297
a	.50	.57	99	3,297
z'	.51	.37	76	4,295

Appendix 1.14 Linear regression tables for above and below average subjects, Models I to IV, no mapping.

NONRETARDED Ss

MODEL I

Parameter	Time	Standard Error	β	Freq.	df
x	538	59	.72	83	1,295
a	226	26	.36	77	1,295
z	-143	79	-.14	3	1,295
c	1278				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
x	.36	.60	169	2,297
a	.49	.36	144	3,296
z	.49	.47	98	4,295

MODEL II

Parameter	Time	Standard Error	β	Freq.	df
x	408	31	.55	169	1,295
a	226	25	.36	80	1,295
z'	236	59	.17	16	1,295
c	1005				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
x	.36	.60	169	2,297
a	.49	.36	144	3,296
z'	.52	.34	106	4,295

MODEL III

Parameter	Time	Standard Error	β	Freq.	df
x	408	31	.55	169	1,295
a	226	25	.36	80	1,295
z'	236	59	.17	16	1,295
c	1005				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
x	.36	.60	169	2,297
a	.49	.36	144	3,296
z'	.52	.34	106	4,295

MODEL IV

Parameter	Time	Standard Error	β	Freq.	df
x'	901	54	.75	281	1,295
a	226	23	.36	99	1,295
z'	-144	62	-.10	5	1,295
c	1279				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
x'	.47	.69	269	2,297
a	.60	.36	227	3,296
z'	.61	.34	155	4,295

RETARDED Ss

MODEL I

Parameter	Time	Standard Error	β	Freq.	df
x	718	120	.57	36	1,295
a	121	52	.11	5	1,295
z	-140	160	-.08	1	1,295
c	2765				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
x	.25	.50	101	2,297
a	.27	.11	54	3,296
z	.27	.41	36	4,295

MODEL II

Parameter	Time	Standard Error	β	Freq.	df
x	540	63	.43	74	1,295
a	121	51	.11	6	1,295
z'	550	117	.24	22	1,295
c	2269				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
x	.25	.50	101	2,297
a	.27	.11	54	3,296
z'	.32	.37	46	4,295

MODEL III

Parameter	Time	Standard Error	β	Freq.	df
x	540	63	.43	74	1,295
a	121	51	.11	6	1,295
z'	550	117	.24	22	1,295
c	2269				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
x	.25	.50	101	2,297
a	.27	.11	54	3,296
z'	.32	.37	46	4,295

MODEL IV

Parameter	Time	Standard Error	β	Freq.	df
x'	1304	110	.65	139	1,295
a	121	47	.11	7	1,295
z'	- 29	127	-.01	1	1,295
c	2655				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
x'	.41	.64	204	2,297
a	.42	.11	108	3,296
z'	.42	.37	71	4,295

Appendix 1.15 Linear regression tables for above and below average subjects, Models I to IV, dual processing in 1 DD' value change only.

NONRETARDED Ss

MODEL I

Parameter	Time	Standard Error	β	Freq.	df
y	348	35	.47	100	1,295
x	188	38	.25	24	1,295
a	226	22	.36	101	1,295
z	80	25	.13	11	1,295
c	1009				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.41	.64	209	1,298
x	.48	.60	136	2,297
a	.61	.36	153	3,296
z	.62	.29	121	4,295

MODEL II

Parameter	Time	Standard Error	β	Freq.	df
y	365	33	.49	124	1,295
x	166	34	.22	24	1,295
a	226	21	.36	114	1,295
z'	227	33	.25	47	1,295
c	953				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.41	.64	209	1,298
x	.48	.60	136	2,297
a	.61	.36	153	3,296
z'	.66	.33	144	4,295

MODEL III

Parameter	Time	Standard Error	β	Freq.	df
y'	668	42	.56	255	1,295
x	198	26	.27	56	1,295
a	226	19	.36	149	1,295
z'	132	28	.14	21	1,295
c	1012				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y'	.53	.73	332	1,298
x	.59	.60	217	2,297
a	.72	.36	258	3,296
z'	.74	.33	212	4,295

MODEL IV

Parameter	Time	Standard Error	β	Freq.	df
y'	596	48	.50	153	1,295
x'	387	53	.32	53	1,295
a	226	19	.36	148	1,295
z'	76	31	.08	6	1,295
c	1075				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y'	.53	.73	332	1,298
x'	.60	.69	227	2,297
a	.73	.36	273	3,296
z'	.74	.33	210	4,295

RETARDED Ss

MODEL I

Parameter	Time	Standard Error	β	Freq.	df
y	408	78	.33	27	1,295
x	318	85	.25	14	1,295
a	121	50	.11	6	1,295
z	108	55	.10	4	1,295
c	2457				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.25	.50	98	1,298
x	.31	.50	66	2,297
a	.32	.11	47	3,296
z	.33	.25	36	4,295

MODEL II

Parameter	Time	Standard Error	β	Freq.	df
y	471	72	.38	43	1,295
x	209	75	.17	8	1,295
a	121	46	.11	7	1,295
z'	536	72	.35	55	1,295
c	2238				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.25	.50	98	1,298
x	.31	.50	66	2,297
a	.32	.11	47	3,296
z'	.43	.41	55	4,295

MODEL III

Parameter	Time	Standard Error	β	Freq.	df
y'	1015	96	.50	113	1,295
x	203	60	.16	11	1,295
a	121	42	.11	8	1,295
z'	406	65	.26	39	1,295
c	2299				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y'	.41	.64	208	1,298
x	.45	.50	121	2,297
a	.46	.11	85	3,296
z'	.53	.41	82	4,295

MODEL IV

Parameter	Time	Standard Error	β	Freq.	df
y'	864	108	.43	64	1,295
x'	527	119	.26	19	1,295
a	121	42	.11	8	1,295
z'	315	70	.20	20	1,295
c	2371				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y'	.41	.64	208	1,298
x'	.49	.64	144	2,297
a	.51	.11	101	3,296
z'	.54	.41	86	4,295

Appendix 2.1 Analysis of variance of solution times for nonretarded and retarded subjects in each cue condition and for each analogy type.

Source	Df	SS	SS%	MS	VR
Cue.Type.Group. Units Stratum					
Cue	3	5800684	1.33	1933561	2.461
Lin	1	5698772	1.31	5698772	7.252**
Quad	1	100056	0.02	100056	0.127
Deviations	1	1856	0.00	1856	0.002
Type	1	125597258	28.77	125597258	159.840**
Group	1	152341410	34.90	152341410	193.876**
Cue.Type	3	102122	0.02	34041	0.043
Lin.Dev	1	2017	0.00	2027	0.003
Quad.Dev	1	3193	0.00	3193	0.004
Deviations	1	96902	0.02	96902	0.123
Cue.Group	3	3966841	0.91	1322280	1.683
Lin.Dev	1	3569355	0.82	3569355	4.543*
Quad.Dev	1	4191	0.00	4191	0.005
Deviations	1	393296	0.09	393296	0.501
Type.Group	1	8761616	2.01	8761616	11.150*
Cue.Type.Group	3	1682859	0.39	560953	0.714
Lin.Dev.Dev	1	1418267	0.32	1418267	1.805
Quad.Dev.Dev	1	56410	0.01	56410	0.072
Deviations	1	208182	0.05	208182	0.265
Residual	176	138295223	31.68	785768	
Total	191	436548013	100.00	2285592	

* significant at .05
** significant at .01

Appendix 2.2 Repeated measures analysis of variance of solution times in sessions 1 and 4 for nonretarded and retarded subjects in each cue condition and for each analogy type.

Source	Df	SS	SS%	MS	VR
Grp.Subject Stratum					
Grp	1	274645473	27.69	274645473	28.809**
Residual	22	209730513	21.15	9533205	31.612
Total	23	484375986	48.84	21059825	69.834
Grp.Subject.Session Stratum					
Session	1	51513795	5.19	51513795	29.977**
Grp.Session	1	36621	0.00	36621	0.021
Residual	22	37805634	3.81	1718438	5.698
Total	24	89356050	9.01	3723169	12.346
Grp.Subject.Type Stratum					
Type	1	245075677	24.71	245075677	243.096**
Grp.Type	1	14266584	1.44	14266584	14.151**
Residual	22	22179176	2.24	1008144	3.343
Total	24	281521437	28.39	11730060	38.897
Grp.Subject.Cue Stratum					
Cue	3	7654975	0.77	2551658	5.277**
Grp.Cue	3	14122266	1.42	4707422	9.735**
Residual	66	31916310	3.22	483580	1.604
Total	72	53693550	5.41	745744	2.473
Grp.Subject.Session.Type Stratum					
Session.Type	1	6014509	0.61	6014509	11.641**
grp.Session.Type	1	419365	0.04	419365	0.812
Residual	22	11366340	1.15	516652	1.713
Total	24	17800213	1.79	741676	2.459
Grp.Subject.Session.Cue Stratum					
Session.Cue	3	1376546	0.14	458849	1.349
Grp.Session.Cue	3	1430177	0.14	476726	1.401
Residual	66	22452757	2.26	340193	1.128
Total	72	25259480	2.55	350826	1.163
Grp.Subject.Type.Cue Stratum					
Type.Cue	3	364777	0.04	121592	0.673
Grp.Type.Cue	3	5796117	0.58	1932039	10.691**
Residual	66	11927685	1.20	180722	0.599
Total	72	18088578	1.82	251230	0.833
Grp.Subject.Session.Type.Cue Stratum					
Session.Type.Cue	3	777040	0.08	259013	0.859
Residual	69	20808243	2.10	301569	
Total	72	21585283	2.18	299796	
Grand Total	383	991680579	100.00		

** significant at .01

Appendix 2.3 Linear regression tables for nonretarded and retarded subjects, Models I to IV.

NONRETARDED Ss

MODEL I

Parameter	Time	Standard Error	β	Freq.	df
y	314	37	.39	73	1,295
x	140	53	.15	7	1,295
a	144	28	.23	27	1,295
z	264	48	.27	30	1,295
c	971				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.37	.61	175	1,298
x	.47	.59	134	2,297
a	.50	.39	97	3,296
z	.54	.46	88	4,295

MODEL II

Parameter	Time	Standard Error	β	Freq.	df
y	369	36	.46	105	1,295
x	206	45	.22	21	1,295
a	115	26	.19	20	1,295
z'	414	54	.30	59	1,295
c	954				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.37	.61	175	1,298
x	.47	.59	134	2,297
a	.50	.39	97	3,296
z'	.58	.32	102	4,295

MODEL III

Parameter	Time	Standard Error	β	Freq.	df
y'	662	52	.50	161	1,295
x	244	40	.26	38	1,295
a	110	24	.18	21	1,295
z'	258	50	.19	27	1,295
c	1095				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y'	.47	.69	269	1,298
x	.58	.59	202	2,297
a	.60	.39	146	3,296
z'	.63	.32	126	4,295

MODEL IV

Parameter	Time	Standard Error	β	Freq.	df
y'	618	56	.47	124	1,295
x'	446	74	.29	37	1,295
a	118	24	.19	25	1,295
z'	183	53	.13	12	1,295
c	1153				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y'	.47	.69	269	1,298
x'	.59	.66	213	2,297
a	.62	.39	158	3,296
z'	.63	.32	125	4,295

RETARDED Ss

MODEL I

Parameter	Time	Standard Error	β	Freq.	df
y	587	83	.40	50	1,295
x	- 86	123	-.05	.49	1,295
a	- 81	61	-.07	2	1,295
z	651	121	.34	29	1,295
c	2862				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.22	.47	86	1,298
x	.24	.33	46	2,297
a	.25	.05	33	3,296
z	.32	.44	34	4,295

MODEL II

Parameter	Time	Standard Error	β	Freq.	df
y	734	82	.50	80	1,295
x	80	103	.05	1	1,295
a	- 84	59	-.07	2	1,295
z'	903	126	.34	51	1,295
c	2682				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.22	.47	86	1,298
x	.24	.33	46	2,297
a	.25	.05	33	3,296
z'	.36	.32	41	4,295

MODEL III

Parameter	Time	Standard Error	β	Freq.	df
y'	1134	126	.47	80	1,295
x	211	96	.12	5	1,295
a	-101	59	-.09	3	1,295
z'	587	124	.23	22	1,295
c	3021				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y'	.29	.53	119	1,298
x	.30	.33	63	2,297
a	.31	.05	45	3,296
z'	.35	.32	41	4,295

MODEL IV

Parameter	Time	Standard Error	β	Freq.	df
y'	1166	135	.48	74	1,295
x'	195	181	.07	1	1,295
a	- 75	59	-.07	2	1,295
z'	575	135	.22	18	1,295
c	2996				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y'	.29	.53	119	1,298
x'	.30	.39	64	2,297
a	.31	.05	45	3,296
z'	.35	.32	40	4,295

Appendix 2.4 Linear regression tables for nonretarded and retarded subjects, Models I, II and IV, alternative procedure.

Nonretarded Ss

MODEL I

Parameter	Time	Standard Error	β	Freq.	df
y	299	38	.41	60	1,295
x	201	69	.27	8	1,295
a	244	23	.39	116	1,295
z	85	77	.09	1	1,295
c	798				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.37	.61	174	1,298
x	.45	.60	121	2,297
a	.60	.39	150	3,296
z	.61	.46	113	4,295

MODEL II

Parameter	Time	Standard Error	β	Freq.	df
y	369	33	.50	122	1,295
x	147	35	.20	18	1,295
a	244	21	.38	140	1,295
z'	400	51	.29	62	1,295
c	552				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.37	.61	174	1,298
x	.45	.60	121	2,297
a	.60	.39	150	3,296
z'	.67	.32	151	4,295

MODEL IV

Parameter	Time	Standard Error	β	Freq.	df
y'	510	48	.43	113	1,295
x'	482	48	.40	101	1,295
a	244	19	.39	170	1,295
c	883				
*					

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y'	.48	.70	279	1,298
x'	.58	.69	202	2,297
a	.73	.39	268	3,296

Retarded Ss

MODEL I

Parameter	Time	Standard Error	β	Freq.	df
y	593	87	.44	47	1,295
x	131	157	.10	1	1,295
a	55	51	.05	1	1,295
z	387	174	.21	5	1,295
c	2572				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.33	.57	147	1,298
x	.39	.55	96	2,297
a	.39	.05	64	3,296
z	.40	.45	50	4,295

MODEL II

Parameter	Time	Standard Error	β	Freq.	df
y	669	79	.49	72	1,295
x	214	82	.16	7	1,295
a	55	49	.05	1	1,295
z'	729	120	.29	37	1,295
c	2307				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.33	.57	147	1,298
x	.39	.55	96	2,297
a	.39	.05	64	3,296
z'	.46	.30	63	4,295

MODEL IV

Parameter	Time	Standard Error	β	Freq.	df
y'	944	130	.43	53	1,295
x'	662	157	.30	18	1,295
a	55	48	.05	1	1,295
z'	108	138	.04	1	1,295
c	2852				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y'	.41	.64	206	1,298
x'	.47	.61	133	2,297
a	.48	.05	89	3,296
z'	.48	.30	67	4,295

* F-level or tolerance level insufficient for further computation

Appendix 2.5 Linear regression tables for nonretarded and retarded subjects, Models I to IV, 0 cue condition.

NONRETARDED Ss

MODEL I

Parameter	Time	Standard Error	β	Freq.	df
y	352	95	.44	14	1,71
x	233	172	.29	2	1,71
z	75	191	.07	.15	1,71
c	1698				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.42	.65	53	1,73
x	.50	.63	36	2,72
z	.50	.48	24	3,71

MODEL II

Parameter	Time	Standard Error	β	Freq.	df
y	448	82	.56	30	1,71
x	139	86	.17	3	1,71
z'	507	125	.34	17	1,71
c	1363				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.42	.65	53	1,73
x	.50	.63	36	2,72
z'	.60	.36	35	3,71

MODEL III

Parameter	Time	Standard Error	β	Freq.	df
y'	763	102	.59	55	1,71
x	214	65	.27	11	1,71
z'	240	105	.16	5	1,71
c	1568				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y'	.58	.76	102	1,73
x	.65	.63	68	2,72
z'	.68	.36	50	3,71

MODEL IV

Parameter	Time	Standard Error	β	Freq.	df
y'	622	120	.48	27	1,71
x'	545	145	.42	14	1,71
z'	23	128	.02	.33	1,71
c	1750				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y'	.58	.76	102	1,73
x'	.69	.75	80	2,72
z'	.69	.36	53	3,71

RETARDED Ss

MODEL I

Parameter	Time	Standard Error	β	Freq.	df
y	572	182	.44	10	1,71
x	35	329	.03	.11	1,71
z	315	366	.18	1	1,71
c	2948				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.27	.52	28	1,73
x	.30	.46	16	2,72
z	.31	.36	11	3,71

MODEL II

Parameter	Time	Standard Error	β	Freq.	df
y	655	166	.51	16	1,71
x	74	174	.06	.18	1,71
z'	689	254	.29	7	1,71
c	2659				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.27	.52	28	1,73
x	.30	.46	16	2,72
z'	.37	.27	14	3,71

MODEL III

Parameter	Time	Standard Error	β	Freq.	df
y'	1010	227	.48	20	1,71
x	217	144	.17	2	1,71
z'	302	233	.13	2	1,71
c	2969				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y'	.35	.60	40	1,73
x	.38	.46	22	2,72
z'	.40	.27	16	3,71

MODEL IV

Parameter	Time	Standard Error	β	Freq.	df
y'	931	272	.44	12	1,71
x'	439	329	.21	2	1,71
z'	144	290	.06	.25	1,71
c	3119				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y'	.35	.60	40	1,73
x'	.39	.54	23	2,72
z'	.39	.27	15	3,71

Appendix 2.6 Linear regression tables for nonretarded and retarded subjects, Models I to IV, 1 cue condition.

NONRETARDED Ss

MODEL I

Parameter	Time	Standard Error	β	Freq.	df
y	347	80	.48	19	1,71
x	248	143	.34	3	1,71
z	32	160	.03	.40	1,71
c	1586				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.50	.70	72	1,73
x	.58	.67	50	2,72
z	.58	.49	33	3,71

MODEL II

Parameter	Time	Standard Error	β	Freq.	df
y	433	68	.60	40	1,71
x	147	72	.20	4	1,71
z'	420	104	.31	16	1,71
c	1285				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.50	.70	72	1,73
x	.58	.67	50	2,72
z'	.66	.33	46	3,71

MODEL III

Parameter	Time	Standard Error	β	Freq.	df
y'	749	80	.64	87	1,71
x	216	51	.30	18	1,71
z'	161	83	.12	4	1,71
c	1482				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y'	.67	.82	147	1,73
x	.75	.67	106	2,72
z'	.76	.33	75	3,71

MODEL IV

Parameter	Time	Standard Error	β	Freq.	df
y'	629	95	.54	44	1,71
x'	509	115	.43	20	1,71
z'	- 35	101	-.03	.12	1,71
c	1653				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y'	.67	.82	147	1,73
x'	.76	.77	117	2,72
z'	.76	.33	77	3,71

RETARDED Ss

MODEL I

Parameter	Time	Standard Error	β	Freq.	df
y	486	175	.36	8	1,71
x	293	315	.22	1	1,71
z	302	352	.17	1	1,71
c	2755				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.31	.56	33	1,73
x	.40	.59	24	2,72
z	.41	.48	16	3,71

MODEL II

Parameter	Time	Standard Error	β	Freq.	df
y	579	158	.43	13	1,71
x	311	165	.23	4	1,71
z'	722	241	.29	9	1,71
c	2429				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.31	.56	33	1,73
x	.40	.59	24	2,72
z'	.47	.33	21	3,71

MODEL III

Parameter	Time	Standard Error	β	Freq.	df
y'	914	215	.42	18	1,71
x	430	137	.32	10	1,71
z'	380	221	.15	3	1,71
c	2701				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y'	.38	.62	45	1,73
x	.48	.59	33	2,72
z'	.50	.33	23	3,71

MODEL IV

Parameter	Time	Standard Error	β	Freq.	df
y'	737	259	.34	8	1,71
x'	908	314	.42	8	1,71
z'	47	277	.02	.29	1,71
c	3009				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y'	.38	.62	45	1,73
x'	.49	.65	34	2,72
z'	.49	.33	23	3,71

Appendix 2.7 Linear regression tables for nonretarded and retarded subjects, Models I to IV, 2 cue condition.

NONRETARDED Ss

MODEL I

Parameter	Time	Standard Error	β	Freq.	df
y	221	67	.41	11	1,71
x	172	120	.32	2	1,71
z	40	134	.05	1	1,71
c	1378				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.39	.63	47	1,73
x	.48	.62	33	2,72
z	.48	.47	22	3,71

MODEL II

Parameter	Time	Standard Error	β	Freq.	df
y	285	58	.53	24	1,71
x	105	61	.19	3	1,71
z'	327	89	.32	14	1,71
c	1155				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.39	.63	47	1,73
x	.48	.62	33	2,72
z'	.56	.35	30	3,71

MODEL III

Parameter	Time	Standard Error	β	Freq.	df
y'	486	74	.55	43	1,71
x	152	47	.28	10	1,71
z'	157	76	.16	4	1,71
c	1285				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y'	.54	.73	84	1,73
x	.61	.62	56	2,72
z'	.63	.35	41	3,71

MODEL IV

Parameter	Time	Standard Error	β	Freq.	df
y'	384	82	.44	22	1,71
x'	390	82	.44	23	1,71
c	1417				1,71
*					

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y'	.54	.73	84	1,73
x'	.65	.73	66	2,72

RETARDED Ss

MODEL I

Parameter	Time	Standard Error	β	Freq.	df
y	580	179	.41	11	1,71
x	219	322	.15	.46	1,71
z	416	359	.22	1	1,71
c	2703				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.34	.59	38	1,73
x	.43	.60	28	2,72
z	.44	.50	19	3,71

MODEL II

Parameter	Time	Standard Error	β	Freq.	df
y	647	162	.46	16	1,71
x	328	170	.23	4	1,71
z'	718	248	.27	8	1,71
c	2469				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.34	.59	38	1,73
x	.43	.60	28	2,72
z'	.49	.31	23	3,71

MODEL III

Parameter	Time	Standard Error	β	Freq.	df
y'	1062	218	.46	24	1,71
x	448	138	.32	11	1,71
z'	333	224	.13	2	1,71
c	2770				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y'	.43	.66	55	1,73
x	.52	.60	39	2,72
z'	.54	.31	27	3,71

MODEL IV

Parameter	Time	Standard Error	β	Freq.	df
y'	976	268	.43	13	1,71
x'	774	324	.34	6	1,71
z'	80	286	.03	1	1,71
c	3038				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y'	.43	.66	55	1,73
x'	.51	.64	37	2,72
z'	.51	.31	24	3,71

* F-level or tolerance level insufficient for further computation

Appendix 2.8 Linear regression tables for nonretarded and retarded subjects, Models I to IV, 3 cue condition.

NONRETARDED Ss

MODEL I

Parameter	Time	Standard Error	β	Freq.	df
y	275	62	.45	20	1, 71
x	150	111	.25	2	1, 71
z	193	124	.24	2	1, 71
c	967				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	:48	.69	67	1, 73
x	.63	.73	61	2, 72
z	.64	.61	42	3, 71

MODEL II

Parameter	Time	Standard Error	β	Freq.	df
y	308	53	.51	34	1,71
x	197	56	.32	12	1,71
z'	345	81	.31	18	1,71
c	849				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.48	.69	67	1,73
x	.63	.73	61	2,72
z'	.70	.37	56	3,71

MODEL III

Parameter	Time	Standard Error	β	Freq.	df
y'	470	71	.48	43	1,71
x	266	45	.44	34	1,71
z'	163	73	.14	5	1,71
c	996				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y'	.55	.74	88	1,73
x	.71	.73	88	2,72
z'	.73	.37	64	3,71

MODEL IV

Parameter	Time	Standard Error	β	Freq.	df
y'	399	86	.41	21	1,71
x'	491	86	.50	32	1,71
c	1162				1,71
*					

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y'	.55	.74	88	1,73
x'	.69	.77	79	2,72

RETARDED Ss

MODEL I

Parameter	Time	Standard Error	β	Freq.	df
y	734	166	.54	19	1,71
x	- 22	299	-.02	1	1,71
z	515	334	.29	2	1,71
c	2435				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.40	.64	50	1,73
x	.45	.57	30	2,72
z	.47	.47	21	3,71

MODEL II

Parameter	Time	Standard Error	β	Freq.	df
y	794	149	.59	29	1,71
x	143	156	.11	1	1,71
z'	787	227	.31	12	1,71
c	2224				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.40	.64	50	1,73
x	.45	.57	30	2,72
z'	.53	.31	27	3,71

MODEL III

Parameter	Time	Standard Error	β	Freq.	df
y'	1172	204	.54	33	1,71
x	332	129	.25	7	1,71
z'	321	209	.13	2	1,71
c	2605				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y'	.48	.69	68	1,73
x	.54	.57	41	2,72
z'	.55	.31	29	3,71

MODEL IV

Parameter	Time	Standard Error	β	Freq.	df
y'	1134	249	.52	21	1,71
x'	529	301	.24	3	1,71
z'	159	265	.06	.36	1,71
c	2791				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y'	.48	.69	68	1,73
x'	.53	.62	40	2,72
z'	.53	.31	27	3,71

* F-level or tolerance level insufficient for further computation

Appendix 2.9 Linear regression tables for nonretarded and retarded subjects, Models I to IV, nondegenerate, Type II analogies.

NONRETARDED Ss

MODEL I

Parameter	Time	Standard Error	β	Freq.	df
y	210	79	.24	7	1,116
x	197	79	.22	6	1,116
a	304	46	.51	44	1,116
ø	957				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.02	.13	2	1,118
x	.05	.10	3	2,117
a	.31	.51	18	3,116

MODEL II

Parameter	Time	Standard Error	β	Freq.	df
y	210	59	.24	13	1,115
x	-192	71	-.22	7	1,115
a	304	34	.51	80	1,115
z'	746	77	.71	95	1,115
c	957				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.02	.13	2	1,118
x	.05	.10	3	2,117
a	.31	.51	18	3,116
z'	.62	.50	48	4,115

MODEL III

Parameter	Time	Standard Error	β	Freq.	df
y'	425	75	.40	32	1,115
x	- 21	78	-.02	1	1,115
a	304	32	.51	92	1,115
z'	428	91	.41	22	1,115
c	930				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y'	.27	.52	44	1,118
x	.35	.10	31	2,117
a	.61	.51	61	3,116
z'	.67	.50	59	4,115

MODEL IV

Parameter	Time	Standard Error	β	Freq.	df
y'	437	58	.41	56	1,116
x'	409	58	.39	49	1,116
a	304	32	.51	93	1,116
c	900				
*					

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y'	.27	.52	44	1,118
x'	.41	.50	41	2,117
a	.67	.51	79	3,116

RETARDED Ss

MODEL I

Parameter	Time	Standard Error	β	Freq.	df
y	376	140	.28	7	1,117
x	300	140	.22	5	1,117
c	3472				
*					

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.03	.17	3	1,118
x	.06	.08	4	2,117

MODEL II

Parameter	Time	Standard Error	β	Freq.	df
y	376	116	.28	10	1,116
x	-275	140	-.20	4	1,116
z'	1104	151	.69	53	1,116
c	3471				
*					

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.03	.17	3	1,118
x	.06	.08	4	2,117
z'	.36	.48	22	3,116

MODEL III

Parameter	Time	Standard Error	β	Freq.	df
y'	756	151	.47	25	1,116
x	30	156	.02	.37	1,116
z'	537	183	.33	9	1.116
c	3425				
*					

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y'	.31	.56	53	1,118
x	.38	.08	36	2,117
z'	.42	.48	29	3,116

MODEL IV

Parameter	Time	Standard Error	β	Freq.	df
y'	738	117	.46	40	1,117
x'	564	117	.35	23	1,117
c	3468				
*					

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y'	.31	.56	53	1,118
x'	.42	.48	43	2,117

* F-level or tolerance level insufficient for further computation

Appendix 2.10 Linear regression tables for nonretarded and retarded subjects, Models I to IV, session 1.

NONRETARDED Ss

MODEL I

Parameter	Time	Standard Error	β	Freq.	df
y	408	64	.38	41	1,295
x	286	115	.27	6	1,295
a	274	38	.31	53	1,295
z	53	129	.04	.17	1,295
c	965				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.32	.57	141	1,298
x	.38	.54	91	2,297
a	.47	.31	89	3,296
z	.47	.40	66	4,295

MODEL II

Parameter	Time	Standard Error	β	Freq.	df
y	488	59	.46	69	1,295
x	204	62	.19	11	1,295
a	274	37	.31	56	1,295
z'	415	90	.21	21	1,295
c	685				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.32	.57	141	1,298
x	.38	.54	91	2,297
a	.47	.31	89	3,296
z'	.51	.24	76	4,295

MODEL III

Parameter	Time	Standard Error	β	Freq.	df
y'	832	78	.48	114	1,295
x	285	49	.27	33	1,295
a	274	34	.31	63	1,295
z'	123	80	.06	2	1,295
c	908				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y'	.41	.64	205	1,298
x	.47	.54	130	2,297
a	.56	.31	126	3,296
z'	.56	.24	95	4,295

MODEL IV

Parameter	Time	Standard Error	β	Freq.	df
y'	722	94	.42	59	1,295
x'	588	113	.34	27	1,295
a	274	35	.31	62	1,295
z'	- 90	100	-.05	1	1,295
c	1108				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y'	.41	.64	205	1,298
x'	.46	.59	126	2,297
a	.55	.31	122	3,296
z'	.55	.24	92	4,295

RETARDED Ss

MODEL I

Parameter	Time	Standard Error	β	Freq.	df
y	600	106	.37	32	1,295
x	344	191	.21	3	1,295
a	9	62	.01	.21	1,295
z	236	213	.11	1	1,295
c	3001				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.30	.55	128	1,298
x	.37	.54	86	2,297
a	.37	.01	57	3,296
z	.37	.43	43	4,295

MODEL II

Parameter	Time	Standard Error	β	Freq.	df
y	658	99	.41	44	1,295
x	378	104	.24	13	1,295
a	9	61	.01	.21	1,295
z'	501	151	.17	11	1,295
c	2796				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.30	.55	128	1,298
x	.37	.54	86	2,297
a	.37	.01	57	3,296
z'	.39	.21	47	4,295

MODEL III

Parameter	Time	Standard Error	β	Freq.	df
y'	1012	137	.39	55	1,295
x	523	87	.33	36	1,295
a	9	60	.01	.22	1,295
z'	113	140	.04	1	1,295
c	3108				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y'	.32	.57	143	1,298
x	.41	.54	102	2,297
a	.41	.01	68	3,296
z'	.41	.21	51	4,295

MODEL IV

Parameter	Time	Standard Error	β	Freq.	df
y'	904	167	.35	29	1,295
x'	914	202	.35	20	1,295
a	9	62	.01	.21	1,295
z'	-188	178	-.06	1	1,295
c	3425				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y'	.32	.57	143	1,298
x'	.38	.55	89	2,297
a	.38	.01	59	3,296
z'	.38	.21	45	4,295

Appendix 2.11 Linear regression tables for nonretarded and retarded subjects, Models I to IV, session 4.

NONRETARDED Ss

MODEL I

Parameter	Time	Standard Error	β	Freq.	df
y	219	36	.36	37	1,295
x	130	65	.21	4	1,295
a	228	21	.44	114	1,295
z	45	73	.06	.39	1,295
c	656				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.26	.51	105	1,298
x	.30	.48	65	2,297
a	.50	.44	98	3,296
z	.50	.36	73	4,295

MODEL II

Parameter	Time	Standard Error	β	Freq.	df
y	291	31	.47	86	1,295
x	55	33	.09	3	1,295
a	228	19	.44	137	1,295
z'	368	48	.32	59	1,295
c	406				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.26	.51	105	1,298
x	.30	.48	65	2,297
a	.50	.44	98	3,296
z'	.58	.32	102	4,295

MODEL III

Parameter	Time	Standard Error	β	Freq.	df
y'	509	40	.51	159	1,295
x	99	26	.16	15	1,295
a	228	18	.44	164	1,295
z'	194	41	.17	22	1,295
c	538				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y'	.40	.63	197	1,298
x	.43	.48	112	2,297
a	.62	.44	163	3,296
z'	.65	.32	137	4,295

MODEL IV

Parameter	Time	Standard Error	β	Freq.	df
y'	411	47	.41	77	1,295
x'	309	57	.31	30	1,295
a	228	17	.44	171	1,295
z'	62	50	.05	2	1,295
c	639				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y'	.40	.63	197	1,298
x'	.47	.62	131	2,297
a	.66	.44	195	3,296
z'	.67	.32	147	4,295

RETARDED Ss

MODEL I

Parameter	Time	Standard Error	β	Freq.	df
y	463	114	.30	17	1,295
x	45	205	.03	.49	1,295
a	15	67	.01	1	1,295
z	486	229	.24	5	1,295
c	2310				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.16	.40	57	1,298
x	.21	.42	39	2,297
a	.21	.01	26	3,296
z	.22	.37	21	4,295

MODEL II

Parameter	Time	Standard Error	β	Freq.	df
y	524	105	.34	25	1,295
x	196	110	.13	3	1,295
a	15	65	.01	1	1,295
z'	758	161	.26	22	1,295
c	2099				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.16	.40	57	1,298
x	.21	.42	39	2,297
a	.21	.01	26	3,296
z'	.26	.28	26	4,295

MODEL III

Parameter	Time	Standard Error	β	Freq.	df
y'	811	146	.32	31	1,295
x	309	93	.20	11	1,295
a	15	65	.01	1	1,295
z'	449	150	.16	9	1,295
c	2347				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y'	.21	.46	80	1,298
x	.25	.42	50	2,297
a	.25	.01	34	3,296
z'	.28	.29	28	4,295

MODEL IV

Parameter	Time	Standard Error	β	Freq.	df
y'	725	175	.29	17	1,295
x'	581	212	.23	7	1,295
a	15	65	.01	1	1,295
z'	249	187	.09	2	1,295
c	2547				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y'	.21	.46	80	1,298
x'	.26	.47	53	2,297
a	.26	.01	35	3,296
z'	.27	.28	27	4,295

Appendix 2.12 Linear regression tables for nonretarded and retarded subjects, Models I to IV, dual processing in 1 DD' value change only.

NONRETARDED Ss

MODEL I

Parameter	Time	Standard Error	β	Freq.	df
y	292	35	.40	69	1,295
x	239	39	.32	38	1,295
a	244	23	.39	116	1,295
z	40	25	.07	3	1,295
c	820				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.37	.61	174	1,298
x	.45	.60	121	2,297
a	.60	.39	150	3,296
z	.61	.25	114	4,295

MODEL II

Parameter	Time	Standard Error	β	Freq.	df
y	319	33	.43	95	1,295
x	192	34	.26	31	1,295
a	244	21	.39	132	1,295
z'	218	33	.24	43	1,295
c	727				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.37	.61	174	1,298
x	.45	.60	121	2,297
a	.60	.39	150	3,296
z'	.65	.33	140	4,295

MODEL III

Parameter	Time	Standard Error	β	Freq.	df
y'	612	42	.51	211	1,295
x	211	27	.29	63	1,295
a	244	19	.39	172	1,295
z'	133	29	.15	22	1,295
c	776				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y'	.48	.70	279	1,298
x	.56	.60	189	2,297
a	.71	.39	247	3,296
z'	.73	.33	204	4,295

MODEL IV

Parameter	Time	Standard Error	β	Freq.	df
y'	526	48	.44	120	1,295
x'	428	53	.36	65	1,295
a	244	19	.39	173	1,295
z'	70	31	.08	5	1,295
c	845				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y'	.48	.70	279	1,298
x'	.58	.69	202	2,297
a	.73	.39	268	3,296
z'	.74	.33	205	4,295

RETARDED Ss

MODEL I

Parameter	Time	Standard Error	β	Freq.	df
y	528	80	.39	43	1,295
x	383	88	.28	19	1,295
a	55	52	.05	1	1,295
z	70	57	.06	2	1,295
c	2799				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.33	.57	147	1,298
x	.39	.55	96	2,297
a	.39	.05	64	3,296
z	.40	.23	49	4,295

MODEL II

Parameter	Time	Standard Error	β	Freq.	df
y	581	76	.43	58	1,295
x	288	79	.21	13	1,295
a	55	49	.05	1	1,295
z'	418	77	.25	30	1,295
c	2613				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.33	.57	147	1,298
x	.39	.55	96	2,297
a	.39	.05	64	3,296
z'	.45	.33	60	4,295

MODEL III

Parameter	Time	Standard Error	β	Freq.	df
y'	1029	106	.47	94	1,295
x	352	67	.26	27	1,295
a	55	47	.05	1	1,295
z'	268	72	.16	14	1,295
c	2711				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y'	.41	.64	206	1,298
x	.47	.55	134	2,297
a	.48	.05	90	3,296
z'	.50	.33	74	4,295

MODEL IV

Parameter	Time	Standard Error	β	Freq.	df
y'	959	123	.44	60	1,295
x'	590	136	.27	19	1,295
a	55	48	.05	1	1,295
z'	195	80	.12	6	1,295
c	2819				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y'	.41	.64	206	1,298
x'	.47	.61	133	2,297
a	.48	.05	89	3,296
z'	.49	.33	70	4,295

Appendix 3.1 Analysis of variance of solution times for nonretarded subjects in each cue condition and for each analogy type.

Source	Df	SS	SS%	MS	VR
Cue.Type. Units Stratum					
Cue	3	31522852	34.50	10507617	79.011**
Lin	1	29520432	32.31	29520432	221.977**
Quad	1	579860	0.63	579860	4.360
Deviations	1	1422561	1.56	1422561	10.697
Type	1	34864267	38.16	34864267	262.160**
Cue.Type	3	13280254	14.53	4426751	33.287**
Lin.Dev	1	11423447	12.50	11423447	85.898**
Quad.Dev	1	273600	0.30	273600	2.057
Deviations	1	1583207	1.73	1583207	11.905
Residual	88	11702993	12.81	132989	
Total	95	91370367	100.00	961793	

* significant at .05
** significant at .01

Appendix 3.2 Repeated measures analysis of variance of solution times in sessions 1 and 4 for nonretarded subjects in each cue condition and for each analogy type.

Source	Df	SS	SS%	MS	VR
Subject Stratum	11	9866962	4.42	896997	9.973
Subject.Session Stratum					
Session	1	18418974	8.26	18418974	54.332**
Residual	11	3729094	1.67	339009	3.769
Total	12	22148068	9.93	1845672	20.521
Subject.Type Stratum					
Type	1	70313105	31.53	70313105	316.631**
Residual	11	2442733	1.10	222067	2.469
Total	12	72755837	32.62	6062986	67.411
Subject.Cue Stratum					
Cue	3	68656596	30.78	22885532	94.335**
Residual	33	8005719	3.59	242598	2.697
Total	36	76662315	34.37	2129509	23.677
Subject.Session.Type Stratum					
Session.Type	1	680680	0.31	680680	7.444*
Residual	11	1005827	0.45	91439	1.017
Total	12	1686508	0.76	140542	1.563
Subject.Session.Cue Stratum					
Session.Cue	3	3216784	1.44	1072261	15.187**
Residual	33	2329965	1.04	70605	0.785
Total	36	5546750	2.49	154076	1.713
Subject.Type.Cue Stratum					
Type.Cue	3	26458511	11.86	8819504	65.147
Residual	33	4467462	2.00	135378	1.505
Total	36	30925973	13.87	859055	9.551
Subject.Session.Type.Cue Stratum					
Session.Type.Cue	3	459797	0.21	153266	1.704
Residual	33	2968032	1.33	89940	
Total	36	3427830	1.54	95217	
Grand Total	191	223020242	100.00		

* significant at .05
** significant at .01

Appendix 3.3 Linear regression tables for nonretarded subjects, Models I, II and IV.

MODEL I

Parameter	Time	Standard Error	β	Freq.	df
y	358	31	.37	130	1,295
x	530	45	.47	136	1,295
a	175	24	.23	54	1,295
z	56	41	.05	2	1,295
c	681				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.48	.69	273	1,298
x	.73	.79	397	2,297
a	.77	.52	329	3,296
z	.77	.41	248	4,295

MODEL II

Parameter	Time	Standard Error	β	Freq.	df
y	393	30	.41	172	1,295
x	500	37	.45	178	1,295
a	176	21	.24	67	1,295
z'	287	45	.17	41	1,295
c	498				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.48	.69	273	1,298
x	.73	.79	397	2,297
a	.77	.52	329	3,296
z'	.80	.24	290	4,295

MODEL IV

Parameter	Time	Standard Error	β	Freq.	df
y'	620	44	.39	194	1,295
x'	980	59	.53	278	1,295
a	187	19	.25	97	1,295
z'	- 44	43	- .03	1	1,295
c	775				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y'	.53	.73	334	1,298
x'	.78	.81	522	2,297
a	.84	.52	501	3,296
z'	.84	.24	376	4,295

Appendix 3.4

Linear regression tables for nonretarded subjects, Models I to IV, 0 cue condition.

MODEL I

Parameter	Time	Standard Error	β	Freq.	df
y	405	93	.42	19	1,71
x	543	167	.56	11	1,71
z	-109	186	- .08	.34	1,71
c	1480				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.54	.74	87	1,73
x	.68	.75	77	2,72
z	.68	.54	51	3,71

MODEL II

Parameter	Time	Standard Error	β	Freq.	df
y	548	78	.57	50	1,71
x	296	81	.31	13	1,71
z'	540	119	.30	21	1,71
c	976				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.54	.74	87	1,73
x	.68	.75	77	2,72
z'	.75	.35	72	3,71

MODEL III

Parameter	Time	Standard Error	β	Freq.	df
y'	970	83	.62	135	1,71
x	376	53	.39	50	1,71
z'	211	86	.12	6	1,71
c	1224				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y'	.72	.85	184	1,73
x	.84	.75	193	2,72
z'	.86	.35	140	3,71

MODEL IV

Parameter	Time	Standard Error	β	Freq.	df
y'	716	89	.46	65	1,71
x'	969	107	.62	81	1,71
z'	-176	95	- .10	3	1,71
c	1547				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y'	.72	.85	184	1,73
x'	.88	.86	262	2,72
z'	.88	.35	182	3,71

Appendix 3.5

Linear regression tables for nonretarded subjects, Models I to IV, 1 cue condition.

MODEL I

Parameter	Time	Standard Error	β	Freq.	df
y	527	77	1	47	1,71
x	455	139	.45	11	1,71
z	44	155	.03	1	1,71
c	1261				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.65	.81	140	1,73
x	.80	.80	143	2,72
z	.80	.60	94	3,71

MODEL II

Parameter	Time	Standard Error	β	Freq.	df
y	601	67	1	80	1,71
x	375	70	.37	29	1,71
z	380	103	.20	14	1,71
c	1001				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.66	.81	140	1,73
x	.80	.80	143	2,72
z	.83	.27	117	3,71

MODEL III

Parameter	Time	Standard Error	β	Freq.	df
y'	908	85	1	114	1,71
z	512	54	.50	90	1,71
z'	27	87	.01	1	1,71
c	1287				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y'	.68	.82	152	1,73
x	.86	.80	226	2,72
z'	.86	.27	149	3,71

MODEL IV

Parameter	Time	Standard Error	β	Freq.	df
y'	746	117	.45	40	1,71
x'	996	142	1	49	1,71
z'	-323	125	- .17	7	1,71
c	1628				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y'	.68	.82	152	1,73
x'	.80	.81	143	2,72
z'	.82	.27	105	3,71

Appendix 3.6 Linear regression tables for nonretarded subjects, Models I to IV, 2 cue condition.

MODEL I

Parameter	Time	Standard Error	β	Freq.	df
y	193	39	.45	24	1,72
z	207	52	.37	16	1,72
c	909				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.34	.59	38	1,73
z	.46	.53	30	2,72

MODEL II

Parameter	Time	Standard Error	β	Freq.	df
y	259	34	1	57	1,72
z'	339	64	.43	28	1,72
c	822				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.34	.59	38	1,73
z'	.53	.39	40	2,72

MODEL III - IV

Parameter	Time	Standard Error	β	Freq.	df
y'	419	57	1	53	1,72
z'	213	66	.27	10	1,72
c	953				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y'	.44	.66	58	1,73
z'	.51	.39	38	2,72

Appendix 3.7 Linear regression tables for nonretarded subjects, Models I to IV, 3 cue condition.

MODEL I

Parameter	Time	Standard Error	β	Freq.	df
z	160	50	.35	10	1,73
c	775				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
z	.12	.35	10	1,73

MODEL II - III - IV

Parameter	Time	Standard Error	β	Freq.	df
z'	160	50	.35	10	1,73
c	775				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
z'	.12	.35	10	1,73

Appendix 3.8

Linear regression tables for nonretarded subjects, Models I to IV, nondegenerate, Type II analogies.

MODEL I

Parameter	Time	Standard Error	β	Freq.	df
y	258	74	.25	12	1,115
x	496	104	.49	23	1,115
a	222	99	.25	5	1,115
z	- 24	88	- .02	1	1,115
c	897				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.26	.51	41	1,118
x	.66	.73	113	2,117
a	.68	.77	80	3,116
z	.68	.10	60	4,115

MODEL II

Parameter	Time	Standard Error	β	Freq.	df
y	293	64	.29	21	1,115
x	336	82	.33	17	1,115
a	310	84	.35	14	1,115
z'	465	79	.29	35	1,115
c	319				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.26	.51	41	1,118
x	.66	.73	113	2,117
a	.68	.77	80	3,116
z'	.75	.32	86	4,115

MODEL III

Parameter	Time	Standard Error	β	Freq.	df
y'	586	77	.39	58	1,115
x	423	74	.42	33	1,115
a	247	70	.28	12	1,115
z'	232	75	.15	10	1,115
c	594				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y'	.37	.61	70	1,118
x	.78	.73	205	2,117
a	.79	.77	144	3,116
z'	.80	.32	118	4,115

MODEL IV

Parameter	Time	Standard Error	β	Freq.	df
y'	424	67	.28	40	1,115
x'	737	105	.46	49	1,115
a	315	54	.35	34	1,115
z'	51	82	.03	.38	1,115
c	718				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y'	.37	.61	70	1,118
x'	.76	.80	186	2,117
a	.82	.77	180	3,116
z'	.82	.32	135	4,115

Appendix 3.9

Linear regression tables for nonretarded subjects, Models I to IV, session 1.

MODEL I

Parameter	Time	Standard Error	β	Freq.	df
y	448	41	.38	121	1,295
x	609	60	.44	101	1,295
a	280	30	.30	87	1,295
z	- 34	60	- .02	.33	1,295
c	810				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.46	.68	250	1,298
x	.67	.74	299	2,297
a	.75	.58	292	3,296
z	.75	.42	219	4,295

MODEL II

Parameter	Time	Standard Error	β	Freq.	df
y	473	41	.40	135	1,295
x	541	51	.39	112	1,295
a	298	29	.32	104	1,295
z'	210	63	.10	11	1,295
c	559				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.46	.68	250	1,298
x	.67	.74	299	2,297
a	.75	.58	292	3,396
z'	.76	.11	229	4,295

MODEL III

Parameter	Time	Standard Error	β	Freq.	df
y'	794	60	.41	175	1,295
x	608	45	.44	182	1,295
a	285	28	.31	106	1,295
c	778				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y'	.45	.67	242	1,298
x	.70	.74	341	2,297
a	.78	.58	343	3,296

MODEL IV

Parameter	Time	Standard Error	β	Freq.	df
y'	703	67	.36	111	1,295
x'	1061	89	.46	143	1,295
a	303	29	.33	111	1,295
z'	-182	66	- .09	8	1,295
c	929				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y'	.45	.67	242	1,298
x'	.65	.74	272	2,297
a	.75	.58	302	3,296
z'	.76	.11	233	4,295

Appendix 3.10

Linear regression tables for nonretarded subjects, Models I to IV, session 4.

MODEL I

Parameter	Time	Standard Error	β	Freq.	df
y	293	39	.32	56	1,295
x	498	58	.46	74	1,295
a	100	29	.14	12	1,295
z	81	57	.07	2	1,295
c	656				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.38	.61	181	1,298
x	.60	.72	224	2,297
a	.61	.41	157	3,296
z	.62	.48	119	4,295

MODEL II

Parameter	Time	Standard Error	β	Freq.	df
y	345	37	.37	85	1,295
x	458	47	.43	96	1,295
a	117	27	.16	19	1,295
z'	374	58	.23	42	1,295
c	359				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.38	.61	181	1,298
x	.60	.72	224	2,297
a	.61	.41	157	3,196
z'	.66	.26	145	4,195

MODEL III

Parameter	Time	Standard Error	β	Freq.	df
y'	646	54	.42	145	1,295
x	488	41	.45	143	1,295
a	106	25	.15	18	1,295
z'	217	53	.13	17	1,295
c	516				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y'	.46	.68	250	1,298
x	.68	.72	314	2,297
a	.69	.41	222	3,296
z'	.71	.26	179	4,295

MODEL IV

Parameter	Time	Standard Error	β	Freq.	df
y'	535	56	.35	92	1,295
x'	955	74	.53	165	1,295
a	109	24	.15	20	1,295
z'	38	55	.02	.48	1,295
c	685				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y'	.46	.68	250	1,298
x'	.70	.78	352	2,297
a	.72	.41	256	3,296
z'	.72	.26	192	4,295

Appendix 3.11

Linear regression tables for nonretarded subjects, Models I to IV, dual processing in application only.

MODEL I

Parameter	Time	Standard Error	β	Freq.	df
y	177	32	.26	30	1,295
x	238	41	.32	33	1,295
a	161	42	.22	15	1,295
z	451	54	.36	71	1,295
c	306				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.11	.33	35	1,298
x	.40	.51	100	2,297
a	.41	.52	70	3,296
z	.53	.49	83	4,295

MODEL II

Parameter	Time	Standard Error	β	Freq.	df
y	226	34	.33	44	1,295
x	319	42	.43	57	1,295
a	139	44	.19	10	1,295
z'	374	73	.22	26	1,295
c	432				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.11	.33	35	1,298
x	.40	.50	100	2,297
a	.41	.52	70	3,296
z'	.46	.21	63	4,295

MODEL III

Parameter	Time	Standard Error	β	Freq.	df
y'	390	50	.36	60	1,295
x	308	40	.41	60	1,295
a	154	41	.21	14	1,295
z'	361	71	.21	25	1,295
c	438				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y'	.13	.37	46	1,298
x	.43	.50	110	2,297
a	.44	.52	79	3,296
z'	.49	.21	70	4,295

MODEL IV

Parameter	Time	Standard Error	β	Freq.	df
y'	330	48	.30	47	1,295
x'	465	60	.38	60	1,295
a	201	38	.27	28	1,295
z'	341	72	.20	23	1,295
c	412				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y'	.13	.37	46	1,298
x'	.41	.52	103	2,297
a	.45	.52	81	3,296
	.49	.21	70	4,295

Appendix 3.12

Linear regression tables for nonretarded subjects, Models I to IV, self-terminating encoding.

MODEL I

Parameter	Time	Standard Error	β	Freq.	df
y	358	32	.37	129	1,295
x	541	47	.48	134	1,295
a	169	23	.23	53	1,295
z	38	46	.03	1	1,295
c	714				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.48	.69	273	1,298
x	.73	.79	397	2,297
a	.77	.52	329	3,296
z	.77	.49	247	4,295

MODEL II

Parameter	Time	Standard Error	β	Freq.	df
y	400	30	.42	180	1,295
x	490	37	.44	172	1,295
a	187	21	.27	76	1,295
z'	128	48	.08	7	1,295
c	625				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.48	.69	273	1,298
x	.73	.79	397	2,297
a	.80	.58	385	3,296
z'	.80	.21	296	4,295

MODEL III

Parameter	Time	Standard Error	β	Freq.	df
y'	529	48	.33	119	1,295
x	531	32	.47	273	1,295
a	221	26	.28	72	1,295
z'	120	41	.07	9	1,295
c	897				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y'	.53	.73	334	1,298
x	.80	.79	578	2,297
a	.83	.75	490	3,296
z'	.84	.21	379	4,195

MODEL IV

Parameter	Time	Standard Error	β	Freq.	df
y'	641	49	.40	171	1,195
x'	829	91	.44	84	1,295
a	266	52	.22	27	1,295
z'	-107	48	- .06	5	1,295
c	1205				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y'	.53	.73	334	1,298
x'	.78	.81	522	2,297
a	.80	.72	392	3,296

Appendix 3.13

Linear regression tables for nonretarded subjects, Models I to Iv, no mapping.

MODEL I

Parameter	Time	Standard Error	β	Freq.	df
x	723	53	.65	190	1,296
a	190	28	.25	47	1,296
z	75	55	.06	2	1,296
c	740				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
x	.62	.79	479	1,298
a	.67	.52	298	2,297
z	.67	.49	200	3,296

MODEL II

Parameter	Time	Standard Error	β	Freq.	df
x	738	41	.66	322	1,296
a	197	27	.26	53	1,296
z'	193	57	.11	11	1,296
c	635				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
x	.62	.79	479	1,298
a	.67	.52	298	2,297
z'	.68	.21	209	3,296

MODEL III

Parameter	Time	Standard Error	β	Freq.	df
x	738	41	.66	322	1,296
a	197	27	.26	53	1,296
z'	193	57	.11	11	1,296
c	635				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
x	.62	.79	479	1,298
a	.67	.52	298	2,397
z'	.68	.21	209	3,206

MODEL IV

Parameter	Time	Standard Error	β	Freq.	df
x'	1385	66	.74	434	1,296
a	193	25	.26	61	1,296
z'	- 84	57	- .05	2	1,296
c	887				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
x'	.66	.81	585	1,298
a	.73	.52	394	2,297
z'	.73	.21	265	3,296

Appendix 3.14

Linear regression tables for nonretarded subjects, dual processing in 1 DD' value change only.

MODEL I

Parameter	Time	Standard Error	β	Freq.	df
y	335	32	.35	108	1,295
x	489	46	.44	110	1,295
a	192	24	.26	62	1,295
z	98	35	.11	8	1,295
c	655				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.48	.69	273	1,298
x	.73	.79	397	2,297
a	.77	.52	329	3,296
z	.78	.53	254	4,295

MODEL II

Parameter	Time	Standard Error	β	Freq.	df
y	320	28	.33	127	1,295
x	423	28	.38	125	1,295
a	217	21	.29	106	1,295
z'	362	41	.26	78	1,295
c	541				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.48	.69	273	1,298
x	.73	.79	397	2,297
a	.77	.52	329	3,296
z'	.82	.54	330	4,295

MODEL III

Parameter	Time	Standard Error	β	Freq.	df
y'	640	42	.40	228	1,295
x	477	32	.43	217	1,295
a	197	19	.26	107	1,295
z'	224	39	.16	33	1,295
c	623				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y'	.53	.73	334	1,298
x	.80	.79	578	2,297
a	.84	.52	504	3,296
z'	.86	.54	428	4,295

MODEL IV

Parameter	Time	Standard Error	β	Freq.	df
y'	582	45	.37	168	1,295
x'	841	62	.45	183	1,295
a	213	19	.29	120	1,295
z'	156	43	.11	13	1,295
c	642				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y'	.53	.73	334	1,298
x'	.78	.81	522	2,297
a	.84	.52	501	3,296
	.84	.54	395	4,295

APPENDIX 3.15

MEAN SOLUTION TIMES FOR TYPE II ANALOGIES

0 AND 1DD' VALUE CHANGE ANALOGIES, NONRETARDED SUBJECTS

		CUE CONDITION			
AB/AC CHANGES	DD' VALUE CHANGES	0	1	2	3
1 1	0	3309	2800	1544	903
1 1	1	2506	3016	1632	1304
1 2	0	3614	3182	1503	986
1 2	1	3001	3040	1661	993
1 3	0	4271	3765	1591	1174
1 3	1	2950	3800	2058	1422
2 1	0	3523	3380	1987	1108
2 1	1	3835	3762	2291	1439
2 2	0	4672	4386	2132	1248
2 2	1	3537	3712	2645	1638
3 1	0	4060	3426	2446	1077
3 1	1	3692	3187	1724	1088

Appendix 4.1 Analysis of variance of solution times for nonretarded and retarded subjects in each cue condition and for each analogy type.

Source	Df	SS	SS%	MS	VR
Cue.Type.Group. Units Stratum					
Cue	1	32564081	11.70	32564081	29.668**
Lin	1	32564081	11.70	32564081	29.668
Type	1	71687810	25.75	71687810	65.313**
Group	1	56172420	20.18	56172420	51.177**
Cue.Type	1	15895793	5.71	15895793	14.482**
Lin.Dev	1	15895793	5.71	15895793	14.482
Cue.Group	1	2380140	0.86	2380140	2.168
Lin.Dev	1	2380140	0.86	2380140	2.168
Type.Group	1	2995560	1.08	2995560	2.719
Cue.Type.Group	1	86160	0.03	86160	0.078
Lin.Dev.Dev	1	86160	0.03	86160	0.078
Residual	88	96589482	34.70	1097608	
Total	95	278371446	100.00	2930226	

** significant at .01

Appendix 4.2 Repeated measures analysis of variance of solution times in sessions 1 and 2, for nonretarded and retarded subjects, in each cue condition and for each analogy type.

Source	Df	SS	SS%	MS	VR
Grp.Subject Stratum					
Grp	1	112349430	19.57	112349430	17.338**
Residual	22	142558737	24.84	6479943	77.403
Total	23	254908167	44.41	11082964	132.385
Grp.Subject.Session Stratum					
Session	1	1584678	0.28	1584678	6.883*
Grp.Session	1	1395543	0.24	1395543	6.061*
Residual	22	5065087	0.88	230231	2.750
Total	24	8045308	1.40	335221	4.004
Grp.Subject.Type Stratum					
Type	1	143346241	24.97	143346241	140.697**
Grp.Type	1	5993593	1.04	5993593	5.883*
Residual	22	22414277	3.91	1018831	12.170
Total	24	171754111	29.92	7156421	85.483
Grp.Subject.Cue Stratum					
Cue	1	65138645	11.35	65138645	71.088**
Grp.Cue	1	4764375	0.83	4764375	5.200*
residual	22	20158747	3.51	916307	10.945
Total	24	90061768	15.69	3752574	44.824
Grp.Subject.Session.Type Stratum					
Session.Type	1	45111	0.01	45111	0.399
Grp.Session.Type	1	280985	0.05	280985	2.485
Residual	22	2487920	0.43	113087	1.351
Total	24	2814016	0.49	117251	1.401
Grp.Subject.Session.Cue Stratum					
Session.Cue	1	19421	0.00	19421	0.116
Grp.Session.Cue	1	387272	0.07	387272	2.305
Residual	22	3696531	0.64	168024	2.007
Total	24	4103223	0.71	170968	2.042
Grp.Subject.Type.Cue Stratum					
Type.Cue	1	31789144	5.54	31789144	86.903**
Grp.Type.Cue	1	173100	0.03	173100	0.473
residual	22	8047598	1.40	365800	4.369
Total	24	40009842	6.97	1667077	19.913
Grp.Subject.Session.Type.Cue Stratum					
Session.Type.Cue	1	352004	0.06	352004	4.205
residual	23	1925499	0.34	83717	
Total	24	2277504	0.40	94896	
Grand Total	191	573973939	100.00		

* significant at .05
** significant at .01

Appendix 4.3 Linear regression tables for nonretarded and retarded subjects, Models I, II and IV.

MODEL I

Nonretarded Ss						Retarded Ss					
Parameter	Time	Standard Error	β	Freq.	df	Parameter	Time	Standard Error	β	Freq.	df
y	349	41	.40	71	1,145	y	548	93	.35	35	1,145
x	588	69	.54	73	1,145	x	750	154	.37	24	1,145
a	101	42	.12	6	1,145	a	413	93	.28	20	1,145
z	47	62	.04	1	1,145	z	212	139	.10	2	1,145
c	789					c	1074				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df	Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.40	.63	98	1,148	y	.28	.53	58	1,148
x	.72	.77	193	2,147	x	.55	.69	91	2,147
a	.73	.36	134	3,146	a	.60	.44	73	3,146
z	.74	.47	101	4,145	z	.61	.43	56	4,145

MODEL II

Parameter	Time	Standard Error	β	Freq.	df	Parameter	Time	Standard Error	β	Freq.	df
y	384	40	.44	95	1,145	y	620	91	.39	47	1,145
x	549	57	.50	93	1,145	x	757	131	.38	33	1,145
a	114	38	.14	9	1,145	a	411	87	.28	22	1,145
z'	294	68	.18	18	1,145	z'	522	155	.18	11	1,145
c	551					c	842				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df	Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.40	.63	98	1,148	y	.28	.53	58	1,148
x	.72	.77	193	2,147	x	.55	.69	91	2,147
a	.73	.36	134	3,146	a	.60	.44	73	3,146
z'	.76	.25	118	4,145	z'	.63	.22	62	4,145

MODEL IV

Parameter	Time	Standard Error	β	Freq.	df	Parameter	Time	Standard Error	β	Freq.	df
y'	600	58	.43	101	1,145	y'	986	150	.38	43	1,146
x'	1077	90	.59	141	1,145	x'	1328	212	.40	39	1,146
a	110	34	.13	10	1,145	a	433	85	.29	26	1,146
z'	- 97	67	-.06	2	1,145	c	1302				
c	930					*					

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df	Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y'	.45	.67	121	1,148	y'	.31	.56	66	1,148
x'	.78	.80	254	2,147	x'	.54	.68	87	2,147
a	.79	.36	186	3,146	a	.61	.44	76	3,146
z'	.80	.25	141	4,145					

* F-level or tolerance level insufficient for further computation

Appendix 4.4 Linear regression tables for nonretarded and retarded subjects, Models I to IV, 0 cue condition only.

MODEL I

Nonretarded Ss						Retarded Ss					
Parameter	Time	Standard Error	β	Freq.	df	Parameter	Time	Standard Error	β	Freq.	df
y	477	89	.45	29	1,71	y	796	196	.44	16	1,71
x	604	160	.57	14	1,71	x	620	354	.35	3	1,71
z	-102	178	-.07	.33	1,71	z	173	394	.07	.19	1,71
c	1268					c	2693				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df	Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.61	.78	113	1,73	y	.47	.69	65	1,73
x	.76	.79	112	2,72	x	.58	.69	50	2,72
z	.76	.57	74	3,71	z	.58	.53	33	3,71

MODEL II

Parameter	Time	Standard Error	β	Freq.	df	Parameter	Time	Standard Error	β	Freq.	df
y	590	78	.56	57	1,71	y	888	181	.50	24	1,71
x	401	82	.38	24	1,71	x	578	190	.32	9	1,71
z'	411	119	.21	12	1,71	z'	590	277	.18	5	1,71
c	870					c	2370				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df	Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.61	.78	113	1,73	y	.47	.69	65	1,73
x	.76	.79	112	2,72	x	.58	.69	50	2,72
z'	.79	.29	90	3,71	z'	.61	.24	36	3,71

MODEL III

Parameter	Time	Standard Error	β	Freq.	df	Parameter	Time	Standard Error	β	Freq.	df
y'	989	89	.58	124	1,71	y'	1347	247	.47	30	1,71
x	505	56	.48	80	1,71	x	779	157	.44	25	1,71
z'	60	91	.03	.43	1,71	z'	67	253	.02	1	1,71
c	1142					c	2792				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df	Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y'	.69	.83	165	1,73	y'	.49	.70	70	1,73
x	.86	.79	226	2,72	x	.63	.69	61	2,72
z'	.86	.29	149	3,71	z'	.63	.24	40	3,71

MODEL IV

Parameter	Time	Standard Error	β	Freq.	df	Parameter	Time	Standard Error	β	Freq.	df
y'	765	111	.45	47	1,71	y'	1144	311	.40	14	1,71
x'	1094	135	.64	66	1,71	x'	1437	376	.50	15	1,71
z'	-346	119	-.18	9	1,71	z'	-422	332	-.13	2	1,71
c	1513					c	3288				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df	Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y'	.69	.83	165	1,73	y'	.49	.70	70	1,73
x'	.83	.83	177	2,72	x'	.58	.68	49	2,72
z'	.85	.29	133	3,71	z'	.58	.24	33	3,71

Appendix 4.5 Linear regression tables for nonretarded and retarded subjects, Models I to IV, 2 cue condition only.

Nonretarded Ss

MODEL I

Parameter	Time	Standard Error	β	Freq.	df
y	216	37	.52	34	1,72
z	181	50	.33	13	1,72
c	926				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.40	.64	49	1,73
z	.50	.51	35	2,72

MODEL II

Parameter	Time	Standard Error	β	Freq.	df
y	273	34	.66	65	1,72
z'	271	63	.35	18	1,72
c	872				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.40	.64	49	1,73
z'	.53	.31	40	2,72

MODEL III - IV

Parameter	Time	Standard Error	β	Freq.	df
y'	425	59	.63	53	1,72
z'	142	67	.18	4	1,72
c	1013				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y'	.44	.67	58	1,73
z'	.47	.31	33	2,72

Retarded Ss

Parameter	Time	Standard Error	β	Freq.	df
y	349	94	.38	14	1,72
z	376	126	.31	9	1,72
c	1845				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.24	.49	23	1,73
z	.33	.45	17	2,72

Parameter	Time	Standard Error	β	Freq.	df
y	468	86	.51	29	1,72
z'	568	161	.33	12	1,72
c	1728				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.24	.49	23	1,73
z'	.35	.30	20	2,72

Parameter	Time	Standard Error	β	Freq.	df
y'	769	142	.52	29	1,72
z'	338	164	.20	4	1,72
c	1963				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y'	.31	.56	33	1,73
z'	.35	.30	20	2,72

Appendix 4.6 Linear regression tables for nonretarded and retarded subjects, Models I to IV, nondegenerate, Type II analogies.

MODEL I

Nonretarded Ss						Retarded Ss					
Parameter	Time	Standard Error	β	Freq.	df	Parameter	Time	Standard Error	β	Freq.	df
y	98	113	.08	.75	1,55	y	199	210	.10	.90	1,55
x	30	195	.03	.23	1,55	x	- 7	363	-.00	.42	1,55
a	646	178	.75	13	1,55	a	1191	332	.76	13	1,55
z	99	149	.09	.44	1,55	z	200	277	.10	1	1, 55
c	- 3					c	23				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df	Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.00	.03	0	1,58	y	.00	.05	0	1,58
x	.49	.68	28	2,57	x	.47	.66	25	2,57
a	.61	.78	29	3,56	a	.58	.76	26	3,56
z	.61	.06	22	4,55	z	.59	.05	19	4,55

MODEL II

Parameter	Time	Standard Error	β	Freq.	df	Parameter	Time	Standard Error	β	Freq.	df
y	153	87	.13	3	1,55	y	247	183	.12	2	1,55
x	-136	130	-.15	1	1,55	x	-149	273	-.09	.30	1,55
a	784	123	.91	40	1,55	a	1310	260	.84	25	1,55
z'	562	107	.41	27	1,55	z'	702	225	.28	10	1,55
c	-693					c	-568				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df	Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.00	.03	0	1,58	y	.00	.05	0	1,58
x	.49	.68	28	2,57	x	.47	.66	25	2,57
a	.61	.78	29	3,56	a	.58	.76	26	3,56
z'	.74	.33	39	4,55	z'	.64	.22	25	4,55

MODEL III

Parameter	Time	Standard Error	β	Freq.	df	Parameter	Time	Standard Error	β	Freq.	df
y'	340	100	.25	12	1,55	y'	576	215	.23	7	1,55
x	- 25	128	-.03	.37	1,55	x	43	274	.03	.25	1,55
a	692	120	.80	33	1,55	a	1149	258	.74	20	1,55
z'	372	109	.27	12	1,55	z'	384	233	.15	3	1,55
c	-385					c	- 60				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df	Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y'	.11	.32	7	1,58	y'	.07	.27	5	1,58
x	.63	.68	49	2,57	x	.56	.66	35	2,57
a	.72	.78	49	3,56	a	.66	.76	36	3,56
z'	.77	.33	46	4,55	z'	.68	.22	29	4,55

MODEL IV

Parameter	Time	Standard Error	β	Freq.	df	Parameter	Time	Standard Error	β	Freq.	df
y'	347	88	.25	16	1,55	y'	563	197	.23	8	1,55
x'	414	168	.30	6	1,55	x'	319	379	.13	1	1,55
a	492	90	.57	30	1,55	a	1047	203	.67	27	1,55
z'	154	121	.11	2	1,55	z'	244	273	.10	1	1,55
c	199					c	279				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df	Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y'	.11	.32	7	1,58	y'	.07	.27	5	1,58
x'	.67	.79	57	2,57	x'	.49	.68	27	2,57
a	.79	.78	69	3,56	a	.67	.76	39	3,56
z'	.79	.33	53	4,55	z'	.68	.22	29	4,55

Appendix 4.7 Linear regression tables for nonretarded and retarded subjects, Models I to IV, session 1.

MODEL I

Nonretarded Ss						Retarded Ss					
Parameter	Time	Standard Error	β	Freq.	df	Parameter	Time	Standard Error	β	Freq.	df
y	426	50	.43	73	1,145	y	531	98	.34	29	1,145
x	627	83	.51	57	1,145	x	827	163	.42	26	1,145
a	121	50	.13	6	1,145	a	290	98	.20	9	1,145
z	16	75	.01	.44	1,145	z	110	147	.05	1	1,145
c	881					c	1519				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df	Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.41	.64	101	1,148	y	.27	.52	55	1,148
x	.69	.74	163	2,147	x	.52	.67	81	2,147
a	.70	.36	115	3,146	a	.55	.38	59	3,146
z	.70	.44	86	4,145	z	.55	.40	44	4,145

MODEL II

Parameter	Time	Standard Error	β	Freq.	df	Parameter	Time	Standard Error	β	Freq.	df
y	457	48	.47	89	1,145	y	589	96	.38	37	1,145
x	571	70	.46	67	1,145	x	786	139	.40	32	1,145
a	140	47	.15	9	1,145	a	303	93	.21	11	1,145
z'	289	83	.16	12	1,145	z'	466	165	.16	8	1,145
c	601					c	1193				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df	Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.41	.64	101	1,148	y	.27	.52	55	1,148
x	.69	.74	164	2,147	x	.52	.67	81	2,147
a	.70	.36	115	3,146	a	.55	.38	59	3,146
z'	.73	.22	96	4,145	z'	.57	.21	49	4,145

MODEL III

Parameter	Time	Standard Error	β	Freq.	df	Parameter	Time	Standard Error	β	Freq.	df
y'	753	72	.47	109	1,145	y'	1001	146	.39	47	1,145
x	651	63	.52	106	1,145	x	879	128	.44	47	1,145
a	113	44	.12	7	1,145	a	272	89	.18	9	1,145
z'	42	79	.02	.29	1,145	z'	143	159	.05	1	1,145
c	902					c	1568				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df	Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y'	.43	.65	110	1,148	y'	.31	.55	65	1,148
x	.74	.74	204	2,147	x	.57	.67	96	2,147
a	.75	.36	143	3,146	a	.59	.38	71	3,146
z'	.75	.22	107	4,145	z'	.59	.21	53	4,145

MODEL IV

Parameter	Time	Standard Error	β	Freq.	df	Parameter	Time	Standard Error	β	Freq.	df
y'	686	77	.43	79	1,145	y'	958	158	.38	37	1,145
x'	1137	117	.55	94	1,145	x'	1372	241	.41	32	1,145
a	133	45	.14	9	1,145	a	327	91	.22	13	1,145
z'	-145	86	-.08	2	1,145	z'	- 64	177	-.02	.13	1,145
c	1041					c	1644				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df	Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y'	.43	.65	110	1,148	y'	.31	.55	65	1,148
x'	.71	.76	179	2,147	x'	.52	.66	79	2,147
a	.73	.36	131	3,146	a	.56	.38	62	3,146
z'	.73	.22	100	4,145	z'	.56	.21	46	4,145

Appendix 4.8 Linear regression tables for nonretarded and retarded subjects, Models I to IV, session 2.

MODEL I

Nonretarded Ss						Retarded Ss					
Parameter	Time	Standard Error	β	Freq.	df	Parameter	Time	Standard Error	β	Freq.	df
y	271	42	.34	42	1,145	y	522	106	.31	24	1,145
x	547	69	.54	62	1,145	x	606	176	.29	12	1,145
a	81	42	.11	4	1,145	a	522	106	.33	24	1,145
z	80	63	.08	2	1,145	z	344	159	.15	5	1,145
c	689					c	648				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df	Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.34	.58	75	1,148	y	.23	.48	44	1,148
x	.68	.76	154	2,147	x	.47	.64	64	2,147
a	.68	.35	105	3,146	a	.53	.46	55	3,146
z	.69	.49	79	4,145	z	.54	.42	43	4,145

MODEL II

Parameter	Time	Standard Error	β	Freq.	df	Parameter	Time	Standard Error	β	Freq.	df
y	309	40	.39	60	1,145	y	607	105	.36	33	1,145
x	526	57	.52	84	1,145	x	684	152	.32	20	1,145
a	88	38	.12	5	1,145	a	496	101	.31	24	1,145
z'	298	68	.20	19	1,145	z'	550	180	.18	9	1,145
c	496					c	582				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df	Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.34	.58	75	1,148	y	.23	.48	44	1,148
x	.68	.76	154	2,147	x	.47	.64	64	2,147
a	.68	.35	105	3,146	a	.53	.46	55	3,146
z'	.72	.27	93	4,145	z'	.56	.21	46	4,145

MODEL III

Parameter	Time	Standard Error	β	Freq.	df	Parameter	Time	Standard Error	β	Freq.	df
y'	575	56	.45	106	1,145	y'	952	163	.35	34	1,145
x	561	49	.56	131	1,145	x	805	143	.38	32	1,145
a	76	34	.10	5	1,145	a	456	99	.29	21	1,145
z'	121	61	.08	4	1,145	z'	229	178	.07	2	1,145
c	671					c	1003				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df	Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y'	.42	.65	106	1,148	y'	.24	.49	47	1,148
x	.76	.76	229	2,147	x	.49	.64	72	2,147
a	.76	.35	158	3,146	a	.56	.46	61	3,146
z'	.77	.27	122	4,125	z'	.56	.21	46	4,145

MODEL IV

Parameter	Time	Standard Error	β	Freq.	df	Parameter	Time	Standard Error	β	Freq.	df
y'	508	58	.39	76	1,145	y'	935	176	.34	28	1,145
x'	1012	81	.60	130	1,145	x'	1174	268	.33	19	1,145
a	87	34	.12	7	1,145	a	520	102	.33	26	1,145
z'	- 48	65	-.03	1	1,145	z'	61	197	.02	1	1,145
c	813					c	1018				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df	Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y'	.42	.65	106	1,148	y'	.24	.49	47	1,148
x'	.76	.80	228	2,147	x'	.44	.61	58	2,147
a	.77	.35	161	3,146	a	.53	.46	54	3,146
z'	.77	.27	121	4,145	z'	.53	.21	40	4,145

Appendix 4.9 Linear regression tables for nonretarded and retarded subjects, Models I to IV, self-terminating encoding.

MODEL I

Nonretarded Ss						Retarded Ss					
Parameter	Time	Standard Error	β	Freq.	df	Parameter	Time	Standard Error	β	Freq.	df
y	349	42	.40	71	1,145	y	548	93	.35	35	1,145
x	588	69	.54	73	1,145	x	750	154	.37	24	1,145
a	101	42	.12	6	1,145	a	413	93	.28	20	1,145
z	47	62	.04	1	1,145	z	212	139	.10	2	1,145
c	789					c	1074				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df	Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.40	.63	98	1,148	y	.28	.53	58	1,148
x	.72	.77	193	2,147	x	.55	.69	91	2,147
a	.73	.36	134	3,146	a	.60	.44	73	3,146
z	.74	.47	101	4,145	z	.61	.43	56	4,145

MODEL II

Parameter	Time	Standard Error	β	Freq.	df	Parameter	Time	Standard Error	β	Freq.	df
y	384	40	.44	95	1,145	y	620	91	.39	47	1,145
x	549	57	.50	93	1,145	x	757	131	.38	33	1,145
a	114	38	.16	9	1,145	a	411	87	.31	22	1,145
z'	180	73	.11	6	1,145	z'	111	168	.04	.44	1,145
c	665					c	1253				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df	Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.40	.63	98	1,148	y	.28	.53	58	1,148
x	.72	.77	193	2,247	x	.55	.69	91	2,147
a	.75	.44	150	3,146	a	.63	.50	82	3,146
z'	.76	.25	118	4,145	z'	.63	.22	62	4,145

MODEL III

Parameter	Time	Standard Error	β	Freq.	df	Parameter	Time	Standard Error	β	Freq.	df
y'	572	61	.41	89	1,145	y'	649	149	.25	19	1,145
x	606	49	.55	152	1,145	x	865	121	.43	51	1,145
a	95	34	.13	8	1,145	a	375	84	.29	20	1,145
z'	82	61	.06	2	1,145	z'	186	151	.06	2	1,145
c	979					c	1999				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df	Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y'	.45	.67	121	1,148	y'	.31	.56	66	1,148
x	.79	.77	278	2,147	x	.59	.69	108	2,147
a	.80	.65	196	3,146	a	.64	.66	87	3,146
z'	.80	.25	148	4,145	z'	.64	.22	66	4,145

MODEL IV

Parameter	Time	Standard Error	β	Freq.	df	Parameter	Time	Standard Error	β	Freq.	df
y'	600	59	.43	102	1,145	y'	986	150	.38	43	1,146
x'	857	137	.47	39	1,145	x'	463	324	.14	2	1,146
a	220	69	.21	10	1,145	a	865	171	.46	26	1,146
z'	- 97	67	-.06	2	1,145	c	2167				
c	1150					*					

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df	Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y'	.45	.67	121	1,148	y'	.31	.56	66	1,148
x'	.78	.80	254	2,147	x'	.54	.68	87	2,147
a	.79	.69	186	3,146	a	.61	.66	76	3,146
z'	.80	.25	141	4,145					

* F-level or tolerance level insufficient for further computation

Appendix 4.10 Linear regression tables for nonretarded and retarded subjects, Models I to IV, dual processing in 1 DD' value change.

Nonretarded Ss

MODEL I

Parameter	Time	Standard Error	β	Freq.	df
y	334	45	.39	56	1,145
x	573	71	.52	66	1,145
a	106	42	.13	6	1,145
z	59	56	.07	1	
c	797				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.40	.63	98	1,148
x	.72	.77	193	2,147
a	.73	.36	134	3,146
z	.74	.60	101	4,145

MODEL II

Parameter	Time	Standard Error	β	Freq.	df
y	313	39	.36	63	1,145
x	509	59	.47	74	1,145
a	127	38	.16	11	1,145
z'	299	64	.22	22	1,145
c	679				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.40	.63	97	1,148
x	.72	.77	193	2,147
a	.73	.36	134	3,146
z'	.77	.56	121	4,145

MODEL III

Parameter	Time	Standard Error	β	Freq.	df
y'	622	61	.44	103	1,145
x	578	52	.53	124	1,145
a	104	34	.13	9	1,145
z'	128	63	.09	4	1,145
c	795				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y'	.45	.67	121	1,148
x	.79	.77	278	2,147
a	.80	.36	196	3,146
z'	.81	.56	151	4,145

MODEL IV

Parameter	Time	Standard Error	β	Freq.	df
y'	586	64	.42	84	1,145
x'	999	97	.55	107	1,145
a	123	35	.15	12	1,145
z'	42	69	.03	.36	1,145
c	809				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y'	.45	.67	121	1,148
x'	.78	.80	254	2,147
a	.79	.36	186	3,146
z'	.79	.56	139	4,145

Retarded Ss

MODEL I

Parameter	Time	Standard Error	β	Freq.	df
y	507	100	.32	26	1,145
x	743	158	.37	22	1,145
a	415	94	.28	20	1,145
z	183	124	.11	2	1,145
c	1199				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.28	.52	58	1,148
x	.55	.69	91	2,147
a	.60	.44	73	3,146
z	.61	.51	56	4,145

MODEL II

Parameter	Time	Standard Error	β	Freq.	df
y	499	91	.32	30	1,145
x	699	137	.35	20	1,145
a	430	88	.29	24	1,145
z'	494	148	.20	11	1,145
c	1092				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.28	.53	57	1,148
x	.55	.69	91	2,147
a	.60	.44	73	3,146
z'	.63	.47	61	4,145

MODEL III

Parameter	Time	Standard Error	β	Freq.	df
y'	943	151	.37	39	1,145
x	814	128	.41	40	1,145
a	392	85	.26	21	1,145
z'	243	156	.10	2	1,145
c	1288				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y'	.31	.56	66	1,148
x	.59	.69	108	2,147
a	.64	.44	87	3,146
z'	.65	.47	66	4,145

MODEL IV

Parameter	Time	Standard Error	β	Freq.	df
y'	921	160	.36	33	1,145
x'	1196	242	.36	24	1,145
a	455	88	.30	27	1,145
z'	196	174	.08	1	1,145
c	1190				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y'	.31	.56	66	1,148
x'	.54	.68	87	2,147
a	.61	.44	76	3,146
z'	.61	.47	58	4,145

APPENDIX 4.11

MEAN SOLUTION TIMES FOR TYPE II ANALOGIES 0 AND 1 DD' VALUE CHANGE ANALOGIES, NONRETARDED SUBJECTS

AB/AC CHANGES	DD' VALUE CHANGES	CUE CONDITION	
		0	2
1 1	0	3104	1308
1 1	1	2501	2536
1 2	0	3410	1423
1 2	1	4133	1878
1 3	0	4276	1590
1 3	1	2953	2872
2 1	0	3516	1674
2 1	1	3476	1909
2 2	0	4056	1857
2 2	1	3470	2086
3 1	0	3803	2075
3 1	1	3371	1883

APPENDIX 4.12

MEAN SOLUTION TIMES FOR TYPE II ANALOGIES 0 AND 1 DD' VALUE CHANGE ANALOGIES, RETARDED SUBJECTS

1 1	0	5376	2577
1 1	1	6526	4358
1 2	0	5099	3199
1 2	1	8128	3476
1 3	0	6285	4279
1 3	1	5588	3407
2 1	0	5310	2705
2 1	1	7336	4855
2 2	0	6703	3721
2 2	1	8721	4823
3 1	0	5922	3018
3 1	1	5085	3465

Appendix 5.1 Analysis of variance of solution times for the experimental group (initial and maintenance phases) and control group 1, in each cue condition and for each analogy type.

Source	Df	SS	SS%	MS	VR
Cue.Type.Group. Units Stratum					
Group	2	14926745	2.75	7463373	3.123*
Reg1	1	445129	0.08	445129	0.186
Reg2	1	14481617	2.67	14481617	6.061*
Cue	1	5344959	0.99	5344959	2.237
Type	1	199871263	36.87	199871263	83.648 **
Cue.Group	2	2497138	0.46	1248569	0.523
Dev.Reg1	1	104742	0.02	104742	0.044
Dev.Reg2	1	2392396	0.44	2392396	1.001
Type.Group	2	146716	0.03	73358	0.031
Dev.Reg1	1	16198	0.00	16198	0.007
Dev.Reg2	1	130518	0.02	130518	0.055
Cue.Type	1	3551654	0.66	3551654	1.486
Cue.Type.Group	2	379535	0.07	189768	0.079
Dev.Dev.Reg1	1	73317	0.01	73317	0.031
Dev.Dev.Reg2	1	306218	0.06	306218	0.128
Residual	132	315404487	58.18	2389428	
Total	143	542122496	100.00	3791066	

* significant at .05
** significant at .01

Appendix 5.2 Repeated measures analysis of variance of solution times in sessions 1 and 2 for the experimental group, (initial and maintenance phases) and control group 1, in each cue condition and for each analogy type.

Source	Df	SS	SS%	MS	VR
Grp.Subject Stratum					
Grp	2	2.980E 7	2.53	1.490E 7	1.049
Residual	33	4.686E 8	39.85	1.420E 7	44.658
Total	35	4.985E 8	42.39	1.424E 7	44.784
Grp.Subject.Session Stratum					
Session	1	1.499E 7	1.27	1.499E 7	16.099**
Grp.Session	2	2.417E 6	0.21	1.209E 6	1.298
Residual	33	3.072E 7	2.61	9.310E 5	2.928
Total	36	4.813E 7	4.09	1.337E 6	4.204
Grp.Subject.Type Stratum					
Type	1	4.001E 8	34.02	4.011E 8	112.212**
Grp.Type	2	2.914E 5	0.02	1.457E 5	0.041
Residual	33	1.176E 8	10.00	3.565E 6	11.211
Total	36	5.180E 8	44.05	1.439E 7	45.247
Grp.Subject.Cue Stratum					
Cue	1	1.074E 7	0.91	1.074E 7	11.317**
Grp.Cue	2	5.025E 6	0.43	2.513E 6	2.648
Residual	33	3.132E 7	2.66	9.490E 5	2.984
Total	36	4.708E 7	4.00	1.308E 6	4.113
Grp.Subject.Session.Type Stratum					
Session.Type	1	1.716E 6	0.15	1.716E 6	3.193
Grp.Session.Type	2	1.514E 6	0.13	7.569E 5	1.408
Residual	33	1.774E 7	1.51	5.375E 5	1.690
Total	36	2.097E 7	1.78	5.824E 5	1.831
Grp.Subject.Session.Cue Stratum					
Session.Cue	1	2.666E 4	0.00	2.666E 4	0.098
Grp.Session.Cue	2	1.266E 6	0.11	6.330E 5	2.332
Residual	33	8.957E 6	0.76	2.714E 5	0.854
Total	36	1.025E 7	0.87	2.847E 5	0.895
Grp.Subject.Type.Cue Stratum					
Type.Cue	1	7.144E 6	0.61	7.144E 6	17.602**
Grp.Type.Cue	2	7.730E 5	0.07	3.865E 5	0.953
Residual	33	1.339E 7	1.14	4.059E 5	1.276
Total	36	2.131E 7	1.81	5.920E 5	1.861
Grp.Subject.Session.Type.Cue Stratum					
Session.Type.Cue	1	6.438E 5	0.05	6.438E 5	2.025
Residual	35	1.113E 7	0.95	3.180E 5	
Total	36	1.177E 7	1.00	3.271E 5	
Grand Total	287	1.176E 9	100.00		

** significant at .01

Appendix 5.3

Linear regression tables for the experiment group (initial and maintenance phases) and control group 1, Models I to IV.

Initial Phase

MODEL I

Parameter	Time	Standard Error	β	Freq.	df
y	741	92	.48	65	1,145
x	416	153	.21	7	1,145
a	166	93	.11	3	1,145
z	473	138	.23	12	1,145
c	1517				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.42	.65	109	1,148
x	.55	.58	89	2,147
a	.55	.21	60	3,146
z	.58	.52	51	4,145

MODEL II

Parameter	Time	Standard Error	β	Freq.	df
y	851	91	.56	88	1,145
x	540	131	.28	17	1,145
a	124	87	.09	2	1,145
z'	681	155	.24	19	1,145
c	1505				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.42	.65	109	1,148
x	.55	.58	89	2,147
a	.55	.21	60	3,146
z'	.60	.26	55	4,145

MODEL III

Parameter	Time	Standard Error	β	Freq.	df
y'	1279	143	.52	80	1,145
x	727	126	.38	33	1,145
a	62	87	.04	.50	1,145
z'	239	157	.08	2	1,145
c	2118				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y'	.43	.66	113	1,148
x	.58	.58	102	2,147
a	.58	.21	68	3,146
z'	.59	.26	52	4,145

MODEL IV

Parameter	Time	Standard Error	β	Freq.	df
y'	1286	157	.52	67	1,145
x'	983	239	.30	17	1,145
a	134	91	.09	2	1,145
z'	108	175	.04	.38	1,145
c	2081				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y'	.43	.66	113	1,148
x'	.54	.58	86	2,147
a	.55	.21	59	3,146
z'	.55	.26	44	4,145

Maintenance Phase

MODEL I

Parameter	Time	Standard Error	β	Freq.	df
y	726	84	.52	75	1,145
x	389	139	.22	8	1,145
a	80	84	.06	1	1,145
z	354	126	.19	8	1,145
c	1648				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.46	.68	126	1,148
x	.56	.56	94	2,147
a	.56	.16	62	3,146
z	.58	.50	51	4,145

MODEL II

Parameter	Time	Standard Error	β	Freq.	df
y	820	81	.59	102	1,145
x	457	117	.26	15	1,145
a	57	78	.04	.54	1,145
z'	621	139	.24	20	1,145
c	1522				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.46	.68	126	1,148
x	.56	.56	94	2,147
a	.56	.16	62	3,146
z'	.61	.25	57	4,145

MODEL III

Parameter	Time	Standard Error	β	Freq.	df
y'	1340	121	.60	122	1,145
x	604	106	.34	32	1,145
a	8	74	.01	.12	1,145
z'	179	133	.07	2	1,145
c	2067				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y'	.53	.72	164	1,148
x	.64	.56	130	2,147
a	.64	.16	65	3,146
z'	.64	.25	88	4,145

MODEL IV

Parameter	Time	Standard Error	β	Freq.	df
y'	1342	132	.60	103	1,145
x'	831	201	.28	17	1,145
a	65	76	.05	1	1,145
z'	67	148	.03	.21	1,145
c	2046				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y'	.53	.72	164	1,148
x'	.61	.57	114	2,147
a	.61	.16	76	3,146
z'	.61	.25	57	4,145

Appendix 5.3 Linear regression tables for the experimental group (initial and maintenance phases), and control group 1, Models I to IV.

Control Group 1

MODEL I

Parameter	Time	Standard Error	β	Freq.	df
y	601	106	.40	32	1,145
x	221	177	.12	2	1,145
a	- 88	107	-.06	1	1,145
z	596	160	.30	14	1,145
c	2851				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.31	.55	65	1,148
x	.35	.41	39	2,147
a	.36	-.01	28	3,146
z	.42	.50	26	4,145

MODEL II

Parameter	Time	Standard Error	β	Freq.	df
y	747	103	.50	53	1,145
x	362	149	.19	6	1,145
a	-135	99	-.10	2	1,145
z'	931	176	.33	28	1,145
c	2762				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.31	.55	65	1,148
x	.35	.41	39	2,147
a	.36	-.01	28	3,146
z'	.47	.34	32	4,145

MODEL III

Parameter	Time	Standard Error	β	Freq.	df
y'	1168	159	.48	54	1,145
x	512	140	.27	13	1,145
a	-185	97	-.13	4	1,145
z'	536	174	.19	9	1,145
c	3281				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y'	.37	.61	87	1,148
x	.42	.41	53	2,147
a	.44	-.01	37	3,146
z'	.47	.34	32	4,145

MODEL IV

Parameter	Time	Standard Error	β	Freq.	df
y'	1201	170	.49	50	1,145
x'	596	260	.19	5	1,145
a	-118	99	-.08	1	1,145
z'	471	191	.17	6	1,145
c	3189				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y'	.37	.61	87	1,148
x'	.41	.43	50	2,147
a	.42	-.01	35	3,146
z'	.44	.34	29	4.145

Appendix 5.4 Linear regression tables for the experiment group (initial and maintenance phases) and control group 1, Models I, II and IV, alternative procedure.

	Initial Phase					Maintenace Phase				
MODEL I										
Parameter	Time	Standard Error	β	Freq.	df	Parameter	Time	Standard Error	β	Freq.	df
y	700	119	.46	34	1,145	y	631	107	.45	35	1,145
x	317	215	.21	2	1,145	x	453	193	.33	5	1,145
a	304	79	.21	15	1,145	a	210	71	.16	9	1,145
z	367	239	.18	2	1,145	z	103	215	.06	.23	1,145
c	1176					c	1437				
Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df		Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df	
y	.42	.65	109	1,148		y	.46	.68	126	1,148	
x	.52	.65	79	2,147		x	.55	.66	90	2,147	
a	.56	.21	63	3,146		a	.58	.16	66	3,146	
z	.57	.52	48	4,145		z	.58	.50	49	4,145	
MODEL II										
Parameter	Time	Standard Error	β	Freq.	df	Parameter	Time	Standard Error	β	Freq.	df
y	747	110	.49	46	1,145	y	725	98	.52	55	1,145
x	430	115	.28	14	1,145	x	376	103	.27	13	1,145
a	304	76	.21	16	1,145	a	209	68	.16	10	1,145
z'	580	168	.20	12	1,145	z'	527	150	.20	12	1,145
c	1011					c	1109				
Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df		Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df	
y	.43	.65	109	1,148		y	.46	.68	126	1,148	
x	.52	.65	79	2,147		x	.55	.66	90	2,147	
a	.56	.21	63	3,146		a	.58	.16	66	3,146	
z'	.60	.26	53	4,145		z'	.61	.25	56	4,145	
MODEL IV										
Parameter	Time	Standard Error	β	Freq.	df	Parameter	Time	Standard Error	β	Freq.	df
y'	976	193	.39	26	1,145	y'	1019	160	.45	41	1,145
x'	1038	233	.42	20	1,145	x'	985	193	.44	26	1,145
a	304	80	.21	14	1,145	a	210	66	.16	10	1,145
z'	-190	206	-.07	1	1,145	z'	-244	170	-.09	2	1,145
c	1734					c	1785				
Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df		Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df	
y'	.43	.66	113	1,148		y'	.53	.72	164	1,148	
x'	.51	.64	76	2,147		x'	.60	.68	110	2,147	
a	.55	.21	60	3,146		a	.62	.16	81	3,146	
z'	.56	.26	45	4,145		z'	.63	.25	62	4,145	

Appendix 5.4 Linear regression tables for the experimental group (initial and maintenance phases) and control group 1, Models I, II and IV, alternative procedure.

Control Group 1

MODEL I

Parameter	Time	Standard	β	Freq.	df
y	661	136	.44	24	1,145
x	- 52	246	-.03	.45	1,145
a	- 14	90	-.01	.26	1,145
z	753	274	.38	8	1,145
c	2519				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.31	.55	65	1,148
x	.38	.56	46	2,147
a	.38	-.01	30	3,146
z	.41	.50	26	4,145

MODEL II

Parameter	Time	Standard Error	β	Freq.	df
y	687	124	.46	31	1,145
x	274	130	.18	4	1,145
a	- 14	86	-.01	.28	1,145
z'	872	190	.31	21	1,145
c	2427				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.31	.55	65	1,148
x	.38	.56	46	2,147
a	.38	-.01	30	3,146
z'	.46	.34	31	4,145

MODEL IV

Parameter	Time	Standard Error	β	Freq.	df
y'	1020	211	.42	23	1,145
x'	615	256	.25	6	1,145
a	- 14	88	-.01	.27	1,145
z'	297	225	.11	2	1,145
c	2975				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y'	.37	.61	87	1,148
x'	.44	.59	57	2,147
a	.44	-.01	38	3,146
z'	.44	.34	29	4,145

Appendix 5.5

Linear regression tables for the experimental group (initial and maintenance phases) and control group 1, Models I to IV, 0 cue condition.

MODEL I

Initial Phase						Maintenance Phase					
Parameter	Time	Standard Error	β	Freq.	df	Parameter	Time	Standard Error	β	Freq.	df
y	918	189	.52	24	1,71	y	694	159	.45	19	1,71
x	370	341	.21	1	1,71	x	709	287	.46	6	1,71
z	372	380	.16	1	1,71	z	-116	320	-.06	.13	1,71
c	2208					c	2314				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df	Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.51	.71	75	1,73	y	.52	.72	80	1,73
x	.59	.67	52	2,72	x	.62	.70	59	2,72
z	.60	.52	35	3,71	z	.62	.50	39	3,71

MODEL II

Parameter	Time	Standard Error	β	Freq.	df	Parameter	Time	Standard Error	β	Freq.	df
y	980	174	.56	32	1,71	y	814	148	.53	30	1,71
x	465	182	.26	7	1,71	x	492	155	.32	10	1,71
z'	650	266	.20	6	1,71	z'	424	226	.15	4	1,71
c	1992					c	1896				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df	Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.50	.71	75	1,73	y	.52	.72	80	1,73
x	.59	.67	52	2,72	x	.62	.70	59	2,72
z'	.62	.24	39	3,71	z'	.64	.21	42	3,71

MODEL III

Parameter	Time	Standard Error	β	Freq.	df	Parameter	Time	Standard Error	β	Freq.	df
y'	1404	241	.49	34	1,71	y'	1280	196	.52	43	1,71
x	712	153	.41	22	1,71	x	662	124	.43	28	1,71
z'	78	248	.02	1	1,71	z'	- 57	201	-.02	1	1,71
c	2466					c	2279				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df	Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y'	.51	.71	75	1,73	y'	.55	.74	89	1,73
x	.63	.67	61	2,72	x	.68	.70	77	2,72
z'	.63	.24	40	2,71	z'	.68	.21	50	3,71

MODEL IV

Parameter	Time	Standard Error	β	Freq.	df	Parameter	Time	Standard Error	β	Freq.	df
y'	1288	307	.45	18	1,71	y'	1041	243	.42	18	1,71
x'	1191	372	.42	10	1,71	x'	1337	294	.54	21	1,71
z'	-302	328	-.09	1	1,71	z'	-537	259	-.19	4	1,71
c	2882					c	2734				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df	Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y'	.51	.71	75	1,73	y'	.55	.74	89	1,73
x'	.57	.66	49	2,72	x'	.63	.71	62	2,72
z'	.58	.24	33	3,71	z'	.65	.21	44	3,71

Appendix 5.5 Linear regression tables for the experimental group (initial and maintenance phases), and control group 1, Models I to IV, 0 cue condition.

Control Group 1

MODEL I

Parameter	Time	Standard Error	β	Freq.	df
y	670	194	.43	12	1,71
x	168	349	.11	.23	1,71
z	612	388	.29	2	1,71
c	2471				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.35	.60	40	1,73
x	.46	.62	30	2,72
z	.48	.53	21	3,71

MODEL II

Parameter	Time	Standard Error	β	Freq.	df
y	713	177	.45	16	1,71
x	404	185	.26	5	1,71
z'	805	270	.27	9	1,71
c	2322				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.35	.60	40	1,73
x	.46	.62	30	2,72
z'	.52	.32	25	3,71

MODEL III

Parameter	Time	Standard Error	β	Freq.	df
y'	1019	246	.40	17	1,71
x	584	156	.37	14	1,71
z'	388	253	.13	2	1,71
c	2667				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y'	.39	.62	46	1,73
x	.51	.62	37	2,72
z'	.52	.32	26	3,71

MODEL IV

Parameter	Time	Standard Error	β	Freq.	df
y'	922	306	.36	9	1,71
x'	982	371	.38	7	1,71
z'	73	327	.02	.50	1,71
c	3009				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y'	.39	.62	46	1,73
x'	.48	.64	33	2,72
z'	.48	.32	22	3,71

Appendix 5.6

Linear regression tables for the experimental group (initial and maintenance phases) and control group 1, Models I to IV, 2 cue condition.

Initial Phase

MODEL I

Parameter	Time	Standard Error	β	Freq.	df
y	483	136	.41	13	1,71
x	265	245	.22	1	1,71
z	362	273	.23	2	1,71
c	1970				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.40	.63	48	1,73
x	.53	.68	40	2,72
z	.54	.57	28	3,71

MODEL II

Parameter	Time	Standard Error	β	Freq.	df
y	515	125	.44	17	1,71
x	395	131	.33	9	1,71
z'	509	191	.23	7	1,71
c	1857				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.40	.63	48	1,73
x	.53	.68	40	2,72
z'	.57	.30	31	3,71

MODEL III

Parameter	Time	Standard Error	β	Freq.	df
y'	758	173	.40	19	1,71
x	519	110	.44	22	1,71
z'	207	178	.09	1	1,71
c	2104				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y'	.42	.65	52	1,73
x	.57	.68	48	2,72
z'	.58	.30	33	3,7

MODEL IV

Parameter	Time	Standard Error	β	Freq.	df
y'	663	220	.35	9	1,71
x'	885	266	.46	11	1,71
z'	- 80	235	-.04	.12	1,71
c	2412				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y'	.42	.65	52	1,73
x'	.52	.67	40	2,72
z'	.52	.30	26	3,71

Maintenance Phase

MODEL I

Parameter	Time	Standard Error	β	Freq.	df
y	567	140	.48	17	1,71
x	198	251	.17	1	1,71
z	322	208	.20	1	1,71
c	1819				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.43	.65	54	1,73
x	.51	.64	38	2,72
z	.52	.51	26	3,71

MODEL II

Parameter	Time	Standard Error	β	Freq.	df
y	636	125	.53	26	1,71
x	259	131	.22	4	1,71
z'	631	190	.28	11	1,71
c	1579				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.43	.65	54	1,73
x	.51	.64	38	2,72
z'	.58	.32	32	3,71

MODEL III

Parameter	Time	Standard Error	β	Freq.	df
y'	1062	161	.55	44	1,71
x	372	102	.31	13	1,71
z'	252	165	.11	2	1,71
c	1872				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y'	.55	.74	88	1,73
x	.63	.64	62	2,72
z'	.64	.32	43	3,71

MODEL IV

Parameter	Time	Standard Error	β	Freq.	df
y'	996	199	.52	25	1,71
x'	633	241	.33	7	1,71
z'	48	213	.02	1	1,71
c	2092				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y'	.55	.74	88	1,73
x'	.61	.68	57	2,72
z'	.61	.32	38	3 71

Appendix 5.6 Linear regression tables for the experimental group (initial and maintenance phases), and control group 1, Models I to IV, 2 cue condition.

Control Group 1

MODEL I

Parameter	Time	Standard Error	β	Freq.	df
y	652	193	.46	11	1,71
x	-272	347	-.19	1	1,71
z	895	387	.47	5	1,71
c	2480				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.26	.51	25	1,73
x	.31	.50	16	2,72
z	.36	.47	13	3,71

MODEL II

Parameter	Time	Standard Error	β	Freq.	df
y	662	176	.47	14	1,71
x	144	184	.10	1	1,71
z'	939	268	.35	12	1,71
c	2446				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.26	.51	25	1,73
x	.31	.50	16	2,72
z'	.41	.36	17	3,71

MODEL III

Parameter	Time	Standard Error	β	Freq.	df
y'	1037	240	.45	19	1,71
x	283	152	.20	3	1,71
z'	548	246	.21	5	1,71
c	2758				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y'	.36	.60	40	1,73
x	.40	.50	24	2,72
z'	.44	.36	19	3,71

MODEL IV

Parameter	Time	Standard Error	β	Freq.	df
y'	1119	292	.49	15	1,71
x'	248	353	.11	.49	1,71
z'	521	312	.20	3	1,71
c	2854				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y'	.36	.60	40	1,73
x'	.40	.55	24	2,72
z'	.42	.36	17	3,71

Appendix 5.7

Linear regression tables for the experiment group (initial and mainteance phases) and control group 1, Models I to IV, nondegenerate, Type II analogies.

Initial Group

MODEL I

Parameter	Time	Standard Error	β	Freq.	df
y	700	119	.46	34	1,55
x	317	215	.21	2	1,55
a	304	79	.21	15	1,55
z	367	239	.18	2	1,55
c	1176				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.42	.65	109	1,58
x	.52	.65	79	2,57
a	.56	.21	63	3,56
z	.57	.52	48	4,55

MODEL II

Parameter	Time	Standard Error	β	Freq.	df
y	747	110	.49	46	1,55
x	430	115	.28	14	1,55
a	304	76	.21	16	1,55
z'	580	168	.20	12	1,55
c	1011				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.42	.65	108	1,58
x	.52	.65	79	2,57
a	.56	.21	62	3,56
z'	.60	.26	53	4,55

MODEL III

Parameter	Time	Standard Error	β	Freq.	df
y'	1081	152	.44	50	1,55
x	615	97	.40	40	1,55
a	304	75	.21	16	1,55
z'	142	156	.05	1	1,55
c	1372				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y'	.43	.66	113	1,58
x	.56	.65	92	2,57
a	.60	.21	74	3,56
z'	.60	.26	55	4,55

MODEL IV

Parameter	Time	Standard Error	β	Freq.	df
y'	976	193	.39	26	1,55
x'	1038	233	.42	20	1,55
a	304	80	.21	14	1,55
z'	-191	206	-.07	1	1,55
c	1734				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y'	.43	.66	113	1,58
x'	.51	.64	76	2,57
a	.55	.21	60	3,56
z'	.56	.26	45	4,55

Maintenance Group

MODEL I

Parameter	Time	Standard Error	β	Freq.	df
y	329	202	.22	3	1,56
x	254	202	.17	2	1,56
a	441	130	.40	11	1,56
c	1802				
*					

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.02	.14	1	1,58
x	.04	.06	1	2,57
a	.20	.40	5	3,56

MODEL II

Parameter	Time	Standard Error	β	Freq.	df
y	329	175	.22	4	1,55
x	-263	212	-.18	2	1,55
a	441	113	.40	15	1,55
z'	993	229	.57	19	1,55
c	1801				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.02	.14	1	1,58
x	.04	.06	1	2,57
a	.20	.40	5	3,56
z'	.41	.39	9	4,55

MODEL III

Parameter	Time	Standard Error	β	Freq.	df
y'	816	223	.47	13	1,55
x	104	230	.07	.21	1,55
a	441	105	.40	18	1,55
z'	381	270	.22	2	1,55
c	1560				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y'	.26	.51	20	1,58
x	.31	.06	13	2,57
a	.47	.40	17	3,56
z'	.49	.39	13	4,55

MODEL IV

Parameter	Time	Standard Error	β	Freq.	df
y'	753	172	.43	19	1,56
x'	475	172	.27	8	1,56
a	441	104	.40	18	1,56
c	1708				
*					

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y'	.26	.51	20	1,58
x'	.33	.39	14	2,57
a	.49	.40	18	3,56

* F-level or tolerance level insufficient for further computation

Appendix 5.7 Linear regression tables for the experimental group (initial and maintenance phases), and control group 1, Models I to IV, nondegenerate, Type II analogies.

Control Group 1

MODEL I

Parameter	Time	Standard Error	β	Freq.	df
y	243	203	.18	1	1, 56
x	283	203	.21	2	1, 56
a	145	131	.14	1	1, 56
c	3503				

* Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.01	.07	.3	1, 58
x	.04	.12	1	2, 57
a	.06	.14	1	3, 56

MODEL II

Parameter	Time	Standard Error	β	Freq.	df
y	243	177	.18	2	1, 55
x	-239	214	-.18	1	1, 55
a	145	114	.14	2	1, 55
z'	1002	230	.62	19	1, 55
c	3503				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.01	.07	.3	1, 58
x	.04	.12	1	2, 57
a	.06	.14	1	3, 56
z'	.30	.46	6	4, 55

MODEL III

Parameter	Time	Standard Error	β	Freq.	df
y'	739	226	.46	11	1, 55
x	121	233	.09	.27	1, 55
a	145	106	.14	2	1, 55
z'	448	273	.28	3	1, 55
c	3148				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y'	.26	.51	20	1, 58
x	.34	.12	15	2, 57
a	.36	.14	11	3, 56
z'	.39	.46	9	4, 55

MODEL IV

Parameter	Time	Standard Error	β	Freq.	df
y'	665	174	.41	15	1, 56
x'	557	174	.35	10	1, 56
a	145	105	.14	2	1, 56
c	3320				

* Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y'	.26	.51	20	1, 58
x'	.37	.46	17	2, 57
a	.39	.14	12	3, 56

Appendix 5.8

Linear regression tables for the experiment group (initial and maintenance phases) and control group 1, Models I to IV, session 1.

MODEL I

Initial Phase						Maintenance Phase					
Parameter	Time	Standard Error	β	Freq.	df	Parameter	Time	Standard Error	β	Freq.	df
y	869	143	.48	37	1,145	y	634	125	.42	26	1,145
x	359	257	.20	2	1,145	x	408	226	.27	3	1,145
a	299	94	.18	10	1,145	a	278	83	.20	11	1,145
z	360	287	.15	2	1,145	z	172	252	.09	.47	1,145
c	1381					c	1419				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df	Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.44	.66	115	1,148	y	.39	.62	93	1,148
x	.51	.63	78	2,147	x	.47	.61	64	2,147
a	.55	.18	58	3,146	a	.50	.20	50	3,146
z	.55	.49	44	4,145	z	.51	.47	37	4,145

MODEL II

Parameter	Time	Standard Error	β	Freq.	df	Parameter	Time	Standard Error	β	Freq.	df
y	699	134	.50	45	1,145	y	684	118	.45	34	1,145
x	491	140	.27	12	1,145	x	423	123	.28	12	1,145
a	299	93	.18	10	1,145	a	276	81	.20	12	1,145
z'	496	205	.15	6	1,145	z	397	179	.14	5	1,145
c	1276					c	1244				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df	Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.44	.66	115	1,148	y	.39	.62	93	1,148
x	.51	.63	78	2,147	x	.47	.61	64	2,147
a	.55	.18	58	3,146	a	.50	.20	50	3,146
z'	.56	.20	47	4,145	z	.52	.20	39	4,145

MODEL III

Parameter	Time	Standard Error	β	Freq.	df	Parameter	Time	Standard Error	β	Freq.	df
y'	1233	189	.42	42	1,145	y'	1041	160	.43	42	1,145
x	735	120	.41	37	1,145	x	576	99	.38	34	1,145
a	299	94	.18	10	1,145	a	278	79	.20	12	1,145
z'	- 27	194	-.01	.19	1,145	c	1566				
c	1717					*					

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df	Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y'	.41	.64	102	1,148	y'	.40	.63	97	1,148
x	.53	.63	82	2,147	x	.50	.61	74	2,147
a	.56	.18	61	3,146	a	.54	.20	57	3,146
z'	.56	.20	46	4,145					

MODEL IV

Parameter	Time	Standard Error	β	Freq.	df	Parameter	Time	Standard Error	β	Freq.	df
y'	1148	240	.39	23	1,145	y'	943	201	.39	22	1,145
x'	1169	291	.40	16	1,145	x'	972	244	.40	16	1,145
a	299	100	.18	9	1,145	a	278	83	.20	11	1,145
z'	-386	256	-.12	2	1,145	z	-317	215	-.11	2	1,145
c	2127					c	1908				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df	Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y'	.41	.64	102	1,148	y'	.40	.63	97	1,148
x'	.46	.60	63	2,147	x'	.45	.59	60	2,147
a	.49	.18	47	3,146	a	.49	.20	47	3,146
z'	.50	.20	36	4,145	z	.50	.20	36	4,145

* F-level or tolerance level insufficient for further computation

Appendix 5.8 Linear regression tables for the experimental group (initial and maintenance phases), and control group 1, Models I to IV, session 1.

Control Group 1

MODEL I

Parameter	Time	Standard Error	β	Freq.	df
y	689	179	.38	15	1,145
x	- 37	322	-.02	.13	1,145
a	-142	118	-.08	1	1,145
z	814	359	.33	5	1,145
c	2905				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.23	.48	45	1,148
x	.30	.50	31	2,147
a	.30	-.08	21	3,146
z	.33	.45	18	4,145

MODEL II

Parameter	Time	Standard Error	β	Freq.	df
y	706	166	.39	18	1,145
x	330	174	.18	4	1,145
a	-142	115	-.08	2	1,145
z'	891	253	.26	12	1,145
c	2846				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.23	.48	45	1,148
x	.30	.50	31	2,147
a	.30	-.08	21	3,146
z'	.36	.29	20	4,145

MODEL III

Parameter	Time	Standard Error	β	Freq.	df
y'	1088	229	.37	22	1,145
x	404	146	.26	11	1,145
a	-142	113	-.08	2	1,145
z'	474	236	.14	4	1,145
c	3181				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y'	.28	.53	59	1,148
x	.35	.50	40	2,147
a	.36	-.08	27	3,146
z'	.37	.29	22	4,125

MODEL IV

Parameter	Time	Standard Error	β	Freq.	df
y'	1103	280	.37	15	1,145
x'	645	339	.22	4	1,145
a	-142	116	-.08	1	1,145
z'	306	299	.09	1	1,145
c	3413				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y'	.28	.53	59	1,148
x'	.33	.52	36	2,147
a	.34	-.08	25	3,146
z'	.34	.29	19	4,145

Appendix 5.9

Linear regression tables for the experiment group (initial and maintenance phases) and control group 1, Models I to IV, session 2.

MODEL I

Initial Phase						Maintenance Phase					
Parameter	Time	Standard Error	β	Freq.	df	Parameter	Time	Standard Error	β	Freq.	df
y	428	127	.31	11	1,145	y	605	123	.41	24	1,145
x	273	229	.20	1	1,145	x	505	222	.35	5	1,145
a	255	84	.19	9	1,145	a	141	81	.10	3	1,145
z	410	255	.22	3	1,145	z	30	248	.02	.14	1,145
c	1097					c	1458				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df	Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.26	.51	51	1,148	y	.40	.64	100	1,148
x	.37	.57	42	2,147	x	.48	.62	69	2,147
a	.40	.19	33	3,146	a	.49	.10	48	3,146
z	.41	.49	26	4,135	z	.49	.46	35	4,145

MODEL II

Parameter	Time	Standard Error	β	Freq.	df	Parameter	Time	Standard Error	β	Freq.	df
y	473	117	.34	16	1,145	y	736	113	.50	43	1,145
x	408	123	.29	11	1,145	x	343	118	.23	8	1,145
a	255	81	.19	10	1,145	a	141	78	.10	3	1,145
z'	614	179	.24	12	1,145	z'	622	172	.23	13	1,145
c	938					c	999				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df	Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.26	.51	51	1,148	y	.40	.64	100	1,148
x	.37	.57	42	2,147	x	.48	.62	69	2,147
a	.40	.19	33	3,146	a	.49	.10	48	3,146
z'	.45	.30	29	4,145	z'	.54	.27	42	4,145

MODEL III

Parameter	Time	Standard Error	β	Freq.	df	Parameter	Time	Standard Error	β	Freq.	df
y'	704	163	.31	19	1,145	y'	1232	147	.52	70	1,145
x	520	104	.37	25	1,145	x	472	94	.32	25	1,145
a	255	81	.19	10	1,145	a	141	73	.10	4	1,145
z'	337	168	.13	4	1,145	z'	183	151	.07	1	1,145
c	1165					c	1339				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df	Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y'	.28	.53	59	1,148	y'	.50	.70	146	1,148
x	.40	.57	50	2,147	x	.58	.62	102	2,147
a	.44	.19	38	3,146	a	.59	.10	70	3,146
z'	.46	.30	30	4,145	z'	.59	.27	53	4,145

MODEL IV

Parameter	Time	Standard Error	β	Freq.	df	Parameter	Time	Standard Error	β	Freq.	df
y'	568	190	.25	9	1,145	y'	1023	177	.43	33	1,145
x'	963	190	.43	26	1,145	x'	1024	214	.43	23	1,145
a	255	83	.19	9	1,145	a	141	73	.10	4	1,145
c	1503					z'	-198	189	-.07	1	1,145
*						c	1686				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df	Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y'	.28	.53	59	1,148	y'	.50	.70	146	1,148
x'	.39	.59	46	2,147	x'	.57	.68	99	2,147
a	.42	.19	36	3,146	a	.59	.10	69	3,146
					z'	.59	.29	52	4,145

* F-level or tolerance level insufficient for further computation

Appendix 5.9 Linear regression tables for the experimental group (initial and maintenance phases), and control group 1, Models I to IV, session 2.

Control Group 1

MODEL I

Parameter	Time	Standard Error	β	Freq.	df
y	633	175	.37	13	1,145
x	- 67	316	-.04	.45	1,145
a	113	115	.07	1	1,145
z	693	352	.30	4	1,145
c	2132				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.20	.45	37	1,148
x	.25	.45	24	2,147
a	.25	.07	16	3,146
z	.27	.40	13	4,145

MODEL II

Parameter	Time	Standard Error	β	Freq.	df
y	669	162	.39	17	1,145
x	217	170	.13	2	1,145
a	113	113	.07	1	1,145
z'	853	248	.26	12	1,145
c	2007				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.20	.45	37	1,148
x	.25	.45	24	2,147
a	.25	.07	16	3,146
z'	.31	.28	16	4,145

MODEL III

Parameter	Time	Standard Error	β	Freq.	df
y'	989	227	.35	18	1,145
x	382	144	.22	7	1,145
a	113	112	.09	1	1,145
z'	462	233	.14	4	1,145
c	2330				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y'	.24	.49	47	1,148
x	.29	.45	30	2,147
a	.30	.07	20	3,146
z'	.31	.28	17	4,145

MODEL IV

Parameter	Time	Standard Error	β	Freq.	df
y'	938	274	.34	12	1,145
x'	585	331	.21	4	1,145
a	113	114	.07	1	1,145
z'	288	292	.09	1	1,145
c	2536				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y'	.24	.49	47	1,148
x'	.29	.48	29	2,147
a	.29	.07	20	3,146
z'	.30	.28	15	4,145

Appendix 5.10

Linear regression tables for the experimental group (initial and maintenance phases) and control group 1, Models I to IV, dual processing in 1 DD' value change only.

MODEL I

Initial Phase						Maintenance Phase					
Parameter	Time	Standard Error	β	Freq.	df	Parameter	Time	Standard Error	β	Freq.	df
y	650	110	.42	35	1,145	y	630	98	.45	41	1,145
x	531	120	.35	20	1,145	x	483	107	.35	20	1,145
a	304	79	.21	15	1,145	a	210	71	.16	9	1,145
z	103	78	.08	2	1,145	z	73	69	.06	1	1,145
c	1352					c	1440				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df	Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.42	.65	109	1,148	y	.46	.68	126	1,148
x	.52	.65	79	2,147	x	.55	.66	90	2,147
a	.56	.21	63	3,146	a	.58	.16	66	3,146
z	.57	.27	48	4,145	z	.58	.26	50	4,145

MODEL II

Parameter	Time	Standard Error	β	Freq.	df	Parameter	Time	Standard Error	β	Freq.	df
y	674	106	.44	40	1,145	y	668	94	.48	51	1,145
x	496	110	.32	20	1,145	x	417	98	.30	18	1,145
a	304	77	.21	16	1,145	a	210	68	.16	10	1,145
z'	313	107	.17	8	1,145	z'	341	95	.20	13	1,145
c	1267					c	1306				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df	Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.42	.65	109	1,148	y	.46	.68	126	1,148
x	.52	.65	79	2,147	x	.55	.66	90	2,147
a	.56	.21	63	3,146	a	.58	.16	66	3,146
z'	.59	.28	52	4,145	z'	.61	.31	57	4,145

MODEL III

Parameter	Time	Standard Error	β	Freq.	df	Parameter	Time	Standard Error	β	Freq.	df
y'	1073	152	.43	50	1,145	y'	1159	127	.51	83	1,145
x	607	96	.40	40	1,145	x	497	80	.36	38	1,145
a	304	75	.21	16	1,145	a	210	63	.16	11	1,145
z'	143	103	.08	2	1,145	z'	169	87	.10	4	1,145
c	1393					c	1422				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df	Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y'	.43	.66	113	1,148	y'	.53	.72	164	1,148
x	.56	.65	93	2,147	x	.63	.66	126	2,147
a	.60	.21	74	3,146	a	.66	.16	93	3,146
z'	.61	.28	56	4,145	z'	.67	.31	72	4,145

MODEL IV

Parameter	Time	Standard Error	β	Freq.	df	Parameter	Time	Standard Error	β	Freq.	df
y'	1046	185	.42	32	1,145	y'	1112	154	.49	52	1,145
x'	858	205	.35	18	1,145	x'	745	170	.33	19	1,145
a	304	80	.21	14	1,145	a	210	66	.16	10	1,145
z'	59	120	.03	.24	1,145	z'	89	100	.05	1	1,145
c	1571					c	1569				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df	Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y'	.43	.66	113	1,148	y'	.53	.72	164	1,148
x'	.51	.64	76	2,147	x	.60	.69	110	2,147
a	.55	.21	60	3,146	a	.62	.16	81	3,146
z'	.55	.28	45	4,145	z'	.63	.31	61	4,145

Appendix 5.10 Linear regression tables for the experimental group (initial and maintenance phases), and control group 1, Models I to IV, dual processing in 1 DD' value change only.

Control Group 1

MODEL I

Parameter	Time	Standard Error	β	Freq.	df
y	535	120	.36	20	1,145
x	-764	370	-.51	4	1,145
a	- 14	88	-.01	.27	1,145
z	1341	361	.88	14	1,145
c	2958				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.31	.55	65	1,148
x	.38	.56	46	2,147
a	.38	-.01	30	3,146
z	.44	.60	28	4,145

MODEL II

Parameter	Time	Standard Error	β	Freq.	df
y	529	115	.35	21	1,145
x	- 19	155	-.01	.15	1,145
a	- 14	84	-.01	.29	1,145
z'	1130	212	.48	28	1,145
c	2891				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.31	.55	65	1,148
x	.38	.56	46	2,147
a	.38	-.01	80	3,146
z'	.48	.62	34	4,145

MODEL III

Parameter	Time	Standard Error	β	Freq.	df
y'	858	180	.35	23	1,145
x	224	135	.15	3	1,145
a	- 14	84	-.01	.29	1,145
z'	722	224	.30	10	1,145
c	3042				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y'	.37	.61	87	1,148
x	.45	.56	61	2,147
a	.45	-.01	40	3,146
z'	.49	.62	35	4,145

MODEL IV

Parameter	Time	Standard Error	β	Freq.	df
y'	983	194	.41	26	1,145
x'	-363	382	-.15	1	1,145
a	- 14	84	-.01	.29	1,145
z'	1238	344	.52	13	1,145
c	3061				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y'	.37	.61	87	1,148
x'	.44	.59	57	2,147
a	.44	-.01	38	3,146
z'	.48	.62	34	4,145

Appendix 5.11 Linear regression tables for control group 1, Models I to IV, dual processing in 1 and 2 DD' value changes.

Control Group 1

MODEL I

Parameter	Time	Standard Error	β	Freq.	df
y	590	118	.39	25	1,145
x	-491	247	-.33	4	1,145
a	- 14	86	-.01	.28	1,145
z	1122	238	.71	22	1,145
c	2764				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.31	.55	65	1,148
x	.38	.56	46	2,147
a	.38	-.01	30	3,146
z	.47	.61	32	4,145

MODEL II

Parameter	Time	Standard Error	β	Freq.	df
y	586	112	.39	27	1,145
x	69	134	.05	.27	1,145
a	- 14	82	-.01	.31	1,145
z'	1071	171	.46	39	1,145
c	2780				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.31	.55	65	1,148
x	.38	.56	46	2,147
a	.38	-.01	30	3,146
z'	.51	.60	38	4,145

MODEL III

Parameter	Time	Standard Error	β	Freq.	df
y'	896	168	.87	28	1,145
x	261	115	.17	5	1,145
a	- 14	82	-.01	.31	1,145
z'	763	173	.32	19	1,145
c	2896				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y'	.37	.61	87	1,148
x	.45	.56	61	2,147
a	.45	-.01	40	3,146
z'	.52	.60	39	4,145

MODEL IV

Parameter	Time	Standard Error	β	Freq.	df
y'	1044	192	.43	30	1,145
x'	- 30	275	-.01	.12	1,145
a	- 14	83	-.01	19	1,145
z'	965	224	.41	19	1,145
c	2921				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y'	.37	.61	87	1,148
x'	.44	.59	57	2,147
a	.44	-.01	38	3,146
z'	.50	.60	36	4,145

Appendix 5.12 Analysis of variance of scores for Ravens Coloured Progressive Matrices for experimental group and control group 2.

Source	Df	Sum of Squares	Mean Square	F	Sign. of F
Main effects	1	16.667	16.667	.569	.459
Group	1	16.667	16.667	.569	.459
Explained	1	16.667	16.667	.569	.459
Residual	22	644.667	29.303		
Total	23	661.333	28.754		

Appendix 6.1 Analysis of variance of solution times for retarded subjects (initial and maintenance phases) in each cue condition and for each analogy type.

Source	Df	SS	SS%	MS	VR
Cue.Type.Group. Units Stratum					
Cue	1	63610844	26.88	63610844	68.185**
Lin	1	63610844	26.88	63610844	68.185
Type	1	67806498	28.65	67806498	72.682**
Group	1	1508763	0.64	1508763	1.617
Cue.Type	1	20883340	8.82	20883340	22.385
Lin.Dev	1	20883340	8.82	20883340	22.385**
Cue.Group	1	96457	0.04	96457	0.103
Lin.Dev	1	96457	0.04	96457	0.103
Type.Group	1	269770	0.11	269770	0.289
Cue.Type.Group	1	384434	0.16	384434	0.412
Lin.Dev.Dev	1	384434	0.16	384434	0.412
Residual	88	82096992	34.69	932920	
Total	95	236657096	100.00	2491127	

** significant at .01

Appendix 6.2 Repeated measures analysis of variance of solution times in sessions 1 and 2 for retarded subjects (initial and maintenance phases) in each cue condition and for each analogy type.

Source	DF	SS	SS%	MS	VR
Grp.Subject Stratum					
Grp	1	2870430	0.58	2870430	0.539
Residual	22	117159458	23.63	5325430	19.904
Total	23	120029888	24.21	5218691	19.505
Grp.Subject.Session Stratum					
Session	1	2239488	0.45	2239488	14.435**
Grp.Session	1	10710	0.00	10710	0.069
Residual	22	3413154	0.69	155143	0.580
Total	24	5663352	1.14	235973	0.882
Grp.Subject.Type Stratum					
Type	1	136606512	27.56	136606512	132.986**
Grp.Type	1	605477	0.12	605477	0.589
Residual	22	22598866	4.56	1027221	3.839
Total	24	159810854	32.24	6658786	24.887
Grp.Subject.Cue Stratum					
Cue	1	128219988	25.86	128219988	191.735**
Grp.Cue	1	156408	0.03	156408	0.234
Residual	22	14712163	2.97	668735	2.499
Total	24	143088559	28.86	5962023	22.283
Grp.Subject.Session.Type Stratum					
Session.Type	1	74183	0.01	74183	0.615
Grp.Session.Type	1	74419	0.02	74419	0.617
Residual	22	2652843	0.54	120584	0.451
Total	24	2801444	0.57	116727	0.436
Grp.Subject.Session.Cue Stratum					
Session.Cue	1	423376	0.09	423376	1.751
Grp.Session.Cue	1	133247	0.03	133247	0.551
Residual	22	5319594	1.07	241800	0.904
Total	24	5876217	1.19	244842	0.915
Grp.Subject.Type.Cue Stratum					
Type.Cue	1	41225547	8.32	41225547	88.102**
Grp.Type.Cue	1	694324	0.14	694324	1.484
Residual	22	10294496	2.08	467932	1.749
Total	24	52214366	10.53	2175599	8.131
Grp.Subject.Session.Type.Cue Stratum					
Session	1	99281	0.02	99281	0.371
Residual	23	6153874	1.24	267560	
Total	24	6253155	1.26	260548	
Grand Total	191	495737837	100.00		

** significant at .01

Appendix 6.3 Linear regression tables for retarded subjects (initial and maintenance phases), Models I, III and IV.

	Initial Phase					Maintenance Phase				
MODEL I Parameter	Time	Standard Error	β	Freq.	df	Parameter	Time	Standard Error	β	Freq.	df
y	420	85	.29	24	1,145	y	388	77	.27	25	1,145
x	763	141	.41	29	1,145	x	567	129	.31	19	1,145
a	397	85	.29	22	1,145	a	629	78	.47	65	1,145
z	229	128	.12	3	1,145	z	211	116	.11	3	1,145
c	1285					c	458				
Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df		Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df	
y	.24	.49	46	1,148		y	.19	.44	35	1,148	
x	.56	.71	94	2,147		x	.51	.69	76	2,147	
a	.61	.47	76	3,146		a	.65	.61	92	3,146	
z	.62	.44	59	4,145		z	.66	.38	71	4,145	
MODEL III Parameter	Time	Standard Error	β	Freq.	df	Parameter	Rime	Standard Error	β	Freq.	df
y'	675	134	.28	25	1,145	y'	637	121	.28	28	1,145
x	930	117	.50	63	1,145	x	711	106	.39	45	1,145
a	341	82	.25	17	1,145	a	581	74	.43	62	1,145
z'	141	146	.05	1	1,145	z'	167	133	.06	2	1,145
c	1588					c	695				
Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df		Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df	
y'	.21	.46	40	1,148		y'	.18	.42	32	1,148	
x	.56	.71	95	2,147		x	.52	.69	79	2,147	
a	.61	.47	76	3,146		a	.66	.61	94	3,146	
z'	.61	.20	57	4,145		z'	.66	.19	71	4,145	
MODEL IV Parameter	Time	Standard Error	β	Freq.	df	Parameter	Time	Standard Error	β	Freq.	df
y'	630	147	.26	18	1,145	y'	645	134	.28	23	1,145
x'	1448	224	.47	42	1,145	x'	958	205	.32	22	1,145
a	400	85	.29	22	1,145	a	652	78	.48	70	1,145
z'	- 78	164	-.03	.23	1,145	z'	40	151	.02	1	1,145
c	1668					c	656				
Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df		Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df	
y'	.21	.46	40	1,148		y'	.18	.42	32	1,148	
x'	.50	.68	73	2,147		x'	.43	.63	55	2,147	
a	.57	.47	64	3,146		a	.62	.61	78	3,146	
z'	.57	.20	48	4,145		z'	.62	.19	58	4,145	

Appendix 6.4 Linear regression tables for retarded subjects (initial and maintenance phases), Models I to IV, 0 cue condition.

MODEL I

Initial Phase						Maintenance Phase					
Parameter	Time	Standard Error	β	Freq.	df	Parameter	Time	Standard Error	β	Freq.	df
y	647	172	.40	14	1,71	y	682	166	.47	17	1,71
x	422	310	.26	2	1,71	x	44	298	.03	.22	1,71
z	540	346	.25	2	1,71	z	741	332	.39	5	1,71
c	2591					c	2519				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df	Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.43	.65	54	1,73	y	.40	.63	48	1,73
x	.60	.73	52	2,72	x	.51	.66	37	2,72
z	.61	.62	36	3,71	z	.54	.58	28	3,71

MODEL II

Parameter	Time	Standard Error	β	Freq.	df	Parameter	Time	Standard Error	β	Freq.	df
y	672	159	.42	18	1,71	y	646	157	.45	17	1,71
x	648	166	.40	15	1,71	x	448	164	.31	7	1,71
z'	653	242	.22	7	1,71	z'	579	239	.22	6	1,71
c	2503					c	2644				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df	Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.43	.65	54	1,73	y	.40	.63	48	1,73
x	.59	.73	52	2,72	x	.51	.66	37	2,72
z'	.63	.31	40	3,71	z'	.55	.28	29	3,71

MODEL III

Parameter	Time	Standard Error	β	Freq.	df	Parameter	Time	Standard Error	β	Freq.	df
y'	901	225	.34	16	1,71	y'	811	224	.35	13	1,71
x	837	143	.52	34	1,71	x	648	143	.45	21	1,71
z'	264	231	.09	1	1,71	z'	207	230	.08	1	1,71
c	2834					c	2968				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df	Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y'	.40	.63	49	1,73	y'	.36	.60	41	1,73
x	.61	.73	57	2,72	x	.52	.66	39	2,72
z'	.62	.31	39	3,71	z'	.53	.28	26	3,71

MODEL IV

Parameter	Time	Standard Error	β	Freq.	df	Parameter	Time	Standard Error	β	Freq.	df
y'	744	295	.28	6	1,71	y'	833	275	.36	9	1,71
x'	1436	357	.55	16	1,71	x'	854	275	.37	10	1,71
z'	-202	314	-.07	.41	1,71	c	3267				
c	3333					*					

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df	Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y'	.40	.63	49	1,73	y'	.36	.60	41	1,73
x'	.54	.70	42	2,72	x'	.44	.60	28	2,72
z'	.54	.31	28	3,71					

* F-level or tolerance level insufficient for further computation

Appendix 6.5 Linear regression tables for retarded subjects (initial and maintenance phases), Models I to IV, 2 cue condition.

MODEL I

Initial Phase						Maintenance Phase					
Parameter	Time	Standard Error	β	Freq.	df	Parameter	Time	Standard Error	β	Freq.	df
y	320	97	.36	11	1,72	y	287	76	.41	14	1,72
z	247	129	.21	4	1,72	z	187	101	.20	3	1,72
c	2125					c	1811				
Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df		Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df	
y	.19	.44	17	1,73		y	.23	.48	22	1,73	
z	.23	.34	11	2,72		z	.26	.34	13	2,72	

MODEL II

Initial Phase						Maintenance Phase					
Parameter	Time	Standard Error	β	Freq.	df	Parameter	Time	Standard Error	β	Freq.	df
y	393	92	.45	18	1,72	y	347	70	.49	24	1,72
z'	218	171	.13	2	1,72	z'	308	131	.23	6	1,72
c	2179					c	1731				
Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df		Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df	
y	.19	.44	17	1,73		y	.23	.48	22	1,73	
z'	.21	.10	10	2,72		z'	.28	.20	14	2,72	

MODEL III-IV

Initial Phase						Maintenance Phase					
Parameter	Time	Standard Error	β	Freq.	df	Parameter	Time	Standard Error	β	Freq.	df
y'	522	158	.37	11	1,72	y'	513	119	.45	19	1,72
z'	53	182	.03	1	1,72	z'	150	137	.11	1	1,72
c	2396					c	1914				
Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df		Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df	
y'	.14	.37	12	1,73		y'	.22	.47	21	1,73	
z'	.14	.10	6	2,72		z'	.24	.20	11	2,72	

Appendix 6.6 Linear regression tables for retarded subjects (initial and maintenance phases), Models I to IV, nondegenerate, Type II analogies.

MODEL I

Initial Phase						Maintenance Phase					
Parameter	Time	Standard Error	β	Freq.	df	Parameter	Time	Standard Error	β	Freq.	df
y	3	183	.00	.24	1,55	y	140	146	.07	1	1,55
x	480	316	.33	2	1,55	x	316	254	.22	2	1,55
a	729	289	.51	6	1,55	a	947	231	.67	17	1,55
z	-145	242	-.07	.36	1,55	z	- 43	194	-.02	.49	1,55
c	1895					c	570				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df	Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.00	-.02	0	1,58	y	.00	.04	0	1,58
x	.54	.73	34	2,57	x	.63	.77	48	2,57
a	.63	.78	32	3,56	a	.75	.86	56	3,56
z	.63	.04	24	4,55	z	.75	.02	42	4,55

MODEL II

Parameter	Time	Standard Error	β	Freq.	df	Parameter	Time	Standard Error	β	Freq.	df
y	74	171	.04	.19	1,55	y	189	135	.10	2	1,55
x	265	256	.18	1	1,55	x	169	202	.12	1	1,55
a	908	243	.63	14	1,55	a	1069	192	.76	31	1,55
z'	203	211	.09	1	1,55	z'	246	167	.11	2	1,55
c	1000					c	- 41				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df	Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.00	-.02	0	1,58	y	.00	.04	0	1,58
x	.54	.73	34	2,57	x	.63	.77	48	2,57
a	.63	.78	32	3,56	a	.75	.86	56	3,56
z'	.64	.12	24	4,55	z'	.76	.11	44	4,55

MODEL III

Parameter	Time	Standard Error	β	Freq.	df	Parameter	Time	Standard Error	β	Freq.	df
y'	258	208	.11	2	1,55	y'	360	162	.16	5	1,55
x	365	265	.25	2	1,55	x	276	207	.19	2	1,55
a	825	250	.57	11	1,55	a	980	195	.70	25	1,55
z'	68	225	.03	1	1,55	z'	39	176	.02	.49	1,55
c	1184					c	319				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df	Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y'	.01	.09	0	1,58	y'	.02	.14	1	1,58
x	.56	.73	36	2,57	x	.64	.77	52	2,57
a	.64	.78	34	3,56	a	.77	.86	63	3,56
z'	.64	.12	25	4,55	z'	.77	.11	47	4,55

MODEL IV

Parameter	Time	Standard Error	β	Freq.	df	Parameter	Time	Standard Error	β	Freq.	df
y'	146	184	.06	1	1,55	y'	276	146	.12	4	1,55
x'	906	354	.39	7	1,55	x'	320	206	.14	2	1,55
a	736	190	.51	15	1,55	a	1071	127	.76	71	1,55
z'	-221	255	-.10	1	1,55	c	244				
c	1710					*					

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df	Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y'	.01	.09	0	1,58	y'	.02	.14	1	1,58
x'	.50	.71	29	2,57	x'	.48	.69	26	2,57
a	.67	.78	37	3,56	a	.77	.86	63	3,56
z'	.67	.12	28	4,55					

* F-level or tolerance level insufficient for further computation

Appendix 6.7 Linear regression tables for retarded subjects (initial and maintenance phases), Models I to IV, session 1.

MODEL I

Initial Phase						Maintenenace Phase					
Parameter	Time	Standard Error	β	Freq.	df	Parameter	Time	Standard Error	β	Freq.	df
y	464	106	.28	19	1,145	y	425	98	.27	19	1,145
x	843	176	.40	23	1,145	x	630	163	.31	15	1,145
a	453	106	.29	18	1,145	a	638	99	.42	42	1,145
z	125	159	.06	1	1,145	z	143	147	.07	1	1,145
c	1250					c	569				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df	Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.21	.45	38	1,148	y	.17	.41	30	1,148
x	.48	.66	69	2,147	x	.44	.64	58	2,147
a	.54	.46	57	3,146	a	.57	.56	64	3,146
z	.54	.37	43	4,145	z	.57	.33	48	4,145

MODEL II

Parameter	Time	Standard Error	β	Freq.	df	Parameter	Time	Standard Error	β	Freq.	df
y	508	106	.30	23	1,145	y	470	98	.29	23	1,145
x	845	153	.40	30	1,145	x	643	142	.32	21	1,145
a	453	102	.29	20	1,145	a	634	94	.42	45	1,145
z'	321	181	.10	3	1,145	z'	316	168	.11	4	1,145
c	1100					c	450				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df	Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.21	.45	38	1,148	y	.17	.41	30	1,148
x	.48	.66	69	2,147	x	.44	.64	58	2,147
a	.54	.46	57	3,146	a	.57	.56	64	3,146
z'	.55	.16	44	4,145	z'	.58	.15	49	4,145

MODEL III

Parameter	Time	Standard Error	β	Freq.	df	Parameter	Time	Standard Error	β	Freq.	df
y'	731	166	.27	19	1,145	y'	678	154	.26	19	1,145
x	966	146	.45	44	1,145	x	755	135	.37	31	1,145
a	412	102	.26	16	1,145	a	597	93	.40	40	1,145
z'	61	182	.02	.11	1,145	z'	76	168	.03	.20	1,145
c	1481					c	801				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df	Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y'	.18	.42	33	1,148	y'	.15	.39	27	1,148
x	.49	.66	70	2,147	x	.45	.64	59	2,147
a	.54	.46	57	3,146	a	.57	.56	64	3,146
z'	.54	.16	43	4,145	z'	.57	.15	48	4,145

MODEL IV

Parameter	Time	Standard Error	β	Freq.	df	Parameter	Time	Standard Error	β	Freq.	df
y'	668	178	.25	14	1,145	y'	679	167	.26	17	1,145
x'	1560	272	.44	33	1,145	x'	1043	255	.31	17	1,145
a	463	103	.29	20	1,145	a	667	97	.44	48	1,145
z'	-181	200	-.06	1	1,145	z'	- 66	187	-.02	.12	1,145
c	1601					c	777				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df	Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y'	.18	.42	33	1,148	y'	.15	.39	27	1,148
x'	.43	.64	57	2,147	x'	.37	.59	42	2,147
a	.51	.46	51	3,146	a	.53	.56	55	3,146
z'	.51	.16	38	4,145	z'	.53	.15	41	4,145

Appendix 6.8 Linear regression tables for retarded subjects (initial and maintenance phases), Models I to IV, session 2.

MODEL I

Initial Phase						Maintenance Phase					
Parameter	Time	Standard Error	β	Freq.	df	Parameter	Time	Standard Error	β	Freq.	df
y	377	92	.26	17	1,145	y	351	94	.23	15	1,145
x	683	154	.37	20	1,145	x	504	155	.27	11	1,145
a	340	93	.25	13	1,145	a	619	94	.44	43	1,145
z	332	139	.17	6	1,145	z	279	141	.14	4	1,145
c	1320					c	347				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df	Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.21	.46	40	1,148	y	.15	.39	26	1,148
x	.50	.67	72	2,147	x	.42	.63	53	2,147
a	.53	.41	54	3,146	a	.54	.56	57	3,146
z	.54	.46	43	4,145	z	.55	.37	45	4,145

MODEL II

Parameter	Time	Standard Error	β	Freq.	df	Parameter	Time	Standard Error	β	Freq.	df
y	450	93	.31	24	1,145	y	423	93	.28	21	1,145
x	778	134	.42	34	1,145	x	562	134	.30	18	1,145
a	309	89	.22	12	1,145	a	600	89	.42	45	1,145
z'	446	159	.16	8	1,145	z'	472	159	.17	9	1,145
c	1346					c	267				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df	Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y	.21	.46	40	1,148	y	.15	.39	26	1,148
x	.50	.67	72	2,147	x	.42	.63	53	2,147
a	.53	.41	54	3,146	a	.54	.56	57	3,146
z'	.55	.22	44	4,145	z'	.57	.21	47	4,145

MODEL III

Parameter	Time	Standard Error	β	Freq.	df	Parameter	Time	Standard Error	β	Freq.	df
y'	618	146	.26	18	1,145	y'	596	146	.25	17	1,145
x	894	128	.48	49	1,145	x	666	128	.35	27	1,145
a	270	89	.19	9	1,145	a	565	89	.40	40	1,145
z'	220	160	.08	2	1,145	z'	258	160	.09	3	1,145
c	1696					c	589				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df	Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y'	.19	.44	35	1,148	y'	.14	.38	25	1,148
x	.50	.67	74	2,147	x	.43	.63	55	2,147
a	.53	.41	55	3,146	a	.55	.56	59	3,146
z'	.53	.22	42	4,145	z'	.56	.21	45	4,145

MODEL IV

Parameter	Time	Standard Error	β	Freq.	df	Parameter	Time	Standard Error	β	Freq.	df
y'	591	160	.25	14	1,145	y'	610	159	.25	15	1,145
x	1336	244	.43	30	1,145	x'	874	242	.28	13	1,145
a	336	93	.24	13	1,145	a	636	92	.45	48	1,145
z'	25	179	.01	.20	1,145	z'	146	177	.05	1	1,145
c	1734					c	536				

Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df	Parameter	Cumulative R^2	r	Cumulative Freq.	Cumulative df
y'	.19	.44	35	1,148	y'	.14	.38	25	1,148
x	.44	.64	57	2,147	x'	.36	.58	41	2,147
a	.48	.41	46	3,146	a	.51	.56	52	3,146
z'	.48	.22	34	4,145	z'	.52	.21	39	4,145

REFERENCES

Atkinson, R.C., & Shiffrin, R.M. (1968) Human memory: A proposed system and its control processes. In K.W. Spence & J.T. Spence (Eds.), The psychology of learning and motivation: Advances in research and theory (Vol. 2). New York: Academic Press.

Baumeister, A.A., & Kellas, C. (1967) Refractoriness in the reaction times of normals and retardates as a function of response-stimulus interval. Journal of Experimental Psychology, 75, 122-125.

Baumeister, A.A., & Kellas, C. (1968) Reaction time and mental retardation. In N.R. Ellis (Ed.), International review of research in mental retardation (Vol. 3). New York: Academic Press.

Belmont, J.M., & Butterfield, E.C. (1969) The relation of short-term memory to development and intelligence. In L.P. Lipsitt & H.W. Reese (Eds.), Advances in child development and behaviour (Vol. 4) New York: Academic Press.

Belmont, J.M., & Butterfield, E.C. (1977) The instructional approach to developmental cognitive research. In R.V. Kail & J.W. Hagen (Eds.), Perspectives on the development of memory and cognition. Hillsdale, N.J.: Lawrence Erlbaum Associates.

Belmont, J.M., Butterfield, E.C., & Borkowski, J.C. (1978) Training retarded people to generalise memorization methods across memory tasks. In M.M. Gruneberg, P.E. Morris, & R.N. Sykes (Eds.), Practical aspect of memory. London: Academic Press.

Belmont, J.M., Butterfield, E.C., & Ferretti, R. (1982) To secure transfer of training instruct self-management skills. In D.K. Detterman & R.J. Sternberg (Eds.), How and how much can intelligence be increased. New Jersey: Ablex Publishing Co.

Belmont, J.M. Ferretti, R., & Mitchell, D. (1982) Memorizing: A test of untrained mildly mentally retarded children's problem-solving. American Journal of Mental Deficiency, 87, 197-210.

Bethell-Fox, C.E., Lohman, D.F., & Snow, R.E. (1984) Adaptive reasoning: Componential and eye movement analysis of geometric analogy performance. Intelligence, 8, 205-238.

Bizanz, J., Bisanz, G.L., & Le Fevre, J. (1984) Interpretation of instructions: A source of individual differences in analogical reasoning. Intelligence, 8, 161-177.

Bjork, R.A. (1972) Theoretical implications of directed forgetting. In A.W. Melton & E. Martin (Eds.), Coding processes in human memory. Washington, D.C.: Winston.

Borkowski, J.G. (1965) Interference effects in short-term memory as a function of level of intelligence. American Journal of Mental Deficiency, 20, 458-465.

Bray, N.W. (1972) Effects of instructions to forget on memory in the retarded. Unpublished doctoral dissertation, University of Illinois, U.S.A.

Bray, N.W. (1973) Controlled forgetting in the retarded. Cognitive Psychology, 5, 288-309.

Bray, N.W. (1978) The effect of task instructions on a simple directed forgetting task with retarded adolescents. Unpublished manuscript, University of Alabama, U.S.A.

Bray, N.W. (1979) Strategy production in the retarded. In N.R. Ellis (Ed.), Handbook of mental deficiency: Psychological theory and research (2nd. ed.). Hillsdale, N.J.: Lawrence Erlbaum Associates.

Bray, N.W., Dann, L., & Gwartnery, O. (1978) The locus of task complexity in the directed forgetting performance of mentally retarded adolescents. Unpublished manuscript, University of Alabama, U.S.A.

Bray, N.W., Goodman, M.A., & Justice, E.M. (1982) Task instructions and strategy transfer in the directed forgetting performance of mentally retarded adolescents. Intelligence, 6, 187-200.

Bray, N.W., Justice, E.M., & Simon, D.L. (1978) The sufficient conditions for directed forgetting in normal and educable mentally retarded adolescents. Intelligence, 2, 153-167.

Brewer, N. (1978) Motor components in the choice reaction time of mildly retarded adults. American Journal of Mental Deficiency, 82, 565-572.

Brewer, N., & Nettelbeck, T. (1977) The influence of contextual cues on the choice reaction time of mildly retarded adults. American Journal of Mental Deficiency, 82, 37-43.

Broadbent, D.E., & Gregory, M. (1965) On the interaction of S-R compatibility with other variables affecting choice reaction time. British Journal of Psychology, 56, 61-67.

Brown, A.L. (1974) The role of strategic behaviour in retardate memory. In N.R. Ellis (Ed.), International review of research in mental retardation (Vol. 7). New York: Academic Press.

Brown, A.L. (1978) Knowing when, where and how to remember: A problem of metacognition. In R. Glaser (Ed.), Advances in instructional psychology (Vol. 1). New Jersey: Lawrence Erlbaum Associates.

Brown, A.L., & Barclay, C.R. (1976) The effects of training specified mnemonics on the metamnenoic efficiency of retarded children. Child Development, 47, 71-80.

Brown, A.L., & Campione, J.C. (1982) Modifying intelligence or modifying cognitive skills: More than a semanticquibble? in D.K. Detterman & R.J. Sternberg (Eds.), How and how much can intelligence be increased. New Jersey: Ablex Publishing Co.

Brown, A.L., Campione, J.C., & Barclay, C.R. (1979) Training self-checking routines for estimating test readiness: Generalisation from list learning to prose recall. Child Development, 50, 501-512.

Brown, A.L., Campione, J.C., Bray, N.W., & Wilcox, B.L. (1973) Keeping track of changing variables: Effects of rehearsal training and rehearsal prevention in normal and retarded adolescents. Journal of Experimental Psychology, 101, 123-131.

Brown, A.L., Campione, J.C.,& Murphy, M.D. (1977) Maintenance and generalisation of trained metamnemonic awareness of educable retarded children. Journal of Experimental Child Psychology, 24, 191-211.

Brown, A.L., & De Loache, J.S. (1978) Skills, plans and self-regulation. In R.S. Siegler (Ed.), Children's thinking: What develops? New Jersey: Lawrence Erlbaum Associates.

Brown, A.L., & Smiley, S.S. (1977) Rating the importance of structural units of prose passages: A problem of metacognitive development. Child Development, 48, 1-8.

Brown, A.L., & Smiley, S.S. (1978) The development of strategies for studying texts. Child Development, 49, 1076-1088.

Buckhalt, J.A., Mahoney, G.J., & Paris, S.G. (1976) Efficiency of self-generated elaborations by EMR and nonretarded children. American Journal of Mental Deficiency, 81, 93-96.

Butterfield, E.C., & Belmont, J.M. (1977) Assessing and improving the cognition of mentally retarded people. In I. Bialer & M. Sternlicht (Eds.), Psychology of mental retardation: Issues and approaches. New York: Psychological Dimensions.

Butterfield, E.C., Wambold, C., & Belmont, J.M. (1973) On the theory and practice of improving short-term memory. American Journal of Mental Deficiency, 77, 654-669.

Campione, J.C., & Brown, A.L. (1977) Memory and metamemory development in educable retarded children. In R.V. Kail & J.W. Hoagen(Eds.), Perspectives on the development of memory and cognition. New Jersey: Lawrence Erlbaum Associates.

Campione, J.C., & Brown, A.L. (1978) Training general metacognitive skills in retarded children. In M.M. Gruneberg, D.E. Morris & R.N. Sykes (Eds.), Practical aspects of memory. London: Academic Press.

Campione, J.C., Brown, A.L., & Ferrara, R.A. (1982) Mental retardation and intelligence. In R.J. Sternberg (Ed.), Handbook of human intelligence. New York: Cambridge University Press.

Carey, S., & Diamond, R. (1977) From piecemeal to configurational representation of faces. Science, 195, 312-314.

Carpenter, P.A., & Just, M.A. (1975) Sentence comprehension: A psycholinguistic processing model of verification. Psychological Review, 82, 1-25.

Carpenter, P.A., & Just, M.A. (1978) Eye fixations during mental rotation. In J. Senders, R. Monty & D. Fisher (Eds.), Eye movements and psychological processes (Vol. II). New Jersey: Lawrence Erlbaum Associates.

Cavanaugh, J.C., & Borkowski, J.G. (1979) The metamemory-memory 'connection': Effects of strategy, training and maintenance. Journal of General Psychology, 101, 161-174.

Chase, W.G. (1978) Elementary information processes. In W.K. Estes (Ed.), Handbook of learning and cognitive processes (Vol. 5). New Jersey: Lawrence Erlbaum Associates.

Chase, W.G., & Clark, H.H. (1972) Mental operations in the comparison of sentences and pictures. In L. Gregg (Ed.), Cognition in learning and memory. New York: John Wiley & Sons.

Chase, W.G., & Simon, H.A. (1973) The mind's eye in chess. In W.G. Chase (Ed.), Visual information processing. New York: Academic Press.

Chi, M.T.H. (1976) Short-term memory limitations in children: Capacity or processing deficits. Memory and Cognition, 4, 559-572.

Chi, M.T.H. (1981) Knowledge development and memory performance. In M.P. Friedman, J.P. Das, & N. O'Connor (Eds.), Intelligence and Learning. New York: Plenum Press.

Chiang, A., & Atkinson, R.C. (1976) Individual differences and interrelationships among a select set of cognitive skills. Memory and Cognition, 4, 661-672.

Clark, H.H., & Chase, W.G. (1972) On the process of comparing sentences against pictures. Cognitive Psychology, 3, 472-517.

Clifton, C. Jr., & Tash, J. (1973) Effect of syllabic word length on memory-search rate. Journal of Experimental Psychology, 99, 231-235.

Cooper, L.A. (1975) Mental rotation of random two-dimensional shapes. Cognitive Psychology, 7, 20-43.

Cooper, L.A. (1976) Individual differences in visual comparison processes. Perception and Psychophysics, 19, 443-444.

Cooper, L.A. (1980a) Spatial information processing; Strategies for research. In R. Snow, P.A. Federico & W.E. Montague (Eds.), Aptitude, learning and instruction: Cognitive process analyses. New Jersey: Lawrence Erlbaum Associates.

Cooper, L.A. (1980b) Recent themes in visual information processing: A selected overview. In R.E. Nickerson (Ed.), Attention and performance (Vol. VIII). New Jersey: Lawrence Erlbaum Associates.

Cooper, L.A. (1982) Strategies for visual comparison and representation: Individual differences. In R.J. Sternberg (Ed.) Advances in the psychology of human intelligence. (Vol. 1) New Jersey: Lawrence Erlbaum Associates.

Cooper, L.A., & Podgorny, P. (1976) Mental transformations and visual comparison processes: Effects of complexity and similarity. Journal of Experimental Psychology: Human Perception and Performance, 2, 503-514.

Cooper, L.A., & Regan, D.T. (1982) Attention, perception and intelligence In R.J. Sternberg (Ed.), Handbook of human intelligence. New York: Cambridge University Press.

Cooper, L.A., & Shepard, R.N. (1983) Chronometric studies of the rotation of mental images. In W.C. Chase (Ed.), Visual information processing. New York: Academic Press.

Detterman, D.K. (1979) Memory in the mentally retarded. In N.R. Ellis (Ed.), Handbook of Mental Deficiency: Psychological theory and research"(2nd Edition) Hillsdale, New Jersey: Erlbaum Associates.

Donders, F.C. (1969) Over de srelbeid van psychische processes. (On the speed of mental processes). Translated by W.G. Koster. Acta Psychologica, 30, 412-431.

Dugas, J., & Kellas, G. (1974) Encoding and retrieval processes in normal children and retarded adolescents. Journal of Experimental Psychology, 17, 177-185.

Ellis, N.R. (1963) The stimulus trace and behavioural inadequacy. In N.R. Ellis (Ed.), Handbook of mental deficiency. New York: McGraw-Hill.

Ellis, N.R. (1970) Memory processes in retardates and normals. In N.R. Ellis (Ed.), International review of research in mental retardation. New York: Academic Press.

Ellis, N.R. (1978) Do the mentally retarded have poor memory? Intelligence, 2, 41-54.

Evans, T.G. (1968) A program for the solution of a class of geometric-analogy intelligence-test questions. In M. Minsky (Ed.), Semantic information processing. Cambridge, Mass.: MIT Press.

Ferretti, R.P. (1982) An analysis of passive memory in normal and mentally retarded persons. Intelligence, 6, 69-87.

Flavell, J.H. (1970) Developmental studies of mediated memory. In H.W. Reese & L.P. Lipsitt (Eds.), Advances in child development and behaviour (Vol. 5). New York: Academic Press.

Flavell, J. H. (1971) First discussant's comments: What is memory development the development of? Human Development, 14, 272-278.

Flavell, J.H., & Wellman, H.M. (1977) Metamemory. In R.V. Kail & J. W. Hagen (Eds.), Perspectives on the development of memory and cognition. New Jersey: Lawrence Erlbaum Associates.

Flavell, J.H., Beach, D.R., & Chinsky, J.M. (1966) Spontaneous verbal rehearsal in a memory task as a function of age. Child Development, 37, 283-299.

Garner, W.R. (1974) The processing of information and structure. New Jersey: Lawrence Erlbaum Associates.

Greeno, J.G. (1978) A study of problem solving. In R. Glaser (Ed.), Advances in instructional psychology (Vol. 1). New Jersey: Lawrence Erlbaum Associates.

Guilford, J.R. (1967) The nature of human intelligence. New York: McGraw-Hill.

Harris, G., & Fleer, R. (1974) High speed memory scanning in mental retardates: Evidence for a central processing deficit. Journal of Experimental Child Psychology, 17, 452-459.

Herman, D.J., & Landis, T.Y. (1977) Differences in the search rate of children and adults in short-term memory. Journal of Experimental Child Psychology, 23, 151-161.

Hick, W.E. (1952) On the rate of gain of information. Quarterly Journal of Experimental Psychology, 4, 11-26.

Hunt, E., (1978) Mechanics of verbal ability. Psychological Review, 85, 109-130.

Hunt, E., (1980a) Intelligence as an information processing concept. British Journal of Psychology, 71, 449-474.

Hunt, E., (1980b) The foundations of verbal comprehension. In R.E. Snow, P.A. Federico & W.E. Montague (Eds.), Attitude, learning and instruction: Vol. 1. Cognitive process analyses of aptitude. New Jersey: Lawrence Erlbaum Associates.

Hunt, E., Frost, N., & Lunneborg, C. (1973) Individual differences in cognition. In G. Bower (Ed.), Advances in learning and memory (Vol. 7). New York: Academic Press.

Hunt, E., Lunneborg, C., & Lewis, J. (1975) What does it mean to be high verbal? Cognitive Psychology, 7, 194-227.

Jensen, A.R. (1979) G: Outmoded theory or unconquered frontier. Creative Science and Technology, 2, 16-29.

Jensen, A.R. (1980) Chronometric analysis of intelligence. Journal of Social Biological Sturcture, 3, 103-122.

Jensen, A.R. (1982a) Reaction time and psychometric g. In H.J. Eysenck (Ed.), A model for intelligence. Berlin & Heidelberg: Springer-Verlag.

Jensen, A.R. (1982b) The chronometry of intelligence. In R.J. Sternberg (Ed.), Advances in the psychology of human intelligence (Vol. 1). New Jersey: Lawrence Erlbaum Associates.

Jensen, A.R., & Munro, E. (1979) Reaction time, movement time and intelligence. Intelligence, 3, 121-126.

Johnson, D.M. (1960) Serial analysis of thinking. Annals of the New York Academy of Sciences, 91, 66-75.

Johnson, D.M. (1962) Serial analysis of verbal analogy problems. Journal of Educational Psychology, 53, 86-88.

Just, M.A., & Carpenter, D.A. (1976) Eye fixations and cognitive processes. Cognitive Psychology, 8, 441-480.

Keating, D.P., & Bobbitt, B.L. (1978) Individual and developmental differences in cog-processing components of mental ability. Child Development, 49, 155-167.

Kendall, C.R., Borkowski, J.G., & Cavanaugh, J.C. (1980) Metamemory and the transfer of an interrogative strategy by EMR children. Intelligence, 4, 255-270.

Kestner, J., & Borkowski, J.G. (1979) Children's maintenance and generalisation of an interrogative learning strategy. Child Development, 50, 485-494.

Kirby, N.H., Nettelbeck, T., & Tiggerman, M. (1977) Reaction time in normal and mentally retarded young adults: Sequential effects and response organisation. American Journal of Mental Deficiency, 81, 492-498.

Kirby, N.H., Nettelbeck, T. & Western, P. (1982) Locating information-processing deficits of mildly mentally retarded young adults. American Journal of Mental Deficiency, 87, 338-343.

Kreutzer, M., Leonard, C., & Flavell, J. (1975) An interview study of children's knowledge about memory. Monographs of the Society for Research in Child Development, 40, (1, Serial No. 159) pp. 1-60.

Krupski, A. (1979) Are retarded children more distractable? Observational analysis of retarded and nonretarded children's classroom behaviour. American Journal of Mental Deficiency, 84, 1-10.

Krupski, A. (1977) Role of attention in the reaction-time performance of mentally retarded adolescents. American Journal of Mental Deficiency, 82, 79-83.

Lally, M. & Nettelbeck, T. (1977) Intelligence, reaction time and inspection time. American Journal of Mental Deficiency, 82, 273-281.

Longstreth, L.E. (1984) Jensen's reaction-time investigations of intelligence: A critique. Intelligence, 8, 139-160.

Lunneberg, C.E. (1977) Choice reaction time: What role in ability measurement? Applied Psychological Measurement, 1, 309-330.

MacLeod, C.M. (1975) Long-term recognition and recall following directed forgetting. Human Learning and Memory, 104, 271-279.

MacLeod, C.M., Hunt, E., & Mathews, N. (1978) Individual differences in the vertification of sentence-picture relationships. Journal of Verbal Learning and Verbal Behaviour, 17, 493-507.

Maisto, A. (1978) Comments on the use of the additive factors method with mentally retarded persons: A reply to Silverman. American Journal of Mental Deficiency, 83, 191-193.

Maisto, A., & Jerome, M. (1977) Encoding and high-speed memory scanning of retarded and nonretarded adolescents. American Journal of Mental Deficiency, 82, 282-286.

Mathews, N., Hunt, E., & MacLeod, C.M. (1980) Strategy choice and strategy training in sentence-picture verification. Journal of Verbal Learning and Verbal Behaviour, 19, 531-548.

McClelland, J.L. (1979) On the time relations of mental processes: An examination of systems of processes in cascade. Psychological Review, 86, 287-330.

McConaghy, J. (1980) The choice reaction times of mildly retarded young adults: The influence of contextual cues. Unpublished Honours Thesis, University of Adelaide, South Australia.

Metzler, J., & Shephard, R.M. (1974) Transformational studies of the internal representation of three-dimensional objects. In R.L. Solso (Ed.), Theories in cognitive psychology: The Loyola symposium. New York: Wiley.

Miller, J.D. (1982) Discrete vs. continuous stage models of human information processing: In search of partial output. Journal of Experimental Psychology: Human Perception and Performance, 8, 273-296.

Miller, J.D. (1983) Can response preparation begin before stimulus recognition finishes? Journal of Experimental Psychology: Human Perception and Performance, 9, 161-182.

Miller, J.D., & Pachella, R.G. (1973) On the laws of the stimulus probability effect. Journal of Experimental Psychology, 101, 227-231.

Mulholland, T., Pellegrino, J., & Glaser, R. (1980) Components of geometric analogy solution. Cognitive Psychology, 12, 252-284.

Naus, M.J., & Ornstein, P.A. (1977) Development differences in the memory search of categorised lists. Developmental Psychology, 13, 60-68.

Neisser, U. (1963) Decision time without reaction time: Experiments in visual scanning. American Journal of Psychology, 76, 276-385.

Nettelbeck, T. (1980) Factors affecting reaction time: Mental retardation, brain damage, and other psychopathologies. In A.T. Welford (Ed.). Reaction Times. London: Academic Press.

Nettelbeck, T. & Brewer, N. (1976) Effects of stimulus-response variables on the choice reaction time of mildly retarded adults. American Journal of Mental Deficiency, 81, 85-92.

Nettelbeck, T. & Brewer, N. (1981) Studies in mild mental retardation and timed performance. In N.R. Ellis (Ed.)., International review of research in mental retardation (Vol. 10). New York: Academic Press.

Nettelbeck, T., & Kirby, N.H. (1983) Measures of timed performance and intelligence. Intelligence, 7, 39-52.

Nettelbeck, T., & Lally, M. (1976) Inspection time and measured intelligence. British Journal of Psychology, 67, 17-22.

Nettelbeck, T., & Lally, M. (1979) Age, intelligence and inspection time, American Journal of Mental Deficiency, 83, 398-401.

Nettelbeck, T., Robson, L., Walwyn, T., Downing, A., & Jones, N. (1984) Unpublished manuscript, University of Adelaide, South Australia.

Newell, A., & Simon, H. (1982) Human problem solving. New York: Prentice Hall.

Norman, D.A., Gentner, D.R., & Stevens, A.L. (1976) Comments on learning schemata and memory. In D. Klahr (Ed.), Cognition and instruction. New Jersey: Lawrence Erlbaum Associates.

Oppenheimer, R. (1956) Analogy in science. American Psychologist, 11, 127-135.

Pachella, R.G. (1974) The interpretation of reaction time in information processing research. In B.H. Kantowitz (Ed.), Human information processing: Tutorials in performance and cognition. New Jersey: Lawrence Erlbaum Associates.

Pellegrino, J. & Glaser, R. (1979) Cognitive correlates and components in the analysis of individual differences. In R.J. Sternberg & D.K. Detterman (Eds.), Human intelligence: Perspectives on its theory and measurement. New Jersey: Ablex Publishing.

Pellegrino, J.W., & Glaser, R. (1980) Components of inductive reasoning In R.E. Snow, P.A. Federico, & W.E. Mentague (Eds.), Aptitude, learning and instruction. Vol 1. Cognitive process analyses of aptitude. New Jersey: Lawrence Erlbaum Associates.

Phillips, C.J., & Nettelbeck, T. (1984) Effects of practice on recognition memory of mildly retarded adults. American Journal of Mental Deficiency, 88, 678-687.

Posner, M.I. (1978) Chronometric explorations of mind. New Jersey: Lawrence Erlbaum Associates.

Posner, M.I., Boies, S., Eichelman, W., & Taylor, R. (1969) Retention of visual and name codes of single letters. Journal of Experimental Psychology Monographs, 79, 1-16.

Posner, M.I., & Mitchell, R. (1967) Chronometric analysis of classification. Psychological Review, 74, 392-409.

Reitman, J.S. (1971) Mechanisms of forgetting in short-term memory. Cognitive Psychology, 2, 185-195.

Reitman, J.S. (1974) Without surreptitious rehearsal, information in short-term memory decays. Journal of Verbal Learning and Verbal Behaviour, 13, 365-377.

Resnick, L.B., & Glaser, R. (1976) Problem solving and intelligence. In L.B. Resnick (Ed.), The nature of intelligence. New Jersey: Lawrence Erlbaum Associates.

Robinson, E.V., & Robinson, N.R. (1983) Communication and metacommunicatio Quality of children's instructions in relation to judgement about the adequacy of instructions and the locus of responsibility for communication failure. Journal of Experimental Child Psychology, 36, 305-320.

Sanders, A.F. (1970) Some variables affecting the relation between relative signal frequency and CRT. In A.F. Sanders (Ed.), Attention and Performance III. Amsterdam: North Holland.

Sanders, A.F. (1980) Stage analysis of reaction processes. In G.E. Stelmach & J. Requin (Eds.), Tutorials in motor behaviour. Amsterdam: North Holland.

Shepard, R.N. (1975) Form, formation and transformation of internal representation. In R.L. Solso (Ed.), Information processing and cognition: The Loyola symposium. New Jersey: Lawrence Erlbaum Associates.

Shif, Z.I. (1969) Development of children in schools for the mentally retarded. In M. Cole & I. Maltzman (Eds.), A handbook of contemporary Soviet psychology. New York: Basic Books.

Silverman, W. (1974) High speed scanning of nonalphanumeric symbols in culturally familially retarded and nonretarded children. American Journal of Mental Deficiency, 79, 44-51.

Silverman, W., & Harris, G. (1982) Reaction time and mild mental retardation: High speed scanning reexamined. American Journal of Mental Deficiency, 87, 96-102.

Smiley, S.S., Oakley, D.D., Worthen, D., Campione, J.C., & Brown, A.L. (1977) Recall of theoretically relevant material by adolescent good and poor readers as a function of written versus oral presentation. Educational Psychology, 69, 381-387.

Smith, E.E. (1968) Choice reactiontime: An analysis of the major theoretical positions. Psychological Bulletin, 69, 77-110.

Smith, G.J. (1981) Analogical reasoning profiles of mentally retarded and normal adults judged against Sternberg's unified componential theory of human reasoning. Unpublished doctorial dissertation, University of Northern Colorado, U.S.A.

Spearman, C. (1972) The abilities of man. New York: Macmillan.

Sperber, R.D., Ragain, R.D., & McCauley, C. (1976) Reassessment of category knowledge in retarded individuals. American Journal of Mental Deficiency, 81, 227-234.

Spitz, H.H. (1970) The role of input organisation in the learning and memory of mental retardates. In N.R. Ellis (Ed.), International review of research in mental retardation. (Vol. 4). New York: Academic Press.

Spitz, H.H. (1973) Consolidating facts into the schematized learning and memory system of educable retardates. In N.R. Ellis (Ed.), International review of research in mental retardation. (Vol. 6). New York: Academic Press.

Spitz, H.H., & Webreck, C.A. (1972) Effects of spontaneous vs. externally-cued learning on the permanent storage of a scheme of retardates. American Journal of Mental Deficiency, 77, 163-168.

Stanovich, K., & Pachella, R. (1977) Encoding, St-Re compatibility and stages of processing. Journal of Experimental Psychology: Human Perception and Performance, 3, 411-421.

Sternberg, R.J. (1975) The componential analysis of human abilities. Unpublished doctorial dissertation, Stanford University.

Sternberg, R.J. (1977a) Intelligence, information processing and analogical reasoning: The componential analysis of human abilities. New Jersey: Lawrence Erlbaum Associates.

Sternberg, R.J. (1977b) Component processes in analogical reasoning. Psychological Review, 84, 353-378.

Sternberg, R.J. (1978a) Isolating the components of intelligence. Intelligence, 2, 117-128.

Sternberg, R.J. (1978b) Componential investigations of human intelligence. In A. Lesgold, J. Pellegrino, S. Fokkema, & R. Glaser (Eds.), Cognitive psychology and instructions. New York: Plenum.

Sternberg, R.J. (1979) The nature of mental abilities. American Psychologist, 34, 214-230.

Sternberg, R.J. (1980a) Sketch of componential subtheory of human intelligence. Behavioural and Brain Science, 3, 573-614.

Sternberg, R.J. (1980b) A proposed resolution of curious conflicts in the literature on linear syllogisms. In R.S. Nickerson (Ed.), Attention and Performance (Vol. VIII).

Sternberg, R.J. (1981) Toward a unified componential theory of human intelligence: I. Fluid ability. In M.P. Friedman, J.P. Das, & N. O'Connor (Eds.), Intelligence and learning. New York: Plenum Press.

Sternberg, R.J. (1982) A componential approach to intellectual development. In R. J. Sternberg (Ed.), Advances in the psychology of human intelligence. (Vol.1). New Jersey: Lawrence Erlbaum Associates.

Sternberg, R.J. (1984) Toward a triadic theory of human intelligence. Behavioural and Brain Science. 7, 269-315.

Sternberg, R.J., & Gardner, M.K. (1983) Unities in inductive reasoning. Journal of Experimental Psychology: General, 112, 80-116.

Sternberg, R.J., & Ketron, J.L. (1982) Selection and implementation of strategies in reasoning by analogy. Journal of Educational Psychology, 74, 399-413.

Sternberg, R.J., & Nigro, G. (1980) Developmental patterns in the solution of verbal analogies. Child Development, 51, 27-38.

Sternberg, R.J., & Rifkin, B. (1979) The development of analogical reasoning processes. Journal of Experimental Child Psychology, 27, 195-232.

Sternberg, R.J., & Weil, E.M. (1980) An aptitude-strategy interaction in linear syllogistic reasoning. Journal of Educational Psychology, 72, 226-234.

Sternberg, S. (1966) High-speed scanning in human memory. Science, 153, 652-654.

Sternberg, S. (1969a) The discovery of processing stages: Extensions of Donder's method. Acta Psychologica, 30, 276-315.

Sternberg, S. (1969b) Memory scanning: Mental processes revealed by reaction time experiments. American Scientist, 57, 421-457.

Sternberg, S. (1975) Memory scanning: New findings and current controversies. Quarterly Journal of Experimental Psychology, 27, 1-32.

Taylor, D.H. (1966) Latency components in two-choice responding. Journal of Experimental Psychology, 72, 481-488.

Taylor, D.A. (1976) Stage analysis of reaction time. Psychological Bulletin, 83, 161-191.

Taylor, D.A. (1977) Time course of context effects. Journal of Experimental Psychology: General, 106, 404-426.

Thurstone, L.L. (1938) Primary mental abilities. Chicago: University of Chicago Press.

Vickers, D., Nettelbeck, T., & Willson, R. (1972) Perceptual indices of performance. The measurement of inspection time and 'noise' in the visual system. Perception, 1, 263-295.

Wanschura, P.B., & Borkowski, J.G. (1975) Long-term transfer of a mediational strategy by moderately retarded children. American Journal of Mental Deficiency, 80, 323-333.

Waters, L.K. (1979) Social reinforcement of the working behaviour of retardates in a rehabilitation centre. Australian Journal of Psychology, 31, 201-211.

Winters, J.J., Jr., & Cundari, L. (1979) Accumulation of and release from proactive inhibition in short-term memory by retarded and nonretarded persons. American Journal of Mental Deficiency, 83, 595-600.

Zigler, E. (1973) The retarded child as a whole person. In D.K. Routh (Ed.), The experimental psychology of mental retardation. Chicago: Aldine Publishing.

Zigler, E., & Balla, D. (1981) Recent issues in the developmental approach to mental retardation. In M.P. Friedman, J.P. Das, & N. O'Connor (Eds.), Intelligence and learning. New York: Plenum Press.