Individual Differences in Expanded Judgement Tasks

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STATEMENT

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

I hereby give my consent that following my acceptance for the award of the degree, this thesis may be made available for photocopying or loan if required.

Signed: ____________________
Elizabeth Foreman
April 1991

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ABSTRACT

The main purpose of this study is to examine the role of individual differences in a specific type of judgmental task, referred to as an Expanded Judgement Task (EJT), in which a series of stimuli is presented on each trial. This type of task was initially investigated by Irwin, Smith & Mayfield (1956), and has been modified by Vickers, Burt, Smith & Brown (1985a). Two experimental paradigms have been distinguished. In one the (E-paradigm), the number of observations is controlled by the experimenter, while, in the other (S-paradigm), the number of observations is controlled by the subject.

The first three experiments were designed to examine subject consistency, the effects of varying discriminability on performance, and individual differences in the amount of information lost in both paradigms. Measures of personality based on Eysenck's Personality Questionnaire (EPQ) were obtained, and were correlated with measures of latency, number of correct responses, and an index of information loss (IR). Results from the first of these studies indicated that variations in discriminability produced differences in performance similar to those found in traditional reaction time experiments. In the second experiment, it was found that subjects' performance in both experimental paradigms showed good test-retest reliability. However, there was no cross-paradigmatic consistency in performance. In the third experiment, measures of information loss (IR) were examined in the E-paradigm only. Results from this experiment showed that subjects' accuracy did not seem to depend on the loss of information systematically related to the magnitude of the stimulus difference. In the first experiment, the Eysenckian dimensions of extraversion (E) and neuroticism (N) correlated with reaction time and accuracy when task difficulty was varied on a trial by trial basis. It was concluded that extraverts showed better adaptation to variations in task difficulty.

There was no association between personality dimensions and a measure of the amount of information lost.

Two further experiments were designed to assess whether performance was dependent upon speed of processing. In these experiments the inspection time (IT) paradigm was used to provide a measure of speed of processing. In addition, subjects completed the Standard Progressive Matrices. These experiments found a significant correlation between IT and EJT performance when the rate of stimulus presentation was equivalent to 3 per second, rather than at faster rates of 12.5 per second and 25 per second. However, EJT performance did not correlate with the measure of intellectual ability obtained from the Standard Progressive Matrices, contrary to other studies conducted by Nicholls (1988) and McDowell (1989), where near identical tasks were used. It was concluded that there is insufficient evidence to disprove an association between IT and EJT.

Overall the results from the series of experiments conducted in this thesis indicate that EJT performance is stable and reliable. Accuracy seems more likely to be determined by limitations in the rate of processing rather than by a parameter, such as IR, which is determined by stimulus magnitude. There is some support for an association between measures of individual difference, particularly intelligence and EJT performance.

CHAPTER ONE.
REACTION TIME MODELS AND INDIVIDUAL DIFFERENCES IN PERFORMANCE.

1.0 Introduction.

This thesis is concerned with individual differences in the way in which people make decisions and judgments involved in simple psychophysical discriminations. Such tasks have relatively simple structures and involve relatively simple processes, for which detailed theoretical models have been developed. The processes involved are fundamental, seem likely to be less prone to influence by cultural factors, and are almost certainly involved in most, if not all, higher cognitive activity. It seems arguable that the parameters of these processes will exert some more general limiting influence on intellectual performance. It also seems possible, though perhaps more contestably, that characteristic ways of performing such simple tasks may be related to more global measures of personality differences, which are supposedly less closely tied to specific situations and tasks. If such a relationship were established, it seems likely that it would help to clarify the interpretation of such measures by linking them to comparatively well developed and systematically investigated theoretical structures, or that it would at least suggest some specific ways in which these concepts might be further differentiated and articulated. At the same time, the attempt to study individual differences in simple discriminative performance provides a useful additional constraint on theorising about such tasks, since it requires that changes and differences in the theoretical parameters be linked to a wider rationale, according to which they are required to vary systematically rather than being idiosyncratically estimated for each situation.

The discriminative task studied in this thesis is a so-called `expanded judgment task', which was designed as an alternative to traditional discriminative reaction time experiments. In such a task, an attempt is made to externalize the hypothesized internal process of sampling observations of the sensory input by presenting a sequence of objectively discrete observations at a comparatively slow rate, thereby `expanding' in time the process of accruing information and reaching a decision. Such a task seems to occupy an intermediate position between traditional speeded reaction time (RT) tasks, which are highly automatic, and the much slower deferred decision tasks studied by behavioural decision analysts such as Busemeyer & Rapoport (1988), which leave more scope for the intrusion of other cognitive activity and the employment of deliberate strategies. Besides the detailed methodological reasons for investigating the expanded judgment task, which we will consider below, this intermediate location seems an appropriate one in which to look for links between the factors determining basic information processing performance and the more general characteristics of mental activity captured by measures of intelligence and personality.

In this first chapter we will begin by looking at various attempts to relate performance in reaction time tasks to theories and measures of individual differences. A number of problems may be identified. These include the different directions in which theories concerning response latency mechanisms, and those concerning individual differences, have developed. It will be argued that, while the former have attempted increasingly to account for the influence of top down factors, the latter have tended to emphasise a biological perspective, in which the importance of cognitive factors is minimised. It will also be argued that the complexity of response latency mechanisms poses problems for the interpretation of reaction time indices in experiments where the multiple factors influencing performance are uncontrolled. One solution, it is suggested, lies in the development of techniques which permit the estimation of the various parameters. Such techniques, however, depend on analyses based on specific theoretical assumptions concerning the underlying mechanisms. A more theory-neutral solution is to attempt to control the various factors by externalising them in the task itself. An expanded judgment task, which attempts to do this, is described, which seems to have a number of possible advantages for the study of individual differences.

1.1 Reaction time experiments: historical background.

The conflicting developments with which this thesis is concerned have been present since the origins of experimental psychology, and were already evident in the earliest studies of the time required to make a simple psychophysical judgment. The earliest studies concerned with the human detection of changes in the environment were those of the astronomer Bessel in 1820, and later Hirsch (1861-1865), as cited by Woodworth & Schlosberg (1954), who were interested in individual differences in the recording of stellar transits. At about the same time similar developments were also being made in the domain of physiology. For example, in 1850, Hemholtz used RT as a means of measuring the speed of neural transmission, thus concentrating more on the motor component (Brebner & Welford 1980). Somewhat later, Donders (1868) focused on simple mental processes in his attempts to measure the time required to execute tasks of varying complexity. Donders suggested a classification of reaction time paradigms. These included: an a-reaction, equivalent to a simple RT paradigm, where subjects had to respond to the presence of a light; a b-reaction, now referred to as a choice RT paradigm, with n stimuli and n responses; and a c-reaction paradigm, which required subjects to respond only if a particular one of n possible stimuli was presented, and not to respond if any of the other stimuli were presented e.g. respond only to the presence of the letter "a" and not to respond if any of the letters "b", "c", "d" or "e" were presented.

The process involved in the a-reaction (or the simple RT paradigm), was quite early divided into three consecutive phases (Woodworth & Schlosberg 1954). Typically, the paradigm involved the presentation of a warning signal, such as a tactual signal, or an auditory signal such as a warning click (Klemmer 1957). This was followed by a stimulus, such as a white light projected through milky plexiglass to give a uniform appearance (Kohfeld 1971). The first phase is the foreperiod, or the time between the warning signal and the stimulus. The second phase is the reaction time or the time between the stimulus presentation and the response. The third phase, or after-period, is the interval between the response and the warning signal of the next trial. Many experiments have been concerned with manipulating the length and predictability of the foreperiod (Luce 1986; Teichner & Krebs 1972). However, experiments on simple RT have more generally been concerned with determining the relationship between RT and the strength of the stimulus, and with comparisons between performance in various sensory modalities. A history of such studies is given by Brebner & Welford (1980).

The second important paradigm, distinguished by Donders, was the b-reaction, now commonly referred to as a choice RT paradigm. The classic experiment of this type is that of Merkel (1885; cited in Welford 1980), who presented subjects with signals drawn from the arabic numerals 1-5 and the roman numerals I-IV, which appeared around the edge of a disc. The arabic numerals corresponded to the response keys associated with the right hand, the roman numerals to those associated with the left hand, and the subject responded to a signal by pressing the corresponding response key. In this reaction time paradigm the number of stimuli is usually matched by the number of responses. However, a number of variations of this paradigm have been employed. For example Welford (1980) has distinguished between experiments which hold discriminability constant, and vary the number of signals, and those which hold the number of signals constant, and vary their discriminability. The first class, which includes the classic experiment of Merkel, received much attention when Hick (1952) and Hyman (1953) reported that reaction time was a linear function of the increase in stimulus information associated with increases in the number or unpredictability of alternative signals.

Choice RT experiments of the second type, in which discriminability is varied, and the number of signals is held constant, are often referred to as two-choice discrimination experiments (Smith & Vickers 1988) because the number of responses is usually restricted to two comparative judgements. In this case, the signals viewed must be made discriminably different, and often two lines of varying lengths (Botwinick, Brinley & Robbin 1958) have been used. In one set of experiments, the subject is asked to classify singly presented stimuli into two categories with respect to some obvious dimension of physical difference, e.g. to categorize a set of singly presented line segments as long(er) or short(er). In another set of experiments, the subject is asked to identify which of two simultaneously presented stimuli is the greater or lesser (Bindra, Donderi & Nishisato 1968; Parducci 1959).

The third experimental paradigm distinguished by Donders (1868) was the c-reaction, where subjects had to respond to a particular stimulus only. This type of paradigm has been employed in the context of memory by Sternberg (1969, 1975), who refers to this as the "item-recognition" paradigm. The paradigm has also been useful in examining the subject's ability to retrieve information from working memory, and in the attempt to distinguish between successive stages of processing. For example, Sternberg's (1969, 1975) studies involved subjects determining whether a test stimulus was drawn from a positive set of stimuli or from a negative set. If the test stimulus was drawn from the positive set, then the subject made a positive response. However, if it was not drawn from this set, the subject made a negative response. By varying such factors as masking, discriminability and stimulus-response compatibility, Sternberg (1969) found effects in the RT data which he believed demonstrated that these factors affected different stages.

The c-reaction paradigm has been extensively used in attempts to distinguish different processing stages, and this issue has been important in the history of RT studies. The assumption that RT was the total time for the operation of a linear sequence of processing stages was first made by Donders (1868). Donders was particularly concerned with the identification of a number of processing stages, and how they could be measured. The a-, b- and c-reactions were assumed to have stages in common, such as stimulus detection. Besides detection, the b- and c-reactions were assumed to share a stage of stimulus identification, while the b-reaction was also assumed to involve an additional process of response selection. By subtracting RT values from two different paradigms, Donders obtained estimates for the operation time of each stage. For example, the difference in the time between the b- and c- reaction was interpreted as an estimate of the time required for response selection.

At the turn of the century, Donders' ideas were dismissed by the introspectionist Kulpe, who asserted that different paradigms involved different processes, rather than involving the addition (or subtraction) of a simple process to (or from) a common chain of processes (Massaro 1975). In 1969 Sternberg introduced the so-called "additive factors" approach, which was designed to overcome the problem that two or more stages might not be independent, and that a single factor might affect two or more stages. According to Sternberg (1969), when RT is determined by the sum of the times required by a number of successive processing stages, then the effects of the factors which independently influence each stage will be additive, while two experimental manipulations that tend to influence a common stage will have an interactive effect on RT. For example, manipulations which were found to affect the stage of perceptual encoding included the presence of a mask and stimulus discriminability, whereas the stage of response selection was affected by stimulus-response compatability and the number of stimulus response pairs employed. A summary of experiments using the additive factor methodology is given by Wickens (1984).

McClelland (1979) pointed out that it may not necessarily be the case that different stages process information in a strictly independent succession, but rather that information might be processed in a continuous flow, with processes arranged in a cascade. As a result, later stages may begin in processing even although earlier stages have not been completed. This model provides explanations of response priming, where the most probable response is initiated before the information presented is identified, and of underadditivity, where the effect on RT is smaller at the more difficult level of one of the manipulations (Wickens 1984).

McClelland's (1979) challenge to the notion of a strict linear sequence of processing stages also foreshadowed the development of a more complex conceptualization referred to as Latent Network Theory by Schweickert (1984, 1983). In this approach, it is assumed that processing stages may be both sequential and concurrent in nature. To demonstrate this, Schweickert used the procedure of critical path analysis, which permits the inference of a network of stages, given that the time taken to complete the task (such as the Stroop test (Schweickert 1983), or Sternberg's digit naming task (Schweickert 1984)) is known. In the critical path procedure, the important factor is to determine whether stages within a network can have their processing prolonged without affecting subsequent stages. This procedure is referred to as estimating the slack. Serial processes, such as the stages in Sternberg's model will result in slack equivalent to zero, i.e. prolonging one stage will naturally affect the next. However when particular values, positive or negative, are obtained for the coupled slack between two stages, it may be inferred that these stages are concurrent.

The research concerning stages has played an important role in the study of reaction time, and research concerned with the identification of processing stages has been described as a functionalist approach (Pieters 1983). One problem with this approach is that the occurrence of additivity does not necessarily identify the number of stages that exist. In contrast to Sternberg's three stages, some have suggested that as many as six stages (Sanders 1980), can be extracted from the data. Again the concept of a stage is difficult to define and may not be strongly implied by specific findings (Luce 1986; Pieters 1983).

In contrast to the functionalist approach, the present thesis adopts a more structuralist approach, in which the prime concern is to examine the distributional properties of RT, and to attempt to explain the details of the stochastic process underlying the latency mechanism (Pieters 1983). Such an approach aims to specify in some detail the entire process operating between the reception of a stimulus and the execution of a response, and to provide ways of estimating the values of the main parameters which determine the operation of this process.

1.2 RT theories and associated parameters.

1.2.1 Theories of RT.

Hick (1952) was responsible for a renewal of interest in RT studies, when he proposed the so-called Hick's law, which asserts that the rate of gain of information by the subject is constant, and that RT increases as a function of the amount of information, measured in bits, provided the stimulus. One implication of this law is that performance is governed by a tradeoff between speed and accuracy, with the speed of information processing given by the slope of the function relating RT to stimulus information. The speed-accuracy tradeoff is a ubiquitous and reliable phenomenon, which must be explained by any comprehensive model of RT (Vickers, Burt, Smith & Brown 1985a; Vickers, Smith, Burt & Brown 1985b).

Consistent with an information theory approach, Hick proposed that stimulus input is identified as being first judged to belong in one half of the possible stimuli, and then judged to belong in one half of the original half, etc., until the stimulus in question is located. A similar, serial dichotomization model has been outlined by Welford (1968, 1976). However, there have been a number of problems associated with the information theory approach, which have been discussed by Wickens (1984), Wilding (1982), and others. These include the fact that information theory fails to account for such factors as subset familiarity, stimulus discriminability, the repetition effect, stimulus-response compatibility, and practice effects. Of these, stimulus discriminability and stimulus-response compatibility have received the most attention, with the effect of practice on performance now receiving more attention (Ackermann & Schneider 1985).

To account for the effects of stimulus discriminability, a number of theories, termed `probabilistic models' by Wickens (1984), have been postulated, in which both RT and accuracy appear as the major dependent variables. While most of these models have been developed to account for the results of psychophysical judgements, some have been more concerned with intuitive statistical inference, and with Bayesian revision of opinion. Because of these differing perspectives, the models naturally lend themselves to a view of the decision process as determined by a number of both sensory and cognitive factors. In acknowledgment of this, some authors consistently refer to RT as "response time" rather than simply "reaction time" (e.g. Smith & Vickers 1988; Vickers 1979). Probabilistic models of response time have been particularly concerned with explaining the tradeoff between speed and accuracy, and with describing the relationship between discriminability and both accuracy and response time.

One of the main assumptions incorporated by most of models of discrimination (particularly those concerned with psychophysical judgment) is that, when a stimulus of variable magnitude (v) is compared with a stimulus of constant, or standard, magnitude (s), the two stimuli are represented in the central nervous system by two normal distributions of sensory effect, with the momentary differences between them (V-S) being also represented by a normal distribution. According to Thurstone (1927a,b), the distribution of sensory effect fluctuates from one judgement to the next, so that, over a series of trials, the momentary differences in sensory effect can be represented by a normal distribution with a mean $\overline{(V-S)} = (\bar{V}-S)$ and a standard deviation of $\sigma_{(V-S)} = \sqrt{2\sigma_V^2} = \sqrt{2\sigma_S^2}$. These assumptions were first utilized in the phi-gamma hypothesis (Corso, 1967), according to which the probability of making a judgment of the form "v is greater than s" is related to the physical difference between v and s by a sigmoid function which takes the form of a cumulative normal ogive. A more detailed model incorporating a number of these assumptions was later put forward, by Tanner & Swets (1954).

In theory of signal detection (TSD), as postulated by Tanner & Swets (1954), stimuli or signals are superimposed upon a background of neural noise, with both the neural noise and the stimulus being represented by normal distributions of sensory effect. The mean difference between these distributions yields a measure of d', which reflects the sensitivity of the observer, and may also be affected by the strength of the signals (Broadbent & Gregory 1963; Williges 1973). Within this model, Tanner & Swets (1954) also incorporated a criterion, or cutoff, which could be placed at any point along the dimension representing the magnitude of sensory effect. An estimate of bias (β) can be obtained by dividing the ordinate of the criterion on the signal distribution by the ordinate of the criterion on the noise distribution. The way in which a subject determines a criterion setting may be influenced by a number of factors, such as those listed by Davies & Parasuraman (1982). In particular, the criterion can be affected by the a priori probability of signals, and the cost of making a particular decision. In the TSD model, an improvement in accuracy is usually due to an adjustment of the criterion, resulting in a greater bias towards responding "signal". However, the TSD model fails to account for those instances where an unbiased improvement in the accuracy of both alternative responses is found as a result of taking more time over each decision (Gescheider, Wright & Evans 1968; Green & Luce 1973; Pike 1973; Pike, McFarland & Dalgleish 1974; Vickers & Packer 1982).

Ollman (1966) and Schouten & Bekker (1967) were among the first to examine the precise nature of the relationship between accuracy and response time. Wickelgren (1977) has discussed ways of manipulating the tradeoff, which include variations in the emphasis on speed or accuracy implied by instructions, and the use of explicit time bands and payoffs. A number of different forms of tradeoff have also been identified, including the micro-tradeoff and macro-tradeoff (Dosher 1979; Wood & Jennings 1976; Vickers et al. 1985a,b). The former is commonly defined as the speed-accuracy tradeoff function (SATF), obtained when accuracy is plotted against changes in the mean RT associated with variation in some independent variable, such as instructional emphasis on speed. The micro-tradeoff, or conditional accuracy function (CAF), on the other hand, is obtained by partitioning the distribution of RTs for a single condition, and plotting the proportion of correct responses against the midpoints of the quantiles of the RT distribution. Differences between the forms of the two functions appear to be linked to the nature of the experimental designs employed (Luce 1986; Swensson & Thomas 1974; Vickers et al. 1985a,b).

The speed-accuracy tradeoff implies that a subject's performance on discrimination tasks is open not only to the effects of bias in favour of one particular response, but also to variations in caution in responding (Vickers 1979). In order to account for the ability of subjects to increase accuracy through caution rather than bias, a number of models, described as "probabilistic" or "stochastic", have been proposed. The earliest of these were "fixed sample" models, such as that postulated by Thomson (1920) and Crossman (1955). Later, a number of so-called "optional stopping" models were developed (e.g. Ashby 1983; Cartwright & Festinger 1943; Heath 1984, 1981; La Berge 1962; Link 1975; Vickers 1970; Vickers Caudrey & Willson 1971).

In fixed sample models, the number of samples viewed, (or observations taken) is predetermined by the subject, depending on the difficulty of the task. For example, in Thomson's (1920) model, it is assumed that the stimulus difference can be represented by a distribution over successive instants within a single trial, so that a subject takes a number (n) of V-S differences in one trial, with n varying as a function the subject's tradeoff between speed and accuracy. A subject's decision is based on the proportion of positive stimulus differences, compared with the proportion of negative stimulus differences. Later, Crossman (1955) presented a similar type of model, in which the number of observations is also determined by the observer, and subjects adjust the size of the sample so as to ensure a fixed proportion of correct responses. The main problem with assuming that the value of n is selected so as to ensure a fixed number of correct responses, is that, when the difficulty of the discrimination is varied randomly from trial to trial, the number of errors has also been found to vary (Morgan & Alluisi 1967; Pickett 1967, 1968), indicating that subjects do not adjust sample size so as to maintain a fixed proportion of correct responses.

To meet this difficulty, Cartwright & Festinger (1943) proposed an optional stopping model, in which the subject is restrained from making a decision if the V-S stimulus difference does not exceed a certain critical value, represented by r_g or r_l, of the evidence for one response or the other. Longer response times are accounted for by assuming that the values for r_g and r_l are increased, reflecting a tendency toward accuracy. Conversely, when subjects follow instructions emphasising speed, the values for r_g and r_l are assumed to be reduced. In either case, the subject is thought of as continuing to sample observations until one or the other critical value is exceeded. Observations which fail to exceed either critical value are simply discarded, and are not remembered. However, a disadvantage of this particular model is that it predicts that the mean time for incorrect responses should be the same as that for correct, whereas most experiments, in which difficulty of discrimination has been varied, have found that errors generally take longer than correct responses (Vickers 1980).

As a consequence of these, and other experimental findings, a number of models have been developed, which assume that subjects accumulate information over time. These include the "runs" model (Audley 1960), the "random walk" or "sequential probability ratio test" (SPRT) (Edwards 1965; Laming 1968; Stone 1960), developed later into the relative judgment theory (RJT)(Link 1975; Link & Heath 1975) and the biased sequential probability ratio test (Ashby 1983). Two other main models which have been proposed include the "recruitment" model (La Berge 1962) and the "accumulator" model (Vickers 1979, 1985; Vickers Caudrey & Willson 1971). A number of variations of these models have been discussed by Luce (1986) and Townsend & Ashby (1983).

Most of these models assume that a subject bases his/her decision upon a series of observations of the momentary stimulus differences which are imposed on a background of neural noise, as assumed in TSD (Vickers 1979). The noise, which is thus a common parameter, may be the result of attentional lapses, other ongoing neural activity, or the after-effects of such activity (Cattell 1893; Welford 1968). Another common feature of these models is that they assume that the sampling of evidence is a discrete process, and that each observation takes an equal amount of time (Vickers & Smith 1986).

While there are a number of similarities between these models, there are also a number of points of difference. One main respect in which the models differ is in the proposed decision rule. For example, in Cartwright & Festinger's (1943) model, the stimulus difference must be greater than the hypothetical value r_g or r_l for a response to be executed. If the stimulus difference does not exceed either of these values, then the observation is classified as falling into a region of `no-decision' and another observation is taken. In the runs model, a critical number of successive observations equal to k_g or k_l is required for a decision (Audley 1960). In both instances, the speed-accuracy tradeoff is accounted for by assuming that the values for k_g and k_l can be increased or decreased.

In the accumulator model, the evidence which is accumulated represents both the sign and magnitude of a stimulus difference (V-S). If the difference is positive, it favours a response of the form (V<S), and is accumulated in one store t_l, whereas if the difference is negative, it favours the alternative response (V>S), and is accumulated in a separate store t_g. The model, as represented in Figure 1.1, proposes that the two stored totals are augmented until one or the other of the two response boundaries, or thresholds, is exceeded. The recruitment model is similar, except that only the sign of each stimulus difference is registered, and no account is taken of the magnitude of this difference.

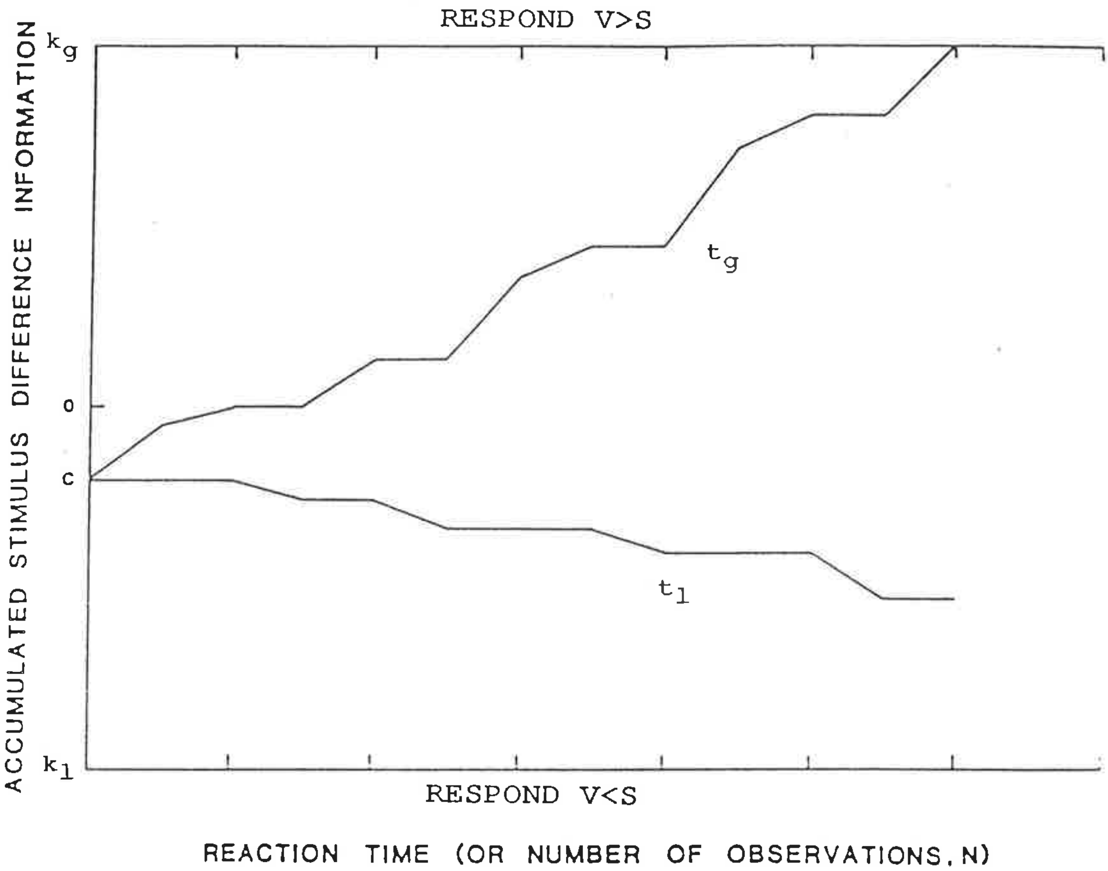

Figure 1.1 *An accumulator model of two-choice discrimination. With each inspection of the stimulus representation the positive stimulus differences are accumulated into one total (t_g) and the negative differences in the other (t_l). The response thresholds are located at the boundaries k_g and k_l. Accumulation begins at the starting point C, and a response is made when an accumulated total exceeds a response boundary. (from Vickers & Smith 1986).*

In contrast to these two models, random walk models assume that the evidence is accumulated in a single counter or total, which is increased or decreased with each observation. According to relative judgment theory (RJT) the total is incremented by a particular value, which depends upon a comparison between a standard referent and a randomly varying momentary value of the variable stimulus. The value of the referent is established by the previous sensory intensities which have been experienced (Link 1975). A transformation of stimulus intensity is also assumed in the SPRT model, except that, in this case, instead of a referent comparison process, the individual calculates the log likelihood ratio between the probability that the observation arose, given one response alternative, and the probability that it arose given the other (Ashby 1983). In both of these variations of the random walk, the walk is eventually absorbed by one or the other response barrier.

Response thresholds are thus major parameters in all optional stopping models. In addition, in the accumulator and random walk models, response bias is a further parameter, which is independent of the decision boundaries, and may be represented by shifts in the starting point (C) at which evidence is accumulated. In these models, it is assumed that, when the subject is biased toward a particular response, the starting point is shifted in the direction of the boundary associated with the favoured response (Vickers 1985).

While most models propose the existence of cognitively mediated parameters, a few have also incorporated sensory components. The theory of signal detection was perhaps one of the first to do so by distinguishing between the cognitive and sensory parameters β and d'. Later, La Berge (1962) proposed that, in addition to response thresholds, a sensory parameter similar to the region of no-decision envisaged by Cartwright & Festinger (1943) might operate. According to this account, V-S observations that do not exceed a particular value are classified as being neutral, and may be interpreted as noise components of the stimulus input. A process akin to this, incorporating an indifference region (IR) surrounding the sensory referent, has been recently postulated by Vickers and his associates (Smith & Vickers 1988; Vickers 1985; Vickers, Foreman, Smith & Gott 1986). The width of the IR is assumed to be determined by characteristics of the stimulus sequence. Unlike response thresholds, which are regarded as being determined by `top down' cognitive components, the IR is thus conceived as determined by a `bottom-up' process, and may even operate antagonistically against `top-down' components (Vickers 1985). Figure 1.2 depicts this system.

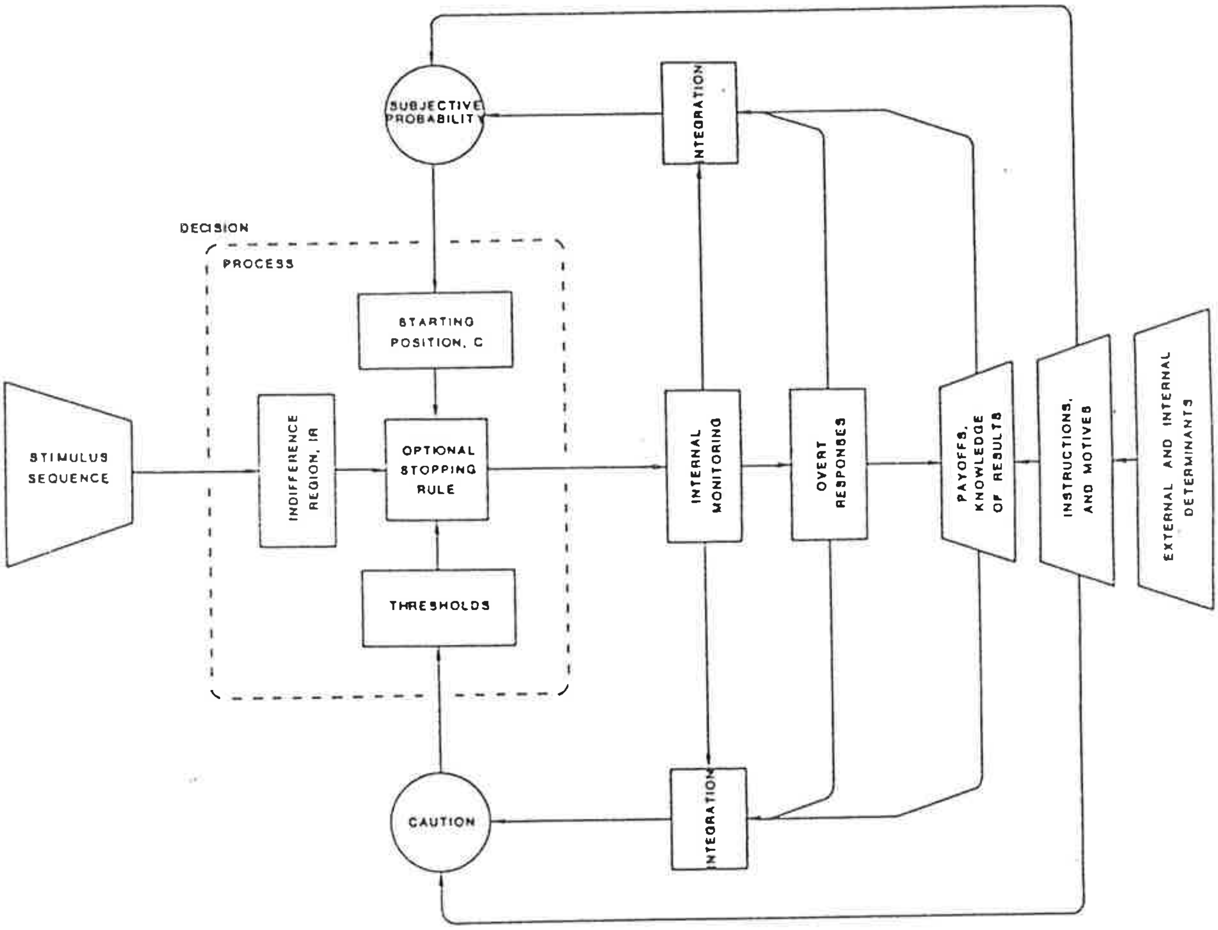

Figure 1.2 *Representation of the dynamic system in which decision process parameters such as sensory thresholds, and the starting point are regulated by expectancy and caution, which are in turn subject to top-down control of cognitive processes. For each pattern of top-down adjustment there corresponds an antagonistic pattern of bottom-up sensory adaptation in which the position, width or both, of the indifference region are altered by properties of the stimulus sequence. (From Vickers 1985).*

There are also, a number of models (eg. the diffusion process of Ratcliff (1978)), which assume continuous processing. In continuous processing it is assumed that the time between successive observations is made arbitrarily small. For example, in Ratcliff's (1978, 1985) diffusion model, the process of matching a probe stimulus with a target stimulus evolves continuously in time. Like random walk models, the accumulated evidence is eventually absorbed into one or the other response barrier.

Luce (1986) has outlined a number of considerations which argue in favour of continuous processing models. For example, continuous processing may help to explain non-constant boundaries and non-constant rates of accumulation. Continuous processing models may also be favoured, since it is difficult to find unambiguous evidence for synchronization in the nervous system. The main disadvantage of continuous processing models is that they tend to be associated with complicated and unwieldy ways of estimating processing parameters.

Recently, the distinction between discrete and continuous sampling has been discussed in connection with models emphasising the differentiation between processing stages (Miller 1988). In Miller's view, the dichotomy between discrete and continuous sampling may be exaggerated, and both forms of processing may operate in one model at different levels. Alternatively, processes may operate discretely in some situations and continuously in others.

1.2.2 Parameters of performance variation associated with RT theories.

While the above models differ in a number of respects, most of them postulate a number of common processes. These include sensory noise, discrete sampling, a memory mechanism accumulating information over successive observations, response thresholds, a parameter representing response bias, and some form of sensory referent or region of indifference.

(1) ***Noise.*** One of the earliest parameters of performance to be assumed is that of sensory noise (Cattell 1893; Jastrow 1888). Originally, sensory noise was used to explain the shape of the psychometric function obtained when response probability was plotted against the stimulus difference (V-S). The continuous, sigmoid curve was interpreted as showing that the all-or-none principle of a definite threshold was not supported (Corso 1967). The causes of noise have been assigned to lapses in attention, neural activity and after-effects of cerebral activity (Cattell 1893; Jastrow 1888; Welford 1968). In most theories of RT it is assumed that the noise may be represented by a normal distribution of sensory effect (Cartwright & Festinger 1943; Link 1975; Tanner & Swets 1954; Thurstone 1927a,b; Vickers 1979) upon which a signal is imposed.

(2) ***Sampling of Evidence.*** The assumption that the sampling of sensory input occurs in a discrete fashion has had a relatively long history (Fraisse 1978; Kahneman 1967; Kristofferson 1967; Stroud 1955), especially in relation to temporal framing or perceptual intermittency. Evidence for discrete sampling has also come from other experimental paradigms, which have not used RT as a main variable, such as masking procedures (Kahneman 1968; Nettelbeck & Lally 1976; Turvey 1977, 1973; Vickers Nettelbeck & Willson 1972), and studies of critical flicker frequency (CFF), simultaneity (Allport 1968; Di Lollo & Wilson 1978; Kristofferson 1967), and apparent motion (Kahneman 1967; Muijen 1969). The rate of sampling sensory evidence in these paradigms has been regarded as being individually determined in accordance with some other variable, such as intelligence (Barrat, Clark & Lipton 1962; Hulme & Turnbull 1983; Lally & Nettelbeck 1977; Pollack 1966b,c; Pollack, Ptashne & Carter 1969; Saccuzzo, Larson & Rimland 1986), or some form of a biologically determined rhythmical process (Kristofferson 1967; Sanford 1971).

Probabilistic models of discrimination and RT also assume that observations are taken as a series of discrete samples of the varying magnitude of the stimulus difference (Smith & Vickers 1988). Furthermore, these observations are assumed to be taken at a steady rate, with each observation taking an equal amount of time (Smith & Vickers 1988; Vickers & Smith 1986). The discrete sampling assumption has been preferred because it has provided mathematically simpler ways of estimating other model parameters. At this stage, only a small amount of research has been conducted which connects continuous models to response time data (Luce 1986).

(3) *The decision rule.* The decision rule in both fixed sample models and optional-stopping models specifies the conditions under which the accumulation of evidence terminates. The decision rule is usually assumed to remain fixed, so that in any one experimental situation only one kind of rule is employed. Furthermore, in situations where the stimuli are presented at a high rate, it is usually assumed that subjects will automatically apply the decision rule in question. However, in instances where the subject performs a deferred decision or expanded judgement task, the information is presented over a longer time and the process may be more open to individual variations in the decision rule.

(4) *Sensory criteria and response thresholds.* Evidence, accumulated by the decision mechanism is eventually absorbed at a barrier or response threshold, and, at this point, a decision is made concerning the stimulus. In a two-choice discrimination task, it is assumed that there are two response thresholds, and their values may not necessarily be equal. The values are affected by the emphasis on speed or accuracy. An emphasis on speed reduces the values, thereby limiting the amount of information accrued in the decision mechanism, while an emphasis on accuracy increases the values of the response thresholds. As these parameters can be directly manipulated by instructions, they are assumed to be cognitively controlled.

In contrast, sensory criteria, cutoffs, or referents appear to vary in accordance with the previously experienced stimuli (Gibson 1933; Helson 1964; Warren 1985). The distinction between sensory and cognitive components is important in some probabilistic models of choice RT. For example Vickers (1985) has suggested that evidence falling within an indifference region (IR) surrounding the sensory referent is not accumulated, and that only "substantial" observations falling outside its boundaries contribute to the eventual response.

1.3 RT and individual differences.

As mentioned above, the earliest interest in RT was that of Bessel, who was concerned with determining the error in astronomers' records of stellar transit times, and with the formulation of a so-called "personal equation", whereby one individual's estimates could be compared directly against those of another. The next main impetus for the study of individual differences in RT came from Galton (1822-1911), who argued that RT should show individual variations in accordance with each individual's mental ability. Galton employed a simple RT paradigm, with an auditory stimulus. However, results from a very large number of experiments were relatively disappointing. In 1894, Gilbert reported a significant association between both simple and choice RT and intelligence, as measured by childrens' abilities, i.e. being classified as "bright", "average" or "dull" by their teachers. Although findings contrary to this were reported by Wissler (1901), Jensen (1982b) has noted that Wissler's study was particularly poor methodologically, as the measure of average RT for each individual was based on only 3 to 5 trials. Intelligence tests were first used by Peak & Boring (1926), who reported a highly significant correlation between simple RT and IQ, though once again a very small sample size (of only 5) was used. In a later study, Lemmon (1927) reported that choice RT was more highly correlated with IQ than was simple RT, a result which in some respects foreshadowed future findings.

After the early interest in individual differences, there was a sudden decline, which may be attributed to a number of developments. According to Eysenck (1984), the research linking individual differences, especially intelligence, with RT was affected firstly by a devaluation of the experimental approach toward psychology, in favour of a psychodynamic approach, such as that put forward by Freud. Secondly, individual difference constructs, such as intelligence, were assumed by certain researchers, such as Binet, to be determined by social, environmental and educational factors. Thirdly, individual differences tended to be viewed as a nuisance factor, which only complicated an experiment, and variance in the indices measured was attributed simply to internal noise. Meanwhile, the study of RT itself was affected from a different direction. In the absence of a comprehensive theoretical account of the data, and in reaction against the Wundtian tradition, the study of RT was neglected in favour of movements inspired by Behaviourism, on the one hand, and Gestalt psychology on the other.

A major change occurred in 1952, when Hick proposed a law relating RT to the number of bits of information processed by a subject in a choice RT experiment. This work provided an encouraging example of the application of information theory, and yielded a measure of the slope of the plot of RT against bits of information, which, it was thought, might vary with intelligence. The choice RT paradigm has been used extensively in recent studies, particularly by Jensen (1982a,b), and experiments have examined a number of relationships between different parameters obtained from choice RT and intelligence. Firstly, there is often a negative correlation between IQ and choice RT, indicating that subjects with higher values for IQ have shorter RTs. For example, Jensen & Munro (1979) report a correlation of $r=-.39$ ($p<.05$) between choice RT and IQ (Raven's Standard Progressive Matrices), and other studies and reviews have also reported significant negative correlations (Carlson & Jensen 1982; Eysenck 1987; Jensen 1982a,b; Jensen & Vernon 1986; Vernon & Jensen 1984). Secondly, not only does IQ correlate with values of mean and median choice RT, it has also been found to correlate with the variability in choice RT. For example, Carlson & Jensen (1982) have reported a correlation of $r=-.71$ ($p<.01$) between variability in choice RT and IQ (Raven's Standard Progressive Matrices), suggesting that intraindividual variability is more pronounced in those with lower IQ's. Thirdly, the movement time, or time it takes for the subject to move his/her finger from the home key to a response button has also been found by Jensen & Munro (1979) to vary inversely with IQ ($r=-.43$, $p<.01$). However, this finding was not replicated by Carlson & Jensen (1982).

Hick's law has also been examined with regard to individual differences in intelligence. Typically, it has been found that the strength of the relationship between choice RT and IQ, with information load held constant, increases for information loads up to 2.58 bits, and thereafter declines (Carlson & Jensen 1982; Jensen & Munro 1979). A linear relationship between choice RT and the amount of information processed (measured in bits) has been found in most normal populations with different levels of intelligence. Choice RT increases as more bits of information are processed. However, when severely retarded subjects were tested, estimates for choice RT were found to be longer, and remained constant across conditions where 1, 2 and 3 bits of information were processed (Jensen 1982b; Jensen, Schafer & Crinella 1981). Studies of the correlation between estimates of the slope of the function relating choice RT to the amount of information processed with intelligence have provided mixed results. For example, Smith & Stanley (1983) report a correlation of r=-.28 (p<.05) between the slope and IQ, or `g', obtained from a factor analysis of the following IQ tests: Cattell's Culture Fair test, Progressive Achievement tests of Reading, Comprehension, and Vocabulary, and lastly the subtests, Picture Completion, Block Design, and Mazes from the WISC-R. Vernon (1981), on the other hand reported an insignificant correlation of r=.09 between the slope and IQ, as measured by Raven's Progressive Matrices.

While many studies have been concerned with the relationship between RT and measures of intelligence, or mental ability, a second group of studies has been more concerned with the relationship between individual differences in RT and indices of personality, or temperament, and, in particular with measures of sociability, impulsiveness, emotionality and stability. Attempts to distinguish between subjects in similar terms have been made since the time of Hippocrates, who proposed that there were four basic personality types. A similar idea was put forward by Kant in 1789, and later by Wundt, who classified individuals into emotional/nonemotional and changeable/unchangeable types. Later, Jung (1923) proposed that personality was characterized by two dimensions, which he referred to as neurosis (stable/unstable), and extraversion (introversion/extraversion). Eysenck (1957) further proposed that each of these dimensions was tied to the physiological, neurological and biochemical structure of the individual. One of the early experimental studies concerned with RT and personality was conducted by Angell (1907). In his study subjects had to discriminate whether sounds elicited by a sound pendulum were either "louder", "softer" or "like" a standard sound. He noted that one of his four subjects, appeared to be quite deliberative by nature, and tended to discriminate more accurately when the differences between the range of the varying sounds and the standard sound was small than when the range in the varying sounds was large. This subject was also more cautious and took longer to express his judgment. In contrast, a more impulsive subject made less accurate judgments when the range between the varying and standard sound was small than when it was large. A more recent study, which reported an association between RT and personality type, was carried out by Nebylitsyn (1960; cited in Brebner 1980). He demonstrated that, when weak visual and auditory stimuli were presented to certain subjects conforming to a "strong nervous system" type, a longer simple RT was recorded. The difference disappeared, however, when the intensity of the stimulus increased.

Recent research into possible relationships between personality and RT has employed a variety of experimental paradigms. In particular, the relationship between choice RT and personality variables, such as those measured by the Eysenckian dimensions P, E, and N, has also received attention. For example, after obtaining measures of movement time and RT in a one-, three- and five-choice paradigm, Larson & Saccuzzo (1986) reported a number of correlations. For example, a significant correlation of -.18 ($p<.05$) between extraversion (EPQ) and simple RT, was found, as well as a correlation of -.18 ($p<.05$) between extraversion and five-choice RT. A correlation between movement time and neuroticism ($r=.22$, $p<.05$) was found in the simple RT condition of Larson & Sacuzzo's (1986) experiment. Barrett, Eysenck & Lucking (1986) also employed Hick's paradigm. However, in this instance, RT did not relate to any of the Eysenckian personality dimensions, nor to impulsiveness or venturesomeness. On the other hand, variability in RT, in the various choice conditions, showed some association with psychoticism and venturesomeness.

Other RT paradigms, including a 2-choice RT paradigm with multiple observations, have shown that impulsiveness, as measured by the Karolinska Scales of Personality (Schalling 1978), was related to RT. A correlation of $r=-.41$ ($p<.01$) was obtained, with impulsive subjects responding faster (Edman, Schalling & Levander 1983). However, in a second session, this trend was not observable. In a simple RT paradigm, impulsiveness, as inferred from Eysenck's P dimension, was also found to vary inversely with RT (Thompson 1985). Shorter RTs were found in high P (PEN) scorers, particularly when the warning signal was omitted.

Besides impulsiveness and psychoticism, extraversion has been reported as varying with simple RT (Brebner & Cooper 1974, 1978; Brebner & Flavel 1978). In Brebner's research, the theoretical assumption is that introverts are "geared to inspect", thereby preferring stimulus analysis, whereas extraverts are "geared to respond", thereby preferring response organization. It is assumed that, given the same level of stimulation, introverts will tend to generate a higher degree of stimulus excitation in comparison to extraverts, who will, in contrast, experience inhibition. Extraverts, will have a tendency to produce greater response excitation than introverts.

By employing specific RT paradigms, Brebner and his associates have tested both the stimulus analysis and response organization hypotheses. In an experiment conducted by Brebner & Cooper (1974), it was found that, with a larger number of trials (i.e., 180 trials against 100), subjects classified as extraverted on the Maudsley Personality Inventory showed longer RTs to the presence of a signal. The authors have argued that longer RTs indicated stimulus inhibition. The second hypothesis, that extraverts will produce more response excitation, was examined by Brebner & Flavel (1978), using a simple RT paradigm. However, on certain (catch) trials the warning light was presented, but the stimulus was omitted. The number of catch trials varied from 10% in one condition to 40% in the second condition, and 70% in the third. The three conditions were presented randomly to minimize order effects. In addition, an initial task, with no catch trials, was presented. Extraverts and introverts did not differ in their RTs in the initial task. However there was a difference in RT according to the number of catch trials that were presented, with extraverts showing progressively longer RTs as the number of catch trials increased.

1.4 Theories of intelligence and personality.

Theories of intelligence developed within an information processing framework have been concerned with the mechanisms underlying intellectual abilities, and with the rate at which these mechanisms process information (Brand & Deary 1982; Eysenck 1987; Jensen 1982a,b) In contrast, the main theories concerned with the Eysenckian dimensions of personality have been more concerned with the elucidation of arousal, and with the ability of the organism to maintain levels of arousal.

1.4.1 Theories of intelligence.

A recent influential approach to the study of intelligence and its relationship to the processing of information has been that of Jensen (1982b), who conceives the brain as a single channel, or limited capacity information processing system, which can deal simultaneously with only a relatively small amount of information. Jensen argues that the limited capacity reduces the number of operations that can be performed simultaneously on both the information that enters the system and also on the information that is retrieved from short or long term memory. In addition, Jensen (1982b) argues that there is a rapid decay of stimulus traces, and this necessitates rehearsal of the information whilst it is in STM before it progresses into long term memory. Consequently, there is a distinct advantage in being able to complete these operations quickly. According to Jensen, therefore, individual differences in RT performance are determined by central rather than peripheral processes, and these are affected in two ways. Firstly, performance is determined by the number of neural elements activated by a stimulus, and consequently by the signal/noise ratio. Secondly, performance is determined by the rate of oscillation in the excitatory-refractory phases of the activated elements.

Other theorists have also argued that the intelligence is largely a speed-of-processing factor. For example, Brand & Deary (1982) have argued that the initial speed of apprehension during the early stages of perception determines the development of general intelligence. In this theory a person with a high IQ may apprehend or encode information more quickly, but it does not necessarily follow that they will respond quickly. The speed of input at the beginning of stimulus encoding is influenced by intelligence. However, the speed of subsequent processes is believed to be influenced by personality variables. Brand & Deary (1982) measure processing speed by means of an "inspection time" task, which is not so much concerned with RT as with the minimum time for which the stimulus must be displayed in order to ensure accurate two-choice discrimination.

Physiological explanations, which also propose that intelligence reflects speed of processing and efficiency in information transmission, have been put forward by the Hendricksons (Hendrickson 1982; Hendrickson & Hendrickson 1980), and also by Eysenck and associates (Eysenck & Eysenck 1985; Eysenck 1987; Eysenck & Barrett 1985). The Hendricksons' approach is concerned with developing a neurological model of information processing which takes into account the chemical properties of the synapse and of neural transmission. At the synaptic level, recognition of the passing of information is effected by a particular species of RNA, which has been labelled eRNA, or engram RNA. Learning is seen, at this microscopic level, as being the formation of eRNA sequences that match stimulus input pulse patterns when they re-occur. Transmission from one neuron to another through the synapse is instigated by a pulse train which may contain errors. Performance in this model is determined by recognition (R) of the pulse chain. Eysenck & Eysenck (1985) have also argued that R is important. However, these authors argue that individual differences are not the result of the speed at which messages are relayed through the CNS. Rather, there are differences in the speed of the reaction to stimuli, and these relate to the number of errors which occur in the transmission. If there are a number of errors in transmission, then it becomes necessary to send a greater number of messages, which in turn delays the speed of the reaction. While there is still a large amount of interest in RT, a large amount of effort has been devoted to examining the pulse train through physiological measures such as the average evoked potential (AEP).

1.4.2 Theories of personality.

Attempts to relate personality to individual differences in perceptual and cognitive performance have concentrated on the dimensions of, extraversion (E), neuroticism (N) and psychoticism (P). While all three dimensions were distinguished early (Eysenck 1957), it has been E and N which have received the most theoretical attention (Eysenck 1967; Eysenck & Eysenck 1969), with the P scale being discussed at length only later (Eysenck & Eysenck 1976, 1975). To date, the importance of the P dimension in the theory remains undetermined (Eysenck & Eysenck 1985), with most of the research being carried out by Claridge (1983, 1981).

Eysenck has postulated two theories concerning the E and N dimensions. The first is commonly called the inhibition theory (Eysenck 1957), and the second, and more favoured, the arousal theory (Eysenck 1967). According to the inhibition theory, extraverts can be distinguised from introverts with respect to inhibition and excitation in ways consistent with the notions developed by Pavlov and Hull. In this view, extraverted individuals develop weak excitatory potentials slowly, and are pre-disposed to hysterical-psychopathic disorders. Introverts, on the other hand, generate strong excitatory potentials quickly, and also tend to develop dysthymic disorders in the case of neurotic breakdown. This theory has been tested by studying susceptibility to various perceptual phenomena linked with inhibition, such as the spiral after-effect (Knowles & Krasner 1965; Lynn 1960), and by administering drugs intended to increase and decrease the level of cortical excitation (Eysenck & Holland & Trouton 1957; Franks & Trouton 1957).

The arousal theory is an extension of the inhibition theory, in which more weight is assigned to arousal, rather than to the balance between excitation and inhibition. A synthesis of the two models has been proposed by Brebner (1980), in which excitatory and inhibitory factors play a part in both stimulus analysis and response organization. In the development of Eysenck's (1967) arousal theory there is little emphasis on the use of drug studies to demonstrate differences, but there is a greater degree of emphasis on the physiological structures associated with variations in E and N. Specifically, it is argued that E and N are two separate personality dimensions, with the former associated with the ascending reticular activating system (ARAS), and the latter with the visceral brain (VB)(Eysenck 1967; Eysenck & Eysenck 1985). It is hypothesized that the activity of the main structure, the ARAS, determines the level of cortical arousal, with introverts being more cortically aroused than extraverts. The VB, on the other hand is suggested as being responsible for the autonomic activation of the individual. In certain instances cortical arousal can be produced by increased levels of activity in the VB. A number of findings have given some support for the contention that E is associated with cortical arousal. Firstly, extraverts have been found to be less cortically aroused (Gale 1981). Secondly, introverts have been found to have greater levels of sensitivity and higher values of the response criterion calculated from TSD analysis (Harkins & Geen 1975; cf Geen, McCown & Broyles 1985).

In both theories it is hypothesized that the E and N dimensions are orthogonal, thus allowing four combinations of the extremes. Gray (1970, 1981) has argued that, in order to bring the theory into line with work in physiology and animal learning, E and N be rotated 45 degrees to allow for two new dimensions i.e. anxiety and impulsivity. Making this theoretical adjustment is arguably preferable to the Brebner-Cooper model (1978, 1974), as the latter model has aspects which are untestable due to the interplay between the two factors operating in both stimulus analysis and response organization.

The third dimension, psychoticism, deserves separate attention. Whilst the dimension has been included in the arousal model, its measurement and interpretation have been problematic, as individuals who have been diagnosed as clinically psychotic often cannot be distinguished from normal individuals

(Bishop 1977; Block 1977a,b), although the scale was designed for use with normal populations (Eysenck & Eysenck 1977). Despite these difficulties, it has been argued that P is best interpreted in terms of arousal, and a number of experiments concerned with arousal and visual sensitivity, as measured by the Two Flash Fusion threshold, have been carried out. For example, it has been found that psychotics (drawn from normal and psychiatric populations) tend to have greater sensitivity at extremely low and high levels of arousal, in contrast to low P scoring non-psychotic patients and normal subjects (Claridge 1972; Claridge & Chappa 1973; Claridge & Birchall 1978; Claridge & Clark 1982; Robinson & Zahn 1985, 1979). Claridge (1983, 1981) has argued that the different pattern of results for psychotics is due to CNS dissociation, or to a "weakening of homeostatic controls in the nervous system" (Claridge, Robinson & Birchall 1985), with a consequent uncoupling of the physiological mechanisms responsible for maintaining integrated CNS functions. Two aspects of CNS function are seen as being involved in this process. The first is emotional arousal, and the second is a mechanism concerned with the regulation of sensory input, including variations in attention and in perceptual sensitivity.

The question of the relation between the Eysenckian dimensions and arousal poses a number of difficulties. Traditionally, arousal has been conceived of as a unidimensional construct (Easterbrook 1959; Yerkes & Dodson 1908), and variations in arousal have been supposed to affect attention (Kahneman 1973), and the amount of processing resources available to complete a number of simultaneous tasks (Bacon 1974; Bahrick 1954; Bell 1978; Hartley 1981). However, this unidimensional construct has been questioned by Broadbent (1971), and by M. Eysenck (1982), who both propose a dual mechanism on the basis of experimental evidence indicating interactions between extraversion and other variables, such as time of day, sleeplessness, etc., in determining performance. Both writers propose a dual mechanism, in which the first mechanism is a passive system, governed by the arousal induced by the task. The second mechanism is an active system, which monitors the operation of the first, and acts as a compensatory system when arousal levels are low (Broadbent 1971; M. Eysenck 1982). It is thought that the activity of the first mechanism is increased by noise and amphetamine, and is decreased by sleeplessness and chlorpromazine, whereas the activity of the second mechanism is enhanced by short tasks, is linked to introversion, and is usually greater in the afternoon. Its effectiveness is decreased by long tasks, extraversion, alcohol, and morning performance. This conceptualization succeeds in relating a number of experimental effects (Blake 1967a,b; Colquhoun 1960; Colquhoun & Corcoran 1964; Eysenck & Folkard 1980; Kjellberg 1977; Larsen 1985), and has led towards the study of a number of variables associated with the relationship between performance and individual levels of arousal.

A second theoretical development in the relationship between personality differences and perceptual and cognitive performance has stemmed from the research of Pavlov concerned with the strength of the nervous system, its balance and mobility (Gray 1964a,b; Nebylitsyn 1964; Teplov 1964). A number of experimental and physiological associations between the school of Eysenck and that of the Soviets have been noted (Frigon 1976; Gray 1967; Robinson 1982). The similarities have been further emphasised by the behavioural approach of Strelau (1983), who has developed the Strelau Temperament Inventory, and shown that this inventory can differentiate performance on certain tasks. More recently, the inventory has also been compared to the dimensions distinguished by Eysenck and a number of correspondences have been found (Larsen & Baggs 1986; Richards 1986; Strelau 1983).

1.5 Difficulties in relating theories of RT to Individual Differences.

While the field of individual differences in RT performance has enjoyed a long, though chequered, history in psychology, the last decade has seen a marked resurgence of interest in this topic. However, this renewed interest has brought to light a number of problems in linking the two areas of research.

One problem is that, while the theoretical approaches in the domain of individual differences tend to favour a physiological approach, with the consequence that RT has often been interpreted as primarily a sensorially determined measure, involving few cognitive components, theories which have been devised to explain performance in discrimination and RT paradigms have concentrated on explaining behaviour in terms of a series of hypothetical mechanisms or stages. These mechanisms, which have received more detailed treatment earlier in this chapter, make assumptions, such as that of normally distributed, internal noise (Cartwright & Festinger 1943; Tanner & Swets 1954; Vickers 1979), and postulate other parameters, such as sensory criteria and response thresholds (Green & Swets 1966; Laming 1979; Vickers 1979). These hypothesized parameters are designed to account for observed variations in performance either when stimuli are manipulated in various ways, such as by varying the magnitude, timing or probability of occurrence of a stimulus, or when the subject's attitude, bias, or set is manipulated by costs and rewards, or by instructions emphasising speed or accuracy (Ashby 1983; Laming 1979; Tanner & Swets 1954; Vickers 1979, 1985). The precise operation of these mechanisms varies from one model to another, and there are differences in the particular parameters assumed by different models. For example, in TSD, variations in the number of correctly detected signals may be interpreted as being due to the adjustment of a sensory cutoff in such a way that more (or fewer), signals are reported, but only at the expense of increasing (or decreasing) the likelihood of making a false alarm (Green & Swets 1966). In probabilistic models, changes in response bias are explained as being due to shifts in the starting point for accumulation, with variations in the overall readiness to respond being interpreted as changes in a separate parameter designated as "caution" (Vickers 1985).

In contrast to the approach generally adopted by RT theorists, many theorists primarily concerned with individual differences have adopted a more physiological approach. This emphasis had led to a number of experiments in which there is little attempt to systematically manipulate the particular variables of interest, such as the average evoked potential (AEP) (Eysenck & Barrett 1985), although, in some instances, some global form of manipulation through the administration of drugs has been used to induce or mimic some behavioural response characteristic of a particular personality type (Eysenck & Eysenck 1985). However, in order to avoid the interpretative complications associated with these methods, most studies, to date, have concentrated on simply examining whether different patterns in electroencephalographic recordings can be observed in different personality types, or associated with different levels of intelligence (Eysenck 1987; Eysenck & Barrett 1985; Gale 1981, 1983; Hendrickson 1982).

In these studies it is usually argued that RT is a measure of physiological difference with regard to both temperament/personality (Brebner 1980; Strelau 1974) and intellectual ability (Jensen 1982a,b). A second assumption, which is often made, is that RT is subject to minimal influence by cognitive components, or "top-down" processes (Longstreth 1984). As a result, it is further assumed that RT paradigms will provide indices of human performance which are `culture fair'.

For example, it has been claimed by Jensen & Vernon (1986) that there tends to be no negative correlation between accuracy and RT, or between accuracy and MT, and that fast RTs are often accompanied by greater accuracy. In contrast to this view, the probabilistic models of RT, outlined above, have assumed that a number of cognitively controlled parameters may be associated with variations in speed-accuracy tradeoffs, such as response thresholds and starting points (Ashby 1983, Laming 1979; Link 1975; Vickers 1979, 1985). Cognitive manipulation of these parameters is possible through varying instructions, differential payoffs, or knowledge of a priori stimulus probabilities. From the viewpoint of these models, it is usually assumed that a speed-accuracy tradeoff involves the "top down" adjustment of response thresholds or starting points, and evidence for this can be obtained by examining correlations between RT and accuracy (Vickers et al. 1985a,b).

Choice RT experiments conforming to the Hick paradigm have also been shown to be influenced by a number of cognitive strategies. One of these strategies concerns the separation of RT from MT through the use of the home key in tasks of the kind conducted by Jensen (1982b). In performing such tasks, it has been argued that a particular subject may adopt a strategy whereby she/he will begin to respond quickly, but leave part of the decision until later, thereby increasing the time spent in movement. "Movement time" then does not merely represent the time required for movement only, but includes time devoted to the decision process (Nettelbeck & Kirby 1983; Smith & Carew 1987; Welford 1986). Another strategy, which may occur in the choice RT paradigm, has been identified by Longstreth (1984) as a transference of knowledge from one choice condition to the next. For example, in the choice RT experimental paradigm, the different set size may be confounded with practice effects, due to the fact that set size is varied in a particular order, starting with a two-choice situation, and extending systematically to an eight-choice discrimination. By adopting this procedure, Longstreth (1984) has argued that a transference of practice or knowledge about the task occurs from one set to the next, thereby lessening the difficulty of subsequent sets.

A further problem arises because these factors may themselves be related to individual differences. To date some limited evidence in support of this notion has been presented by Larson & Saccuzzo (1986), who report that observable performance differences in a speed-accuracy tradeoff situation are related to the Eysenckian dimensions of personality.

One way of clarifying the nature of the association between individual differences and performance in RT tasks may be to employ an experimental task for which a plausible theory acknowledges both "top down" and "bottom up" components. In addition, it would be useful if the factors, known to influence performance in such a task, such as sensory noise and response thresholds, could be controlled and/or estimated, thereby limiting the number of unknown parameters. The existence of these parameters can provide difficulties when interpreting reaction time indices. Another approach lies in developing techniques which permit the estimation of the various parameters. Such techniques, based on the random walk and accumulator model have been developed by Heath (1984), and also Smith & Vickers (1988). In both approaches the interpretations of these parameters are evaluated in terms of their ability to account for reaction time orderings and their relation to overall response probabilities.

One particular experimental paradigm, which enables the control of various parameters, is the expanded judgment task (EJT). The EJT was originally pioneered by Irwin, Smith & Mayfield (1956), who presented subjects with a series of cards printed with numbers. The numbers were drawn from one of two normal distributions, with one having a mean above zero and the other having a mean below zero. The cards were drawn randomly, and presented one at a time to subjects, who had to decide whether the mean of the numbers viewed was positive or negative. Consequently, subjects had to perform some mental calculation based on the information integrated over time. A recent analogue of this experiment, described by Vickers et al. (1985a,b), involves the presentation of a series of line segments, falling to the left or right of a midline, at the rate of approximately 3 per second. The line segments are drawn from two normal distributions, with one having a positive mean value and the other a negative mean value, and a common variance. The subject's task is to determine whether the average of the number used to generate the line segments presented is positive or negative.

The EJT has been employed in association with two main experimental paradigms. In the first, the experimenter controls the number of observations that are to be sampled by the subject. This is referred to as the Experimenter-controlled paradigm (E-paradigm). In the second, referred to as the Subject-controlled paradigm (S-paradigm), the subject is free to sample as much information as he or she wishes.

The EJT allows a number of problems associated with RT research to be addressed. Firstly, the objective specification of the stimulus information permits some estimation of the amount of noise associated with the stimuli (Vickers, Caudrey & Willson 1971). Instead of a signal being imposed solely against a background of neural noise, stimuli in the EJT are generated in a controlled manner, with the objective variance being so high so that differences in the internal level of neural noise are minimized. Secondly, by assuming that each overt observation corresponds to one covert observation, the number of sampled observations may be estimated. In the case of the E-paradigm, the effect of presenting a limited number of observations is thus to control the response threshold (i.e. to fix the value of k). As a result, one of the main, cognitively influenced sources of variation, the speed-accuracy tradeoff, can be controlled, since each subject can be assumed to sample the same number of observations. In contrast, the S-paradigm, which employs a full optional-stopping procedure, allows each subject to determine his or her own response threshold. By comparing performance in the two paradigms, effects of differences in set for speed or accuracy on performance can be examined.

In the E-paradigm it is extremely difficult for a subject to adopt particular cognitive strategies which facilitate discrimination, as each trial is generated randomly, with the a priori probability of a trial being either left (negative) or right (positive) usually set at .5, and each line segment within each trial also generated randomly. Complete details are stored about the sequence of stimulus values presented on each trial, so that it is possible subsequently to relate this information to the responses made by the subject. Such an analysis may permit, for example, the estimation of other parameters, such as the Indifference Region (IR).

As mentioned previously, the EJT has been used in experiments concerned with sequential presentation of probabilistic information (Edwards 1965; Erlick 1961; Sanders & Ter Linden 1967). Such tasks are commonly referred to as deferred decision tasks (Busemeyer 1982; Busemeyer & Rapoport

1988), and research in this area has been encouraged by the fact that the study of such deferred decisions has a wide number of practical applications.

The sequential integration of information in a deferred decision has been explored within the framework of Bayes' theorem, which provides an optimal model of hypothesis revision (Edwards 1965; Edwards, Lindman & Savage 1963). This theorem states that the posterior odds in favour of one hypothesis, after the acquisition of a piece of information, should equal the prior odds multiplied by the likelihood ratio. The likelihood ratio is the probability of observing a particular observation given that one hypothesis is true $P(D/H_1)$, divided by the probability of observing the same observation, given that the alternative hypothesis is true $P(D/H_2)$. Thus posterior odds are given by the equation:

$$\frac{P(H_1/D)}{P(H_2/D)} = \frac{P(H_1)}{P(H_2)} \times \frac{P(D/H_1)}{P(D/H_2)}$$

where $P(H_1/D)$ is the posterior odds in favour of hypothesis one after the acquisition of a piece of information; $P(H_2/D)$ is the posterior odds in favour of hypothesis two after a piece of information; $P(H_1)$ is the prior odds of hypothesis one, and $P(H_2)$ is the prior odds of hypothesis two. Although the equation represents optimum performance, Edwards (1968) noted that subjects tend to be conservative in decision making, fail to utilize all of the information presented, and opt for conservative probabilistic revision. Important in the demonstration of this point is the role of confidence in human judgment, which has been studied in a wide number of contexts (Busemeyer 1982; Vickers et al. 1985b). Conservative judgments, or judgments which fail to utilize all of the available information, mean that subjects often appear to be less confident than they could be (Wickens 1984).

As suggested earlier, another important factor has been the way in which information has been presented. In particular, certain experiments by Erlick (1961) and by Sanders & Ter Linden (1967) have suggested that the actual sequence of events viewed influences the judgment about which of two alternative stimuli is the more frequent. Even if the frequencies of two events are the same, the event which has the higher degree of clustering is perceived as having the higher frequency of occurrence. A further finding is that increasing the rate of presentation results in a decrease in the ability to assimilate information (Sanders & Ter Linden 1967).

As the EJT is an experimental task which can be examined from the perspectives of both RT theories and Decision theory, it offers an interesting way of examining the phenomena of reaction and decision. The individual differences approach to RT, has tended to concentrate on sensorially determined differences, such as extraversion, or neural processes, such as speed of information transmission. In these cases, the experimental task is believed to involve the automatic application of a decision rule. However, in cases where the information is presented over a more protracted period of time, as in a deferred decision task, it is arguable that the decision process itself is subject to variation from one individual to another in accordance with cognitive or personality differences in processing information.

Although, it has been recognized that individual differences account for variation in both psychophysical and decision making experiments, there has been little research, employing EJT tasks, which has been interpreted in the same terms as the traditional RT paradigm, and linked to theories of individual differences. An RT paradigm, in which subjects had to view a number of stimuli, in the form of flashing lights within one trial in order to make a response was conducted by Edman, Schalling & Levander (1983). In this experiment, the personality variables of impulsivity and psychoticism appeared to vary with response time and also with the number of correct responses. However, the measurement of these parameters of individual difference is not evident in research concerned with Behavioural Decision theory, where individual differences are more usually assumed to be reflected in such personality concepts as dogmatism and inability to tolerate ambiguity (Brightman & Urban 1974; Wright 1985; Wright & Phillips 1979). In these experiments, the important factor is the subject's estimate of the probability of occurrence of events, rather than his/her response time, even though speed of decision making and amount of information sampled have been recognized as important elements in cognitive style (Driver & Mock 1975).

CHAPTER TWO.
THE EXPANDED JUDGMENT TASK: RELIABILITY AND INDIVIDUAL DIFFERENCES IN PERFORMANCE.

A. EXPERIMENT 1. Individual differences and the effects of varying discriminability and stimulus scaling in an expanded judgment task conforming to the S-paradigm.

In order for results from the expanded judgment task (EJT) to be interpretable in the same terms as those from more conventional reaction time paradigms (RT), there must be some grounds for believing that the processes involved in the EJT do not differ in important ways from those involved in RT experiments. In most RT tasks, subjects are presented with a single stimulus, and are required to make a choice or discrimination. Most recent theories of RT assume that the subject achieves this by taking a series of `covert' observations of the stimulus. In the EJT, on the other hand, a sequence of several stimulus elements or observations is presented on a single trial. In what follows, therefore, we will begin by assuming that the processing of an `overt' observation in the EJT is analogous to that of a covert observation in an RT task, except that it proceeds at a slower rate, determined by the objective speed of presentation of the stimulus elements.

Following Smith & Vickers (1988), a second assumption we will make is that the internal representation of the stimulus elements (line segments) has a direct, monotonic relationship to the actual physical magnitude (length) of the overt observation. If we make the further assumption that the magnitude of the internal random variability, or neural noise, is very small by comparison with the objective variability in the overt observations, then we can regard these overt observations effectively as the input to the hypothesized decision mechanism, and treat the parameters (specifically the mean, μ, and standard deviation, σ) of the distribution of overt observations as providing a good estimate of the parameters of the input to the decision process. That is, we can assume that individual differences in internal noise (due, for example, to differences in arousal level) are so small, relative to the objective variability in the overt observations, as to be negligible.

A fourth assumption we will make is that decisions are made concerning these overt observations in the same way as they are concerning the sequence of covert observations made by the subject when viewing a single, static stimulus in a conventional RT task. That is, observations are classified as favouring one response alternative or the other, and accumulated until some decision rule is satisfied. As a working hypothesis, we will assume that the decision rule in question corresponds to that specified by the accumulator model of RT proposed by Vickers (1979) and Smith & Vickers (1988): namely, that observations are accumulated until a critical evidence total in favour of one or the other response is reached. Such a model has been found by Smith & Vickers (1988) to provide a good description of response time and accuracy data in an EJT, provided it was assumed that observations smaller than a certain magnitude (e.g. those falling within an indifference region) were discarded.

If these assumptions are justified, then we may hope to discover some systematic relationships between measures of individual differences with respect to personality or intelligence and the parameters which characterise the decision process carried out by the subject. One aim of the initial experiment was to test the validity of the above assumptions. Specifically, this experiment was designed to test three predictions which follow from these assumptions. Firstly, the relationship between stimulus discriminability, on the one hand, and accuracy and response time, on the other, should be the same in the EJT as they are in a conventional RT task. Secondly, relationships between accuracy and response time should be the same in the EJT as they are in conventional RT tasks, whether these tasks conform to a subject-controlled (S-paradigm) or an experimenter-controlled (E-paradigm) paradigm. Finally, if overt observations falling within an indifference region (IR) are discarded, as suggested by Smith & Vickers (1988), then fewer should be discarded from sequences which have the same distributional characteristics (i.e. the same relationship between the mean and standard deviation), but have been re-scaled upwards in terms of absolute magnitude.

A second aim of the initial experiment was to investigate possible relationships between measures of individual differences and the parameters characterizing the decision process in the case of individual subjects.

In the research reviewed in the last chapter, intelligence was identified as a main predictor of RT performance. This research also suggested that a major determinant of intelligence is the ability to process information faster. This hypothesis tends to be linked with the assumption that RT is primarily a physiological reaction, which does not incorporate cognitive components, and a similar approach has also been adopted by some personality theorists. However, others, such as Larson & Saccuzzo (1986) have acknowledged the importance of cognitive components in processing. For example, the consideration of cognitive and sensory components, and their relationship to the Eysenckian dimensions of personality, is evident in some TSD studies, where the Eysenckian dimension extraversion has been found to correlate with sensitivity (d') and criterion (β)

(Harkins & Geen 1975). Specifically, introverts have been found to have higher values for d' and β. Probabilistic models of RT have many resemblances to TSD, and these studies suggest that it may be worthwhile to conduct a pilot investigation to examine whether the Eysenckian dimensions of personality correlate with EJT performance. The study of personality instead of intelligence, as a predictor of performance in this type of task, also promises to be more fruitful, since intelligence is hypothesized as being limited by the speed of information processing. If the rate of information presentation is constant, as in the EJT, and is less than the critical value associated with processing limitations in discrete sampling, which has been estimated as approximately 10 observations per second (Kristofferson 1967; Sanford 1971), then individual differences associated with the acquisition of information and speed of processing should in theory be reduced or eliminated.

Predictions concerning the correlation between performance parameters and individual differences in relation to personality are not immediately obvious. A study by Edman et al. (1983) suggests that performance may vary according to the P score measured from the EPQ. However, the results obtained from TSD research also suggest that subjects' performance may be related to extraversion, with introverts being more sensitive and more cautious, due to their higher level of cortical activity (Eysenck & Eysenck 1985). If this is the case, then it may be expected that, in the EJT, introverts will generally be more cautious, set larger response threshold values, and thereby produce a higher level of correct responding.

The purpose of the first study is therefore twofold. Firstly, the experiments will examine the effect of varying the scaling and discriminability of the stimuli on both accuracy and response threshold. Secondly, the experiments will investigate the possibility that such performance is related to the Eysenckian personality dimensions.

2.1 Method.

2.1.1 Subjects.

Thirty five undergraduates, enrolled in the third year Psychology course at the University of Adelaide participated as subjects. All had normal or corrected vision and were naive with respect to the aims of the experiment.

2.1.2 Stimuli.

A series of green horizontal line segments of varying lengths were displayed on a grey Northstar computer screen. Each line segment was presented for 175 msec., with an inter-line interval of 150 msec. Furthermore, each line extended to the left or the right from a common point on a continuously present vertical mid-line. A description of the stimulus, is also provided by Vickers, Foreman, Nicholls, Innes & Gott (1989, Figure 2).
On any one trial, the series of lengths was determined by a computer program which selected values from one of eighteen normal distributions. The distributions could either have a mean of $\mu=\pm2,3$, or 4 and a standard deviation of either $\sigma=4,6$, or 8. Consequently, nine different discrimination levels were formed from eighteen distributions.
These are presented, in ascending order of discriminability, in Table 2.1.

Table 2.1 Discrimination level parameters in ascending order of discriminability.

Discrimination Level	μ	σ	μ/σ
1	2.00	8.00	.25
2	2.00	6.00	.33
3	3.00	8.00	.38
4	2.00	4.00	.50
5	3.00	6.00	.50
6	4.00	8.00	.50
7	4.00	6.00	.67
8	3.00	4.00	.75
9	4.00	4.00	1.00

A nominal mean value of +2 was equivalent to a line measuring 5.9 mm and projecting to the right of the mid-line, and a nominal mean value of -3 was equivalent to a line measuring 8.8 mm projecting to the left of the mid-line. Finally, a nominal mean value of +4 was equivalent to a line measuring 11.8 mm projecting from the right of the mid-line.

2.1.3 Apparatus.

The experiment was controlled by a Northstar Advantage computer and subjects' responses were made on the response keyboard. Subjects indicated whether, on average, the endpoint of all the line segments viewed fell to the left or the right of the vertical mid-line by pressing one of two keys, marked L or R, with the index finger of their preferred hand. Subjects initiated the next trial by pressing a home key.

2.1.4 Tests and measures - The EPQ.

All subjects completed Eysenck & Eysenck's (1975) Personality Questionnaire (EPQ). The EPQ is a written questionnaire, containing ninety items, which form four subscales. Each item is answered by responding either `Yes' or `No'. Of the sub-scales, three of these measure personality dispositions, namely: psychoticism (P); extraversion (E); neuroticism (N). The last, labelled the lie scale (L), yields a measure of the subject's tendency to respond in a favourable manner. Eysenck & Eysenck (1975) have referred to psychoticism as a measure of `toughmindedness' and risk taking, extraversion as a measure of sociability and impulsiveness, and neuroticism as a measure of emotionality.

2.1.5 Design and Procedure.

The experiment involved two sessions, with session one being, at maximum, five days before session two. In the first session, subjects completed the EPQ. The second session involved an S-controlled expanded judgement task which had one block of 18 practice trials, with 2 trials at each of the 9 levels of discriminability. On average, the endpoint of the line segments fell to the left of the mid-line on half of these trials, and to the right for the remainder. (That is the average of the number used to generate the line segments was negative on half of the trials, and was positive on the remainder). Following practice, subjects were presented with 3 blocks of 108, trials with 12 trials at each level of discriminability, distributed unpredictably throughout each block. As in practice, the endpoint of the line segments fell to the left or the right in a random sequence. However, out of the whole 324 experimental trials, the mean endpoint of the line segments fell to the right of the mid-line on 162 trials, and the mean endpoint of the line segments fell to the left of the mid-line on 162 trials.

Subjects were told that the sequence of lines presented on any trial was random, and that the level of difficulty might vary from one trial to the next. They were further instructed to examine the display, and to determine whether the endpoint of the line segments fell on average to the left or the right of the mid-line. They were told that the probability of a trial being either left or right was .5. They were discouraged from attempting to use a deliberate, cognitive strategy, and were asked to make a response on an impressionistic basis. They were instructed to examine the display, and then respond, thus terminating the display. They were asked to maintain a stable compromise between speed and accuracy when responding.

Following each primary response, subjects initiated the next trial by pressing the home key with the index finger of their preferred hand.

Subjects took approximately 50-60 minutes to complete the EJT task.

2.2 Results.

In this experiment, overall measures of RT and the number of correct responses (NC), for the entire experimental session were recorded. In addition, these variables were broken down according to the discrimination level.

2.2.1 Means and standard deviations.

Means and standard deviations for the entire experimental session, collapsed across block and discrimination level are presented in Table 2.2. The mean performance measures were accompanied by large standard deviations, indicating that performance in this S paradigm experiment was subject to individual variation, even though identical instructions were given to subjects.

Table 2.2 *Means and standard deviations for the experimental measures. RT is in msecs and NC is the number of correct responses. Psychoticism (P), Extraversion (E), Neuroticism (N) and the Lie Scale (L) are the scores obtained from the EPQ. (N=35).*

	Mean	SD
RT	4591.6	3000.1
NC	298.8	17.5
P	3.0	2.7
E	14.0	4.0
N	11.2	5.5
L	7.3	3.1

In this experiment, the personality descriptives obtained are quite similar to those published by Eysenck & Eysenck (1975). Intercorrelation of the sub-scores showed a number of significant associations. The E subscale was found to correlate with both the N subscale ($r=-.29$, $p<.05$) and the L subscale ($r=-.37$, $p<.05$). In both cases, subjects who scored high on extraversion also tended to be less neurotic and give lower scores on the lie scale.

When RT and NC are broken down according to discrimination level, as in Table 2.3, a number of trends can be observed. For RT, it is evident that, as discriminability increases, RT decreases, and this is also accompanied by a gradual increase in NC. However, when the discrimination level is considered to be constant ($\mu/\sigma=.50$), a decline in RT can be observed as the scaling factor increases, i.e. shorter RT in condition $\mu/\sigma=4/8$ than in condition $\mu/\sigma=3/6$ or 2/4. However, there appears to be no change in the number of correct responses across these parameter combinations.

Table 2.3 *Means and standard deviations for the nine discrimination levels. The measure for RT is in msecs whereas NC is the number of correct responses. The discrimination level as represented by μ/σ is presented in ascending order of discriminability. (N=35)*

μ/σ	RT Mean	RT SD	NC Mean	NC SD
.25	5105.7	3308.0	28.9	3.5
.33	5140.1	3505.9	30.9	3.4
.38	4821.8	3209.3	32.0	3.5
.50 (2/4)	4758.0	2953.9	34.0	2.2
.50 (3/6)	4568.5	2944.8	33.7	2.1
.50 (4/8)	4269.8	2802.2	33.7	2.8
.66	4261.2	2877.2	35.0	1.3
.75	4404.2	2933.2	34.9	1.8
1.00	3994.7	2679.3	35.5	0.9

2.2.2 Overall Performance.

A Pearson correlation coefficient of .56 ($p<.01$) between RT and NC across subjects was obtained. This suggests that a speed-accuracy tradeoff was clearly influencing individual differences in the number of observations viewed, and consequently the number of correct responses made.

2.2.3 Performance according to discrimination level.

2.2.3.1 Discrimination and RT.

A repeated measures analysis of variance was conducted with two within-subjects factors, i.e. μ and σ. Figure 2.1 shows a plot of RT for the nine levels of discriminability broken down according to μ and σ.

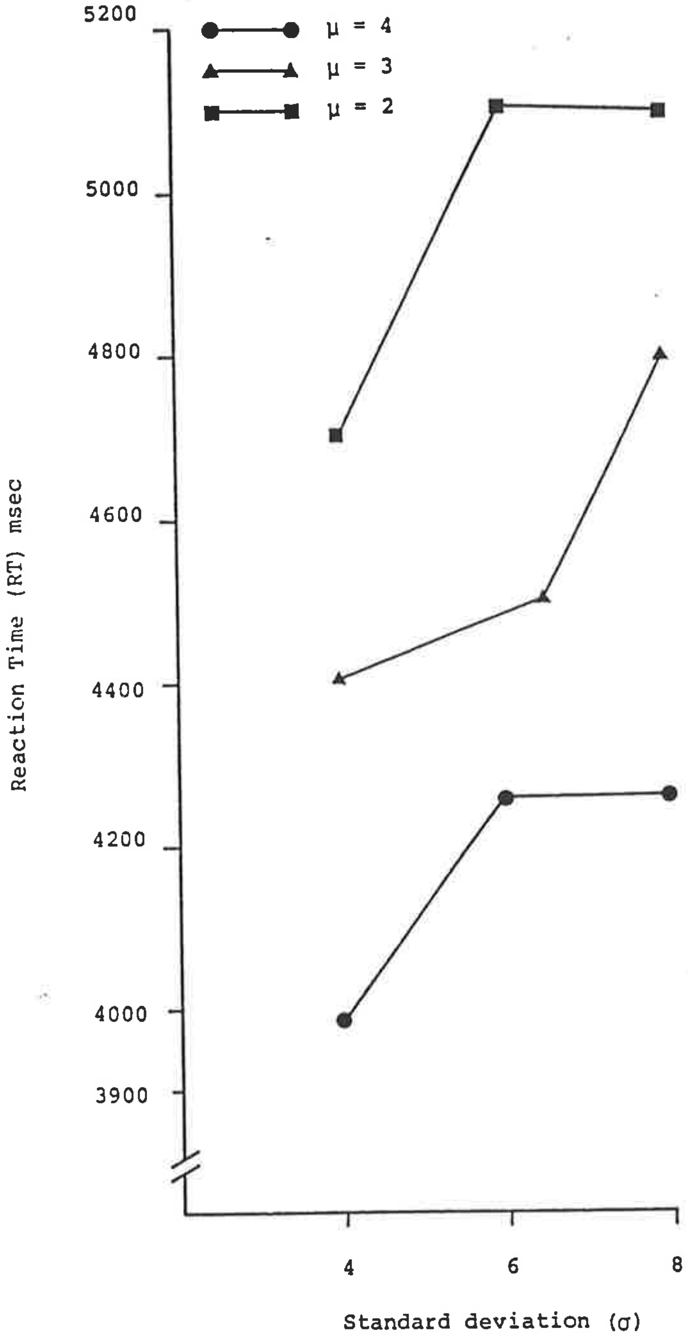

Figure 2.1 *The effect of discriminability on RT.*

The graph portrays three distinct functions. Univariate statistics show that the effect of μ on RT was significant ($F(2,68)=43.68$, $p<.01$) as was σ ($F(2,68)=11.36$, $p<.01$). A significant linear polynomial contrast for the main effect of μ was found ($t(1,68)=-7.13$, $p<.01$), and similarly the main effect of σ, ($t(1,68)=.403$, $p<.01$). However no interaction between μ and σ was evident ($F(4,136)=1.36$, ns).

2.2.3.2 Discrimination and NC.

As in the above instance, a repeated measures analysis of variance was conducted, with μ and σ as within-subjects effects.

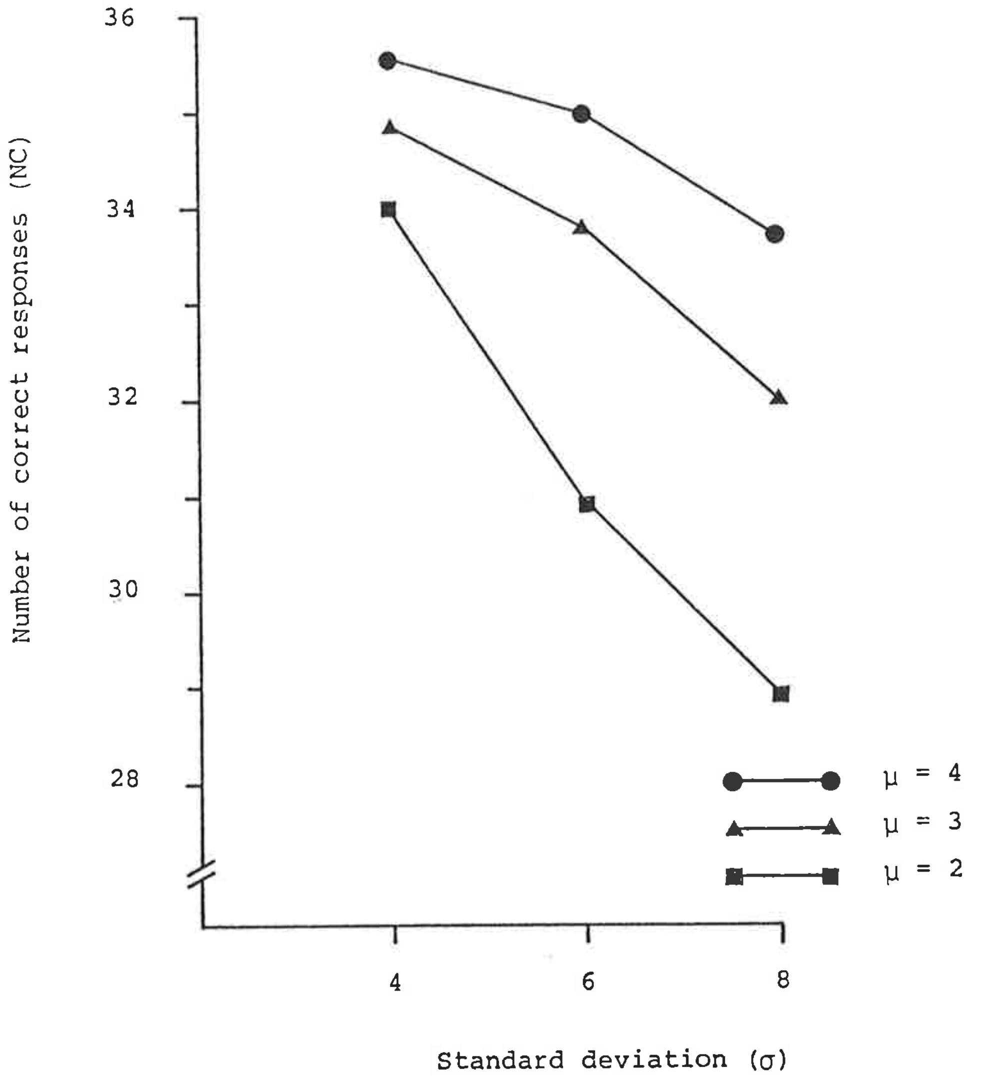

Figure 2.2 The effect of discriminability on NC.

Figure 2.2 shows a plot of NC for the nine levels of discriminability, broken down according to μ and σ. As can be seen there are three distinct functions. The graph portrays three distinct functions. Univariate statistics obtained show that the effect of μ on NC was significant ($F(2,68)=87.90$, $p<.01$), as was σ ($F(2,68)=62.16$, $p<.01$). The poynomial contrasts for μ suggested that a significant linear ($t(1,68)=12.61$, $p<.01$), and quadratic component ($t(1,68)=-2.28$, $p<.05$) exist. In contrast to this, polynomial contrasts for σ showed only a negative linear trend ($t(1,68)=-10.16$, $p<.01$). There was also a significant interaction between μ and σ ($F(4,136)=11.07$, $p<.01$).

2.2.3.3 RT and NC for μ/σ=.50.

As noted earlier, three parameters were of equal nominal discriminability. Due to the different stimulus scaling, the largest stimulus observations were drawn from μ/σ= 4.0/8.0 whereas the smallest observations were drawn from μ/σ=2.0/4.0. For RT, the effect of the different scaling levels was significant ($F(2,68)=17.26$, $p<.01$), and a polynomial contrast revealed a significant negative linear trend ($t(1,68)=-5.40$, $p<.01$). Consequently, subjects were faster for the higher stimulus scaling. In contrast, NC did not differ across stimulus scaling levels ($F(2,68)=.77$, ns).

2.2.4 Individual differences in performance.

In this section of results the two main measures of performance were correlated with the measures of personality. First of all, the overall measures taken from the entire experimental session were correlated, and the coefficients

Table 2.4 *Pearson correlation coefficients between RT and NC, and the personality dimensions P, E, N, and L.*

	P	E	N	L
RT	.07	.53*	-.36#	-.34#
NC	-.16	.46*	-.25	-.14

* $p<.01$

\# $p<.05$

are printed in Table 2.4. The strongest indicator of performance was extraversion, yielding high correlations with both RT and NC. Significant correlations with RT were also obtained for the N and L scales. However, this may be due to the fact that the subscales E, N and L of the EPQ were inter-related. Extraverts took longer to respond, and were also more correct than introverts.

Partial correlations were also examined in order to look at the strength of the correlations between RT and E, NC and E, RT and N, and lastly NC and N. In these analyses the effects of the interrelated personality dimensions were controlled. When controlling for the interrelated dimensions of N and L, a partial correlation coefficient of .51 ($p<.01$) was obtained for RT and E, and a partial correlation coefficient of .39 ($p<.01$) was obtained between NC and E.

When controlling for the interrelated dimensions of E and L, a partial correlation coefficient of .43 ($p<.05$) was obtained for RT and N, and a partial correlation coefficient of -.28 ($p=.06$) was obtained between NC and N.

2.3 Discussion.

2.3.1 Performance in the EJT.

It was argued in the introduction that the EJT is similar to a conventional RT task. If this is the case, then it is expected that variations in discriminability should result in correlated changes in RT and NC. These changes are due to the fact that a different number of (V-S) observations are required before a decision is made. If the value for k is assumed to be constant, as in the case where a single speed or accuracy emphasis is imposed, then it is expected that, for more difficult discrimination levels, more (V-S) observations will be required, so that longer RTs and fewer correct responses are predicted. A previous experiment conducted by Vickers et al. (1985a), which utilized an S-paradigm EJT, demonstrated this. The results from Experiment 1 demonstrated that variations in discrimination, effected by changing the values of μ and σ, influenced both RT and NC. In μ/σ conditions that made discriminability difficult subjects' response times were longer and fewer correct responses were made. Furthermore, if the EJT is similar to conventional RT tasks, it was also expected that tradeoffs between speed and accuracy should be evident. In the S-paradigm EJT employed by Vickers et al. (1985a), the number of observations required before a response is elicited was correlated with the number of correct responses. Likewise, in Experiment 1, subjects' RTs correlated significantly with NC. Consequently the setting of a response threshold (k), in this S-paradigm experiment seems likely to be a prime source of individual difference.

If the magnitude of the stimulus or the V-S difference is an important component in the accumulation of evidence, then it would be expected that, in those trials where μ/σ=.5, performance would vary according to the stimulus scaling applied. In this experiment, the ordering for RT was in the expected direction, with shorter RTs at the higher stimulus scaling. However, there was no significant difference in the number of correct responses. The apparent inconsistency between RT and NC remains a problem, but may perhaps be a ceiling effect of the high level of accuracy exhibited by the subjects at each scaling level.

2.3.2 Individual differences in performance.

Before discussing the main relations between the Eysenckian dimensions of personality and performance in the EJT, the correlation between E and N deserves attention. Typically, the study of individual differences relies on the use of a correlational statistic, and this statistical procedure is affected when a sample, which is thought not to be representative of the population, or is extreme in some way, is drawn. In the domain of intelligence, this poses a problem, as samples which are too widely dispersed can inflate correlations, whereas samples that are too restricted in the range of intelligence scores can attenuate correlations (Irwin 1984; Nettelbeck & Kirby 1983; Vernon 1986). In research on personality, particularly on the Eysenckian dimensions of E and N, extreme scores in a relatively homogeneous sample, such as University students may be obtained, and were indeed found in our experimental population. Extreme scores on the P scale, on the other hand, are less common, and may be due to some weakness in the measuring instrument (Bishop 1977; Block 1977a,b; Eysenck, Eysenck & Barrett 1985). While extreme scores cause inflated correlational values, the main problem in this experiment is that two dimensions, assumed to be orthogonal, are actually correlated. As this appears to be a somewhat isolated finding, it probably constitutes insufficient grounds for challenging the assumption of orthogonality. Rather, it can be assumed that a biased sample was drawn. Subjects who were extreme on the E dimension happened to score lower on the N dimension. In addition, the entire experimental population tended to be extraverted. As the sample was biased, formulating some conclusion about individual differences in the EJT is somewhat difficult. To overcome this problem, therefore, partial correlations were conducted.

The partial correlations obtained in this experiment suggest that extraverts were generally more cautious, showed longer RTs, and achieved a greater number of correct responses. Subjects low on neuroticism had longer RTs, but did not achieve, significantly, a greater number of correct responses. The P scale did not correlate with either RT or NC. This result is contrary to that reported by Edman et al. (1983), who found a correlation between the number of correct responses in a two choice RT paradigm and psychoticism (EPQ) ($r=-.48$, $p<.001$). Like the EJT, Edman's et al. experiment involved the presentation of a series of stimuli within each trial. In Edman's experiment, however, the stimuli were a series of lights, similar to those employed by Vickers et al. (1971), instead of a series of line segments. Furthermore, Edman et al., presented a fixed number of stimuli in one trial, as in an E-paradigm, and may thereby be assumed to have controlled the response threshold. It is also quite possible that performance in this particular paradigm is correlated with scores on the P scale, rather than the other scales, as the P scale is particularly associated with attentiveness and regulation of sensory input (Claridge 1983, 1981), which are necessary components in a data limited environment.

Returning to the E and N scales, a number of points arise. Firstly, the correlation between RT and N suggests that those higher on the N scale had a tendency to respond faster, without incurring a decrease in NC. A similar finding (that higher N individuals have shorter RTs, but are not less accurate) was obtained by Larson & Saccuzzo (1986). In their experiment, N was related to movement time in a one choice RT condition, and was associated with fewer errors. Such faster responding may to some extent be due to an increased level of autonomic activation in higher N subjects (Eysenck 1967). Secondly, the correlations with E indicated that high E scorers were more cautious, and had a higher degree of sensitivity to the stimuli. This seems contrary to the results from vigilance and signal detection studies, which reported the reverse findings (Harkins & Geen 1975). However, even within the vigilance literature, extraverts have on occasion been found to make more correct detections than introverts. For example, extraverts will make significantly more detections if their cortical arousal is increased by exposure to cortically arousing agents, such as auditory noise (Geen, McCown & Broyles 1985), or when the signal probability is decreased (Vickers, Leary & Barnes 1977). In particular, the adjustment of extraverts to declining signal probability, is believed to be the result of their tendency to respond less conservatively. Even though the EJT is not strictly a vigilance type of task, it still may be susceptible to manipulations which have been found to affect vigilance. By randomly varying the level of discriminability, and employing stimuli characterised by a high degree of random variability, the level of cortical arousal may have been increased, resulting in more cautious responding on the part of extraverts. In this experiment, the cautious responding may have been further compounded by the fact that the majority of extraverts were low on N and were perhaps less autonomically activated.

Another explanation for the extraverts' longer estimates for RT, may lie in the possibility that they may have been forced to take more observations to maintain a certain level of accuracy, due to the operation of a different processing parameter. For example, it may be the case that the IR parameter associated with the accumulation of evidence is different in extraverts. In Chapter 1, the IR was described as a region of indifference around a sensory referent, responsible for the classification of evidence, and likely to be at least partly determined by the degree of stimulus variability.

B. EXPERIMENT 2. Individual differences in an S-paradigm and E-paradigm Expanded Judgment task.

2.4 Introduction.

The second experiment was designed to asses the reliability and validity of performance measures obtained from both the E- and the S-paradigm of the EJT, and also to examine their relationships to individual differences in personality. By comparing performance in an S-paradigm, in which accuracy is limited by information quality, with that in an E-paradigm, in which it is limited by quantity of information, it should be possible to determine whether the performance measures obtained possess validity across quite different experimental paradigms. As in Experiment 1, measures of P, E, and N were obtained, to examine whether personality, particularly the P dimension, correlated with performance in the E-paradigm, as suggested by the finding of Edman et al. (1983) from a similar experiment. Finally, an attempt was made to ascertain whether the correlation between extraversion and RT, and between extraversion and NC, would persist when subjects were required to deal with only one level of discriminability.

The results obtained from Experiment 1 suggested that a number of modifications be made for the second experiment. One modification was to employ only one discrimination level, thereby eliminating any adjustments in performance that might arise when several discrimination levels are presented. The discrimination level chosen was relatively difficult, so as to ensure that a certain proportion of errors was made, thereby providing scope for a greater range of individual differences.

2.5 Method.

2.5.1 Subjects.

Twenty-two undergraduates enrolled in Psychology I at the University of Adelaide participated as volunteer subjects in this experiment. All had normal or corrected vision, and were naive with respect to the aims of the experiment.

2.5.2 Stimuli.

As in Experiment 1, the stimuli consisted of a series of green horizontal line segments of varying lengths, displayed on a grey Northstar Advantage computer screen. The line segments were drawn from a distribution having a mean of $\mu=\pm2.33$ and a common standard deviation of $\sigma=6.00$. A nominal mean of 2.33 corresponded to a line length of approximately 6.1 mm on the screen.

2.5.3 Apparatus.

The same equipment that was used in Experiment 1, and is outlined in Section 2.1.3, was used in this experiment. The line segments were generated on a Northstar screen and subjects' responses were recorded on a response keyboard. Subjects indicated whether a trial was judged as left or right by pressing one of two microswitched keys marked L or R. Following a response, subjects pressed the home key to start the next trial.

2.5.4 Tests and measures - The EPQ.

Subjects also completed the Eysenck Personality Questionnaire as described in Section 2.1.4.

2.5.5 Design and Procedure.

For this experiment each subject had to complete four sessions. In two of the experimental sessions subjects completed an E-paradigm condition, where the number of line segments (n) was pre-determined as being either n=6,9,12,15 or 18. In the other two experimental sessions, subjects completed a S-paradigm condition. All subjects completed one S-paradigm (S1) and one E-paradigm (E1), and then repeated this to provide a second set of results for the S-paradigm (S2) and E-paradigm (E2). The mean time between S1 and S2 was 91 days with a range from 58 to 118 days, and the mean separation between E1 and E2 was 81 days with a range of 49 days to 124 days.

At each session there were 2 blocks of 20 practice trials, all at one level of discriminability, with the endpoint of the line segments falling to the left on half of these trials and to the right on the remainder. Following practice, subjects were presented with an uninterrupted block of 200 trials, again all at one level of discriminability. As in the practice trials, the endpoint of the line segments fell to the left or the right of the mid-line in a random sequence. Of the 200 trials, the endpoint of the line segments fell to the right on 100 trials, and to the left on 100 trials.

For the S-paradigm subjects were given instructions identical to those reported in Section 2.1.5. They were instructed to observe a sequence of horizontal line segments and determine whether on average the endpoint of the line segments fell to the right or left of the mid-line. They were told that the line segments were generated randomly, and that there was a .50 probability that the trial was either right or left.

For the E-paradigm, subjects were also informed that there was an equal probability for a trial to be right or left, and that the line segments were generated randomly. However, unlike the S-paradigm, subjects were informed that the number of line segments would be pre-determined by the computer program, and would vary unpredictably from trial to trial. They were instructed to respond immediately at the end of each trial, by pressing either a right or a left response key with the index finger of their preferred hand, and then to initiate the next trial by pressing the home key.

2.6 Results.

For each subject who completed the two sessions of the S-paradigm (S1 and S2), the mean reaction time (RT), and the total number of correct responses (NC) were recorded. Each subject also completed two E-paradigm conditions (E1 and E2), and, from these sessions, the mean overall latency (LAT), and the total number of correct responses (NC) was recorded. The mean overall latency consisted of the mean "post-summative decision latency" obtained for each value of n. The post-summative decision latency is defined as the total time from the start of a trial sequence to the depression of the response key minus the length of time taken to display the stimulus sequence.

2.6.1 Means and standard deviations.

Means and standard deviations for the entire experiment are presented in Table 2.5. For the S-paradigm, measures were accompanied by larger standard deviations, indicating considerable individual variation in performance, although identical instructions were given to subjects. In neitherparadigm did there appear to be much change across sessions.

Table 2.5 *Means and standard deviations for the S-paradigm, S1 and S2, and the E-paradigm, E1 and E2. The measures LAT and RT are in msecs and NC is the number of correct responses. (N=22).*

	S1		S2	
	RT	NC	RT	NC
Mean	4348.1	175.9	4372.4	174.7
SD	1975.2	10.4	1738.2	9.8

	E1		E2	
	LAT	NC	LAT	NC
Mean	1418.0	163.7	1319.7	163.7
SD	536.5	5.3	596.4	4.6

For the S-paradigm a Pearson correlation of r=.79 (p<.01) between RT and NC in S1 was obtained, whereas, in S2, a correlation of r=.86 (p<.01) was obtained between these two variables. In contrast, for the E-paradigm, there was only an insignificant correlation between LAT and NC in E1 (r=-.12, ns), and also between these two variables in E2 (r=-.02, ns).

Means and standard deviations for the personality measures have been presented in Table 2.6. Values are for both males and females, collapsed across various age ranges. Intercorrelating these measures produced a number of significant findings. The correlation between the P and L scales was significant r=-.43 (p<.05). Secondly the correlation between P and E was also significant (r=.40, p<.05), which suggests that high P scorers tended to have higher E scores.

Table 2.6 *Means and standard deviations for the personality dimensions of psychoticism (P), extraversion (E), neuroticism (N) and the lie scale (L) obtained from the EPQ. (N=22).*

	P	E	N	L
Mean	4.7	13.7	12.5	6.0
SD	2.7	4.9	5.2	3.6

2.6.2 Reliability of RT and NC for both the S-paradigm and the E-paradigm.

For each of the measures obtained, a Pearson's correlation coefficient was calculated to determine whether subjects performed consistently across the experimental sessions. For RT a highly significant correlation of r=.63 (p<.01) between performance in S1 and S2 was obtained, and, for NC, a highly significant correlation of r=.57 (p<.01) between performance in S1 and S2 was also obtained. For LAT, a correlation of r=.88 (p<.01) between performance in E1 and E2 was obtained, and, for NC, a correlation of r=.49 (p<.01) between performance in E1 and E2. The main performance indices measured in both paradigms were at least moderately consistent overtime.

Furthermore, for the S-paradigm, there appears to be no mean difference between sessions in either RT (t(1,21)=-.07, two tailed, ns), or NC (t(1,21)=.57, two tailed ns). Likewise, for the E-paradigm, there was no mean difference between sessions for either LAT (t(1,21)=1.62, two tailed, ns), or NC (t(1,21)=.46 two tailed, ns). It would thus appear that subjects are overall performing in a quite stable manner across experimental sessions.

2.6.3. Cross paradigmatic consistency.

One of the main concerns of this experiment was to assess whether subjects were consistent across experimental paradigms. This includes consistency with respect to overall decision latency and RT, and NC. Since the measures of LAT, RT and NC were stable and consistent they were averaged for the remainder of the analysis.

(a)RT and LAT.

The main point to examine was whether those subjects who had a shorter response latency in the E-paradigm had shorter RTs in the S-paradigm. The correlation between LAT and RT was insignificant ($r=.14$, ns).

(b)NC.

In order to determine whether subjects that were more accurate in one paradigm were more accurate in the other paradigm a Pearson correlation between the average number of correct responses for each paradigm was conducted. The correlation between E- and S-paradigm NC was insignificant ($r=.14$, ns).

2.6.4 Individual differences in performance.

The performance measures for each experimental paradigm were correlated with the scores obtained from the EPQ, and are presented in Table 2.7.

Table 2.7 *Pearson correlation coefficients for personality (EPQ), and performance measures obtained from both experimental paradigms.*

	S-paradigm RT	S-paradigm NC	E-paradigm LAT	E-paradigm NC
P	-.13	-.27	-.09	-.15
E	-.25	-.15	-.22	-.05
N	-.10	-.05	-.26	.12
L	.11	.01	-.12	-.24

# p<.05

For neither paradigm was there a significant correlation between the personality dimensions and the averaged performance measures.

2.7 Discussion.

2.7.1 Performance in the S-paradigm and E-paradigm.

If subjects perform a task consistently in a re-test situation, it suggests that, not only are subjects adhering to instructions, but the task in itself is little affected by practice, and is not affected by any major subjective change, i.e. subjects are conducting the same kind of discriminatory process in both sessions.

According to Vickers et al. (1985a), the subject engages in a similar process of evidence accumulation in both the E-paradigm and S-paradigm. In this process, observations which are registered as V>S are accumulated one special store t_g, whereas observations which are classified as V<S are accumulated in a separate store t_l . The magnitude of the difference (V-S) and the number of observations are both important factors in this process. In the S-paradigm, whichever store exceeds a value established by the response

threshold, determines the response. In the E-paradigm, it is assumed that the subject decides which of the two accumulated stores is larger at the end of the sequence.

If a similar process of evidence accumulation is involved in both paradigms, it might be expected at first sight that subjects who perform this task efficiently in one paradigm would do so in the other. The failure to obtain a significant correlation between correct responses from both paradigms, contradicts this expectation. This does not necessarily imply however, that different types of accumulation processes are involved in each paradigm. Given that subjects are free to adopt different response thresholds in the S-paradigm it is possible that this is responsible for intra-individual differences. In the E-paradigm, however, subjects may simply be trying to perform as accurately as possible.

2.7.2 Individual differences.

As in Experiment 1, the sample that was drawn for this experiment was biased. In this instance there was a significant correlation between the P and L scales, with higher P scorers showing lower L scores. A correlation between these two variables is quite common, according to Eysenck & Eysenck (1976), who refer to this phenomenon as dissimulation. It is assumed that dissimulation is the result of high P scorers deflating their P scores, or responding negatively to P questionnaire items, and increasing their L responses. This strategy may be adopted because the L scale reflects socially desirable and acceptable behaviour, in contrast to the anti-social attitudes expressed in the P scale. In addition, higher P scorers tended to have higher E scores, suggesting that, in this sample, E and P dimensions shared a certain component. As in Experiment 1, such biases will affect the interpretation of the results.

For the measures of RT, LAT and NC, there were no correlations with the personality dimensions, contrary to the results obtained in Experiment 1. The main difference between the two experiments, was the fact that Experiment 1 contained multiple discrimination levels. Rapid changes in stimulus discriminability may have altered the arousal of extraverts, resulting in better adaptation and more correct responses.

CHAPTER THREE.
SENSORY CONSTRAINTS: THE INDIFFERENCE REGION IN THE EXPANDED JUDGEMENT TASK.

3.1 Sensory parameters in performance.

A number of writers, notably Helson (1964), have argued that characteristics of the stimulus can affect discrimination performance. In particular, it has been suggested that sensory adaptation may be determined automatically by the stimulus sequence, as well as being dependent on some form of cognitive manipulation. Examples of adaptive phenomena are varied, and have been found to occur in signal detection (Parducci & Sandusky 1970, 1965; Treisman & Williams 1984), and also in a number of other perceptual contexts, such as after-effects (Warren 1985). Treisman & Williams (1984) have developed a comprehensive theory of criterion adjustment. According to their approach, sequential effects, such as alternations between the stimuli on consecutive trials, or repetition of the stimuli, are believed to determine the setting of the criterion. In their theory, a long term process, based on past experience and knowledge of signal probability, is assumed to establish the intial criterion, and two short-term processes are responsible for reviewing the criterion, so that the subject can match the probabilities of stimulus alternatives and maximize accuracy.

If performance in traditional discrimination tasks is affected by sensory adaptation, it may well be that similar processes are involved in the EJT. The IR was identified in Chapters 1 and 2, as a parameter likely to be associated with adaptation.

3.1.1 The indifference region.

The concept of an indifference region has been applied in a variety of contexts where the measure of RT is an important variable. The concept has been applied to memory (Hockley & Murdock 1987; Murdock 1983), as well as to discrimination and recognition (Atkinson & Juola 1974; Cartwright & Festinger 1943; Krueger 1978; Petrusic & Baranski 1989).

Historically, Cartwright & Festinger (1943) proposed one of the most earliest models to incorporate the notion of an indifference region, or interval of uncertainty. They proposed that the individual sampled an observation of the stimulus difference, and, if this difference did not exceed the particular values of r_g and r_l, but fell into an interval of uncertainty between r_g and r_l, then it was discarded, and another observation was sampled. On the other hand, if the V-S difference exceeded either r_g or r_l, a response of the form "V>S" or "V<S", respectively was made. Thus a response could be made after only a single observation.

Atkinson & Juola (1974) state that the IR is an important component in their model for recognition. In their experiments the subjects complete a memory task where they match a target stimulus, (a noun) against a well - memorized list of words. A response is made when the target stimulus is identified as either belonging or not belonging to the memorized set. If a subject is indifferent, then he/she will extend the memory search. Increased time spent in memory searching increases the subject's response time, and, according to Atkinson & Juola (1974), guarantees that the subject makes a correct response. The distributed memory model of Murdock (Hockley & Murdock 1987; Murdock 1983) also contains a similar process. In this model, it is assumed that a subject can take an observation, and make a response, or wait for another observation before responding. Hockley & Murdock (1987) claim that, when a given observation is classified as indifferent (i.e. falls into the `wait' region), another observation is taken. During the process of taking observations, it is hypothesized that the criteria r_g and r_l converge at a particular rate, until eventually the distance between the two criteria approaches zero, and a decision must be made. The number of observations that a subject samples determines RT. Theoretically, it would be expected that if the time to take an observation is constant, RT would be determined simply by the number of observations taken to reach a decision. However, Hockley & Murdock (1987) found that latency (RT) distributions did not conform to this assumption. Rather, it was necessary to assume that the duration of the observation becomes greater as time passes, and they suggest that this is most likely caused by increasing interference, or inhibition, from the process as it continues. Furthermore, the model also assumes that the convergence of the parameters, r_g and r_l, is affected by the speed-accuracy tradeoff. When subjects are instructed to trade speed for accuracy, r_g and r_l are expected to converge more quickly than when accuracy is emphasized.

Krueger (1978) also utilizes a similar concept to the IR in his theory of perceptual matching, developed to account for same-different judgments. In his experiments subjects had to match pairs of letters. If the subject is indifferent as to whether the pair is the same or different, the subject will "re-check" the information, extending the search time.

All of these models have assumed that a process similar to the concept of an indifference region, affects individual performance. Petrusic & Baranski (1989) have argued that adjustments in the indifference region parameter depend upon the stimulus intensity, with less discriminable stimuli producing a larger indifference region. This interpretation is somewhat different to the region of indifference proposed by Hockley & Murdock (1987). In their model, if the indifference region is expanded, only those observations which are more diagnostic will be accrued, and there will be an increased probability that an observation will be regarded as indifferent.

3.1.2 Indifference region in the EJT.

Like the IR proposed by Petrusic & Baranski (1989), the IR in the EJT may be hypothesized as being determined by the stimulus sequence, as a consequence of adaptation to the distribution of sensory intensities which the individual has experienced (Vickers & Smith 1986). Specifically, it may be assumed that the IR can be represented as a region, with the width of this region being dependent upon the range in the distribution of sensory intensities as depicted in Figure 3.1.

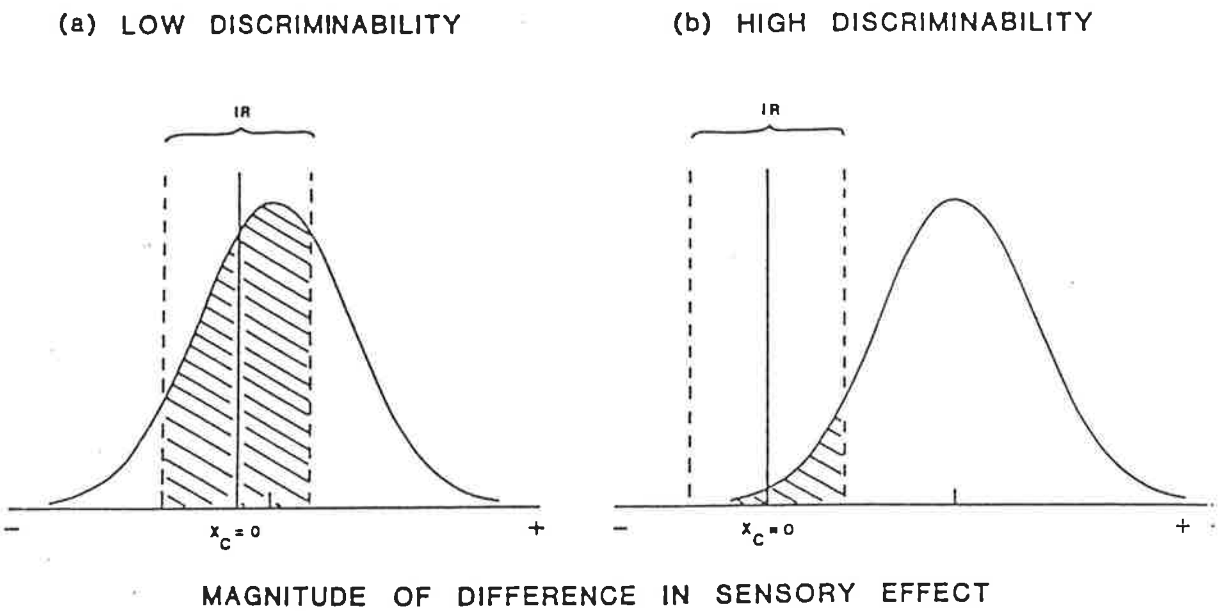

Figure 3.1 *Comparison of the effects of an indifference region (IR) for a distribution of stimulus differences (a) when discriminability is low, and (b) when discriminability is high. (From Vickers & Smith 1986).*

In the case of the boundary conditions, where the limits of the IR are equivalent to the response thresholds set for the accumulation process, the process then becomes similar to the memoryless model put forward by Cartwright & Festinger (1943). In contrast, if the IR value is set at zero, the process conforms to a simple accumulator.

As it is assumed to operate in the accumulator model, therefore, the IR performs a similar function to the indifference region posited by Hockley & Murdock (1987), Petrusic & Baranski (1989), and also Cartwright & Festinger (1943). However, unlike these latter models, the IR in the Accumulator model governs the accumulation of evidence. For example, within the S-paradigm large values for r_g and r_l mean that only larger V-S values are accumulated into t_g or t_l, and consequently, on a given trial, only more diagnostic observations are used to reach a decision. Therefore, subjects in the S-paradigm, who have larger values for r_g and r_l, but who maintain the same accumulation thresholds values k_g and k_l, will have a higher level of accuracy. In the E-paradigm, however, a somewhat different picture emerges, as the number of observations is limited by the experimental program. In this case, therefore, larger values for r_g and r_l, will result in more observations being lost, and overall accuracy should decline. Consequently, subjects who adopt smaller values for r_g and r_l should achieve more correct responses than those who adopt larger values for r_g and r_l. It is possible that this difference in the relationship between IR and accuracy for the S- and E-paradigm may explain the lack of apparent cross-pardigmatic validity obtained in the previous experiment.

3.2 Individual differences and adaptation.

It has been argued earlier that adjustments in performance, in both signal detection and vigilance tasks, are primarily due to changes in the criterion. The existence of such shifts in these particular paradigms has been studied in connection with parameters of individual difference, particularly personality, as outlined in Eysenck & Eysenck (1985).

In vigilance, criterion shifts can result in either a vigilance increment or decrement (Broadbent 1971; Davies & Parasuraman 1982). Such factors as the time on the task, signal probability and the payoff matrix often affect the value of β. The time on the task often results in an increment in β, whereas there is a general tendency for a decrement in β when there is an increase in the a priori signal probability (Parasuraman 1986). Criterion shifts have been explained by a number of theories, such as those concerned with expectancy and subjective probability (Davies & Tune 1970; Deese 1955), and also by the ideal observer hypothesis, according to which the observer attempts to maintain optimal behaviour (Vickers et al. 1977; Williges 1973). It has also been found that sensitivity, or d', can vary within an experimental session (Mackworth 1965, 1968; Swets 1977). In particular, a decline in sensitivity can be produced when the event rate, or the presentation of signal and non-signal events, is varied (Parasuraman & Davies 1976). Other factors, such as variations in signal strength, i.e., signal intensity and duration, have also been found to affect sensitivity (Broadbent & Gregory 1963; Williges 1973). However, in the EJT, it is expected that changes in sensitivity will not occur, as the underlying distributions representing the stimuli remain constant throughout the experiment. Furthermore, the presentation of the stimulus elements within a trial is fixed at the rate of three line segments per second, and the duration of the stimulus elements is also fixed.

If there is an association between adaptation and individual differences, it is expected that β will correlate with indices such as extraversion. If β is not measured, as is often the case in vigilance experiments, then higher levels of false alarms may be interpreted as evidence of some form of criterion adjustment. A few experiments concerned with personality have reported significant effects in relation to β, and also in relation to the false alarm rate. For example, Harkins & Geen (1975) have reported that introverts had higher criterion values than extraverts. Extraverts also tended to make more false alarms. A replication of this study by Geen et al. (1985), however, failed to find an interaction between extraversion, the criterion and the false alarm rate. Other studies have also referred to an association between false alarm rate and extraversion (Carr 1971; Krupski, Raskin & Bakan 1971). In these studies, extraverts tended to report more false alarms. One other study reported that neuroticism was associated with the criterion, with neurotics adopting lower criterion values and obtaining a higher false alarm rate (Gupta & Nicholson 1985). The reported correlations between personality and criterion can also be affected by such factors as the time of day and exposure to noise (Davies & Hockey 1966; Gupta & Nicholson 1985). In certain cases, introducing these experimental manipulations can reverse the findings. However, there seems to be some evidence that introverts will generally tend to adopt high values for the criterion, and thus attempt to reduce the number of false alarms.

The second set of experiments relevant to adaptation and individual differences is concerned with after-effects. As discussed in Chapter 1, Warren (1985) suggested that the criterion will be adjusted according to the properties of the stimulus sequence. Research with kinesthetic after-effects has found that some subjects, classified as augmenters, tend to overestimate the size of the stimulus, whereas others, classified as reducers, tend to under-estimate the size of the stimulus (Petrie 1978).

Eysenck & Eysenck (1985) have hypothesized that, due to the higher levels of arousal in introverts, there is a tendency for them to amplify stimuli. As a result, it is expected that introverts will be augmenters and extraverts will be reducers.

The spiral after-effect (SAE), according to Eysenck & Eysenck (1985) is caused by the stimulation of particular cells sensitive to movement, resulting in the build up of inhibition. According to the inhibition theory, individuals who develop inhibition more readily, i.e. extraverts, should have longer after-effects. However, Eysenck (1957) has argued the opposite, stating that extraverts will tend to have shorter after-effects, as they tend to miss effective stimulation. In contrast, the arousal theory predicts that introverts will have longer after-effects as they tend to augment stimuli. A number of studies have reported results that have been consistent with the suggestion that introverts have longer after-effects (Lynn 1960; Paramesh 1963). Rawlings (1985) has also found that individuals who were higher on the P scale tended to have longer after-effects.

From the research concerned with vigilance and after-effects, it seems that introverts are more ready to make criterion adjustments based on the stimuli. There has, however, been one exception to this. In an experiment in which TSD methodology was utilized, Vickers et al. (1977) reported that when the a priori probability of the stimuli was varied, extraverts appeared to adjust values of B more quickly than introverts.

3.3 Experimental Hypotheses.

Experiment 3 has been designed to examine a number of issues. In this experiment, it was decided that the E-paradigm should be utilized, as it enables the estimation of the ideal level of correct responses. When the number of observations is controlled, and the IR value is set at zero, the ideal level of performance should be given by the square root of the number of observations as outlined in equation 3.1.

$$z = \sqrt{n}\,(\mu/\sigma) \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \; 3.1$$

In this case, the probability of a correct response should be given by the proportion of the distribution of accumulated observations with a mean z, lying above or below zero, and should increase as the square root of the number of observations (Vickers et al. 1986).

As the number of line segments is pre-determined by the program, the trials are identical for each individual, within a session, and are also identical for each each individual across sessions. This provides an opportunity to examine the adjustments made in performance, and whether certain sensory parameters, assumed to be determined by the stimulus sequence (i.e., the IR), are stable over sessions.

To test the assumption that the IR is determined by the distribution of sensory intensities the individual experiences, some subjects in this experiment viewed experimental sessions which had nominally identical discrimination parameters (μ/σ=.38), but different stimulus scaling. If the IR is affected by the magnitude of the stimulus, then it is expected that, when different scaling is applied, different values for the IR will be obtained.

The final aim of this experiment was to examine whether the IR would relate to measures of individual difference, particularly personality. A number of predictions are made from the literature reviewed earlier. The main prediction is that different personality types will either augment or reduce the stimulus, due to different levels of cortical arousal. Introverts, due to their higher levels of arousal will be extremely sensitive to stimulation and tend to `augment' stimuli, whereas extraverts, due to lower levels of cortical arousal, will not be so sensitive to stimulation, and will tend to `reduce' the stimuli. Due to the different levels of arousal, it is expected that introverts will assign more importance to the stimulus intensities, and will utilize more stimulus information. If this is the case, then it is hypothesized that they should have smaller estimates for IR. In contrast, extraverts should have larger values for IR, as they have less sensitivity to stimulation and will reduce stimulus information.

3.4 Method.

3.4.1 Subjects.

Thirty six undergraduate students, enrolled in Psychology III and Psychology I at the University of Adelaide, were used as subjects in this experiment. All had normal or corrected vision, and were naive with respect to the aims of the experiment.

3.4.2 Stimuli.

The stimuli utilized in this experiment were similar to those used in the previous experiments. However, unlike the stimuli detailed earlier, the line segments were drawn from distributions with a mean of μ=+1.5 and a standard deviation of σ=4.0, or a distribution with a mean of μ=+3.0 and a standard deviation of σ=8.0. Consequently, two different scaling levels were presented, with the higher level comprising a high mean and standard deviation combination (μ=3.0, σ=8.0), and the lower level comprising a low mean and standard deviation (μ=1.5, σ=4.0). A nominal mean value of 1.5 corresponded to a line measuring 3.0 mm, whereas a nominal mean value of 3.0 corresponded to a line measuring 6.0 mm.

3.4.3 Apparatus.

The same apparatus as described in Section 2.1.3, was used in this experiment. The stimuli were presented on a grey Northstar Advantage computer screen, and responses were made by pressing one of two microswitched buttons, located on a separate response keyboard.

3.4.4 Tests and measures - The EPQ.

As in Experiment 1 and Experiment 2 the EPQ was administered.

3.4.5 Design.

In this experiment there were two sessions for each subject, with a one week interval between session one (E1) and session two (E2). All subjects completed E2 on exactly the same day and same time as E1, so as to control for time of day effects. Each session contained two blocks of 12 practice trials, all at the same scaling level as they were to encounter in the test trials. The average endpoint of the line segments fell to the left (negative) on half of these trials, and to the right (positive) on half of the trials as well. Following practice, subjects were presented with one block of 240 trials at one scaling level. As in the practice trials, the a priori probability that a trial had either a left or right average was equivalent to .5. The number of horizontal line segments that could be viewed on any one trial was given by n=3,6,9,12,15 or 18, with the value of n for each trial being randomly determined. There were 40 trials for each value of n.

The experiment contained two sub-designs, each having different discrimination parameter combinations.

(A) Design A.

In this design nine subjects completed two sessions with the discrimination level set at a mean of μ= 3.0 and the standard deviation set at σ=8.00. A second group of nine subjects completed two sessions with the discrimination level set at μ= 1.5 and a low standard deviation of σ=4.00. As can be seen from Table 3.1, this design was a repeated measures design.

Table 3.1 Experimental groups for Design A.

Group	Sess	μ	σ	Type	μ/σ	N
A1	1	3.0	8.0	High	.38	9
	2	3.0	8.0	High	.38	
A2	1	1.5	4.0	Low	.38	9
	2	1.5	4.0	Low	.38	

(B) Design B.

For this design there were two groups, each containing nine subjects. One of these groups completed the experimental condition with the high scaling level first, followed a week later by the second condition with the low scaling level. The second group completed the condition with the low scaling level first, followed one week later by the high scaling level. This has been represented in Table 3.2. In contrast to Design A, Design B was a classic crossover design.

Table 3.2 *Experimental groups for Design B.*

Group	Sess	μ	σ	Type	μ/σ	N
B1	1	1.5	4.0	Low	38	9
	2	3.0	8.0	High	.38	
B2	1	3.0	8.0	High	.38	9
	2	1.5	4.0	Low	.38	

3.4.6 Procedure.

Subjects were told that they would observe a number of horizontal line segments in a trial, and that the number of line segments would vary from trial to trial. They were instructed to examine the display, and, when the trial terminated, they were told to respond immediately by pressing one of two microswitched keys. One key represented a right (positive) endpoint and the other a left (negative) endpoint. To start the next trial, subjects pressed the home key. All responses were made with the index finger of the dominant hand. Subjects were informed that the a priori probability of a right or left trial was .5, and they were not told what group or design they were assigned to.

3.5 Results for Experiment 3.

In both designs, the mean overall latency (LAT) and number of correct responses (NC), in session one (sess 1) and two (sess 2) was obtained. The mean overall latency consisted of the mean post-summative decision latency obtained for each value of n. The post-summative decision latency is defined as the total time from the start of a trial sequence to the depression of the response key by the subject, minus the length of time taken to display the stimulus sequence. In addition to these measures, values for IR were estimated. Results for Design A were examined first, followed by those for Design B.

3.6 Design A.

3.6.1 Means and standard deviations.

For this design mean and standard deviations for both RT and NC for both sessions are presented in Table 3.3. As can be seen from this table, LAT was subject to change across both sessions, becoming shorter for both groups. In contrast, NC appeared to change little across session and also appeared to be similar, irrespective of the condition.

Table 3.3 *Means and Standard Deviations for LAT and NC. LAT is in msecs and NC is the number of correct responses.*

Group			Sess 1 Mean	SD	Sess 2 Mean	SD	N
A1	H/H	LAT	1690	318	1555	315	9
		NC	191	5	194	5	
A2	L/L	LAT	1648	169	1452	241	9
		NC	196	3	195	3	

The mean overall latency correlated across session in both Groups. However, NC did not correlate across session for either group. Table 3.4 also shows that LAT did not correlate with the number of correct responses.

Table 3.4 *Pearson correlation coefficients between LAT and NC for Session 1 (1) and Session 2 (2) for each Group.*

Group A1 (N=9)	LAT(2)	NC(1)	NC(2)
LAT(1)	.76*	.07	-.10
LAT(2)		.23	.43
NC(1)			.28

Group A2 (N=9)	LAT(2)	NC(1)	NC(2)
LAT(1)	.60#	.04	-.25
LAT(2)		-.32	-.33
NC(1)			.55

# p<.05 * p<.01

Means and Standard Deviations for the EPQ are presented in Table 3.5.

Table 3.5 *Means and Standard Deviations for the personality dimensions psychoticism (P), extraversion (E), neuroticism (N) and the lie scale (L) obtained from the EPQ. (N=18).*

	P	E	N	L
Mean	3.6	12.8	10.0	7.3
SD	2.1	5.0	4.7	3.6

Inter-correlation of the P, E, N and L scales resulted in no significant correlations, suggesting that, unlike the previous two experiments, the dimensions in this experiment were independent.

3.6.2 Analysis for LAT and NC.

For both variables a repeated measures analysis of variance was conducted with a within-subject factor of session (s), and a between-subjects factor of group (g). The results for this analysis have been printed in Table 3.6.

Table 3.6 shows that LAT changed across session. There was no difference between the groups for LAT.

For NC subjects' accuracy did not change across session and once again there was no apparent difference between groups.

Table 3.6 *Repeated measures analysis of variance for LAT and NC.*

LAT	DF	F	Sig
between Ss			
within cells	16		
cons	1	739.86	<.01
g	1	.38	ns
Within-Ss (s)			
within cells	16		
s	1	11.38	<.01
g x s	1	.39	ns
NC			
Between Ss			
within cells	16		
cons	1	49565.68	<.01
g	1	3.28	ns
Within-Ss (s)			
within cells	16		
s	1	.36	ns
g x s	1	2.02	ns

3.7 The IR in Design A.

3.7.1 Calculation.

To obtain a value for the IR, a number of simulations were conducted. In each simulated trial the actual line segments presented on the trial were separately totalled for right and left responses. A simulated response was then made, which corresponded to the greater of these two totals. A sequence of 51 simulations, each of which employed a different value for IR, ranging from 0 to 100, in steps of 2, were conducted. A step size of 2 was used as this corresponded to the smallest possible incremental step on the computer display.

In each of these simulations, all line lengths

which fell within the operative IR were excluded from the accumulation process. For each simulated session the proportion of trials on which subjects made the same response as the simulation process was then calculated. This proportion gives a measure of response consistency. The estimated value for IR was the value employed on a simulation which gave the greatest level of response consistency. The mean values for IR are presented in Table 3.7.

Table 3.7 *Means and standard deviations for IR, scaled in millimetres for both groups in Design A.*

		Sess 1	Sess 2
Group A1	Mean	5.9	4.4
	SD	2.6	3.4
Group A2	Mean	2.7	1.5
	SD	2.1	1.6

3.7.2 The consistency of the IR and its correlation with accuracy.

The estimated mean value for the IR in Group A1 was twice the size of that estimated for Group A2. The stability of the IR was examined by a repeated measures analysis of variance with session (s) as a within-subject and group (g) as a between-subject factor. This analysis showed a significant difference between the groups, with the IR estimates in Group A1 being greater than the IR estimates for Group A2.

Table 3.8 *Repeated measures analysis of variance for IR.*

	DF	F	Sig
Between Ss			
within cells	16		
constant	1	54.82	<.01
g	1	9.80	<.01
Within cells (s)			
within	16		
s	1	4.17	ns
g x s	1	.08	ns

To assess individual consistency across sessions, Pearson correlations between the IR estimated in session 1 and the IR estimated in session 2 were calculated. The results in Table 3.9 also show correlations between IR and the number of correct responses (NC).

Table 3.9 *Pearson correlation matrix for IR and NC for each group.*

Group A1 (N=9)				Group A2 (N=9)			
	NC(1)	IR(2)	NC(2)		NC(1)	IR(2)	NC(2)
IR(1)	-.43	.35	-.29	IR(1)	.18	.52	.47
NC(1)		-.15	.27	NC(1)		.46	.55
IR(2)			-.52	IR(2)			.62#

\# p<.05

Results from this analysis show that subjects within each group did not have consistent IR values and also that IR did not predict the number of correct responses in either session, except in the case of Group A2 session 2, where a large value for IR was associated with more correct responses.

3.8 Individual differences in performance for Design A.

Since there appears to be very little difference across groups and sessions with respect to LAT, NC or IR, the groups were collapsed into one sample. Furthermore, the estimates for LAT, NC and IR were averaged across both sessions.

Table 3.10 *Pearson correlation coefficients between personality (EPQ) and performance measures. (N=18).*

	P	E	N	L
LAT	.23	-.27	-.12	-.09
NC	-.04	.29	-.01	.01
IR	.14	-.23	.02	-.37
	# p<.05	* p<.01		

Table 3.10 shows that there were no correlations between the performance measures LAT, NC and IR and the personality dimensions P ,E, N, and L.

3.9 Design B.

3.9.1 Means and standard deviations.

In this design subjects completed one session of each of the conditions, so that this design was equivalent to a classic cross-over design. Means and standard deviations for LAT and NC are presented in Table 3.11

Table 3.11 *Means and standard deviations for LAT and NC. LAT is in msecs and NC is the number of correct responses.*

Group			Sess 1 Mean	SD	Sess 2 Mean	SD	N
B1	L/H	LAT	1575	307	1328	155	9
		NC	191	6	192	5	
B2	H/L	LAT	1674	435	1507	339	9
		NC	192	6	193	5	

Again, the most observable trend was that, irrespective of the experimental group, there was a tendency for LAT to decrease across sessions. However, there appeared to be little variation in the number of correct responses.

Pearson correlations between subjects' mean overall decision latency showed that, for both groups, LAT was correlated across sessions. Correlations for NC showed that subjects' level of accuracy was consistent across session for Group B1 but not for Group B2.

Table 3.12 *Pearson correlation coefficients between LAT and NC in Session 1 (1) and Session 2 (2).*

Group B1 (N=9)				Group B2 (N=9)			
	LAT(2)	NC(1)	NC(2)		LAT(2)	NC(1)	NC(2)
LAT(1)	.64#	-.13	.33	LAT(1)	.94*	.36	.33
LAT(2)		.19	.22	LAT(2)		.17	.23
NC(1)			.60#	NC(1)			.46
				# p<.05		* p<.01	

The subjects' mean overall decision latency did not correlate with the number of correct responses in either group.

Means and standard deviations for the Eysenck Personality Questionnaire are presented in Table 3.13.

Table 3.13 *Means and standard deviations for the personality dimensions psychoticism (P), extraversion (E), neuroticism (N) and the Lie scale (L) obtained from the EPQ. (N=18).*

	P	E	N	L
Mean	2.5	13.0	13.4	6.1
SD	2.3	4.2	3.7	3.9

There were no inter-correlations between any of the personality dimensions, suggesting that they were independent in this population.

3.9.2 Analysis for LAT and NC.

As this design was a classic crossover design, the repeated measures analysis of variance is slightly different from that in Design A. Instead of session being a within-subjects factor, it is neccessary to assume that session is replaced by condition (c), i.e. Low or High variance. This, however, is accompanied by the problem that there exists greater sensitivity in the analysis toward this effect. A between-subjects factor of order (o) is also neccessary, rather than group. Results from this analysis are printed in Table 3.14.

Table 3.14 *Repeated measures analysis of variance for LAT and NC for Design B.*

LAT	DF	MS	Sig
Between Ss			
within cells	16		
cons	1	437.48	<.01
o	1	.91	ns
Within-Ss (c)			
within cells	16		
c	1	18.29	<.01
o x c	1	.67	ns
NC			
Between Ss			
within cells	16		
cons	1	24643.16	<.01
o	1	.43	ns
Within-Ss (c)			
within cells	16		
c	1	.86	ns
o x c	1	.04	ns

From Table 3.14 it can be seen that subjects' latency differed according to condition. There was, however, no difference between the different experimental orders.

For accuracy, Table 3.14 shows that the condition effect was not significant. Furthermore, there was no difference between the different experimental orders.

3.10 The IR in Design B.

3.10.1 Calculation.

The same procedure outlined for Design A was used in Design B to obtain estimates for IR. The mean IR values for each Group are presented in Table 3.15.

Table 3.15 *Means and standard deviations for IR, scaled in millimetres, for both groups in Design B.*

		Sess 1	Sess 2
Group B1	Mean	2.6	3.7
	SD	2.5	3.9
Group B2	Mean	4.6	2.4
	SD	3.5	1.7

From this table it can be seen that IR varies according to the condition, being larger when the high variance condition was employed.

3.10.2 The consistency of the IR and its correlation with accuracy.

To test the differences between orders a repeated measures analysis of variance was conducted.(As in the analyses conducted above it was necessary to assume a between-subjects effect of order and a within-subjects factor of condition existed.)

Table 3.16 *Repeated measures analysis of variance for IR Design B.*

	DF	F	Sig
Between Ss			
within	16		
cons	1	28.46	<.01
o	1	.07	ns
Within Ss (c)			
within	16		
c	1	.62	ns
o x c	1	5.59	<.05

This analysis shows that IR did not differ according to order, nor was there a between-subjects factor of condition. However, there was an order by condition effect.

The consistency of the IR, and its ability to predict the number of correct responses, was analysed by Pearson correlations. Results from this analysis showed that subjects in Group B1 had consistent IRs across session, and that there was also a trend for those in Group B2 to be consistent. IR did not predict the number of correct responses for either group.

Table 3.17 *Pearson correlation matrix between the measures IR and NC.*

Group B1. (N=9)				Group B2. (N=9)			
	NC(2)	IR(1)	IR(2)		NC(2)	IR(1)	IR(2)
NC(1)	.60#	-.01	.24	NC(1)	.52	.21	.14
NC(2)		-.50	.02	NC(2)		.15	-.18
IR(1)			.68#	IR(1)			.52

# p<.05

3.11 Individual differences in performance for Design B.

Since there appeared to be little differences between experimental condition and order with respect to LAT, NC or IR, the groups in this design were collapsed into one sample.

Table 3.18 *Pearson correlation coefficients for personality (EPQ) and performance measures. (N=18).*

	P	E	N	L
LAT	.12	.34	-.26	-.13
NC	.48#	.06	.39	-.06
IR	-.02	-.07	-.01	-.37

# p<.05

Results from this analysis showed only one significant correlation: that between NC and P. Subjects who achieved more correct responses were found to have higher scores on the P scale.

3.12 Design A vs Design B.

3.12.1 LAT and NC.

Since there appeared to be very little difference within each design with respect to the main variables, the groups within each design were collapsed, and an analysis examining differences between designs was then performed. In order to do this it is neccessary to assume that Design B is equivalent to Design A, so that subjects were completing simply a repeated measures design, and, therefore, the within-subjects factor of condition should simply be replaced by session as in the case of Design A. Results from this analysis can be found in Table 3.19.

For LAT a significant within-subjects session effect was found. There was no interaction between design and session.

For NC, table 3.19 shows that there were no differences in this variable between designs. There was also no within-subject interaction for session.

Table 3.19 *Repeated measures analysis of variance for LAT and NC, Design A vs Design B.*

LAT	DF	F	Sig
Between Ss			
Within cells	34		
cons	1	1130.82	<.01
D	1	.50	ns
Within Ss (s)			
within cells	34		
s	1	30.04	<.01
d x s	1	.37	ns
NC			
Between Ss			
Within cells	34		
cons	1	64581.20	<.01
D	1	1.72	ns
Within Ss (s)			
within cells	34		
s	1	1.20	ns
d x s	1	.09	ns

3.12.2 The IR.

Repeated measures analysis of variance for the IR was also conducted. Table 3.20 reports the values that were obtained. The repeated measures

Table 3.20 *Repeated measures analysis of variance for Design A vs Design B.*

	DF	F	sig
Between Ss			
within	34		
const	1	66.10	<.01
D	1	.15	ns
Within Ss			
within	34		
S	1	3.15	ns
D x S	1	.63	ns

analysis of variance indicated that there were no differences between the Designs for IR. There was no significant within-subjects effects either.

3.12.3 Conclusion to Design A vs Design B.

The failure of the main variables to differ across design suggests that the experimental conditions did not cause a performance decrement or increment. Although there may be a number of reasons as to why this is the case, it nevertheless provides clear justification for amalgamating the design into one large experimental sample.

3.13 Results collapsed across experimental Design.

3.13.1 LAT and NC.

It was found that the mean value for LAT differed across sessions ($t(1,35)=5.53$, two-tailed, $p<.01$). However, correlation between session 1 and session 2 LAT ($r=.77$, $p<.01$) suggested that subjects were quite reliable, even though there was some form of performance adjustment between sessions.

With respect to NC there was no difference across session ($t(1,35)=-1.11$, two-tailed, ns), and, furthermore subjects were also quite reliable in regard to the number of correct responses made ($r=.49$, $p<.01$).

Correlation between LAT and NC for session 1 was insignificant ($r=.13$, ns) and the correlation for session 2 between LAT and NC was also insignificant ($r=.05$, ns).

3.13.2 The IR.

(1)Consistency across session.

A Pearson correlation between IR for session 1 and session 2 obtained a coefficient of $r=.48$ ($p<.01$), indicating that, overall, subjects' estimates for this variable were quite consistent.

(2)Prediction of Accuracy.

For session 1 a correlation of $r=-.07$ (ns) between NC and IR was obtained. For Session 2 a correlation of $r=-.17$ (ns) between IR and NC was recorded. In both instances the IR failed to predict the number of correct responses.

The final way of assesing the validity of the IR was to examine whether its imposition improved response consistency. This was done by comparing the level of response consistency when IR=0 to the level of response consistency when a non-zero IR was imposed. In session 1 a total of 7 subjects were assigned an IR=0 on the basis that this best described response consistency. For session 2 a total of 11 subjects were assigned an IR=0. Of these cases, 4 subjects were assigned an IR=0 in both session 1 and session 2. In those subjects assigned an IR=0 in session 1, the mean level of response consistency was 89.37% of the trials, and of those assigned an IR=0 in session 2 the mean level of response consistency was 89.98% of the trials.

Of the subjects that could be assigned a non-zero IR value the mean level of response consistency is tabled shown in table 3.21. The imposition of an IR

Table 3.21 *Mean percentage of response consistency for IR and IR=0.*

session 1			session 2		
IR=0	IR	N	IR=0	IR	N
88.03%	89.20%	29	88.73%	89.80%	25

gives only a very small improvement to the response consistency. The level of response consistency estimated when no IR is imposed is equivalent to subjects being consistent on 211 trial out of 240 trials. By imposing an estimate for IR subjects become consistent on approximately 2 more trials. Therefore the IR does not appear to improve consistency.

3.14 Individual differences in performance.

In this last section of results, the entire experimental sample was used to examine whether the personality dimensions, as measured by the EPQ, varied according to any of the performance measures detailed. Pearson correlation coefficients are presented in Table 3.22.

Table 3.22 *Pearson correlation coefficients between personality (EPQ) and performance measures. (N=36).*

	P	E	N	L
LAT	.19	.04	-.21	-.09
NC	.30#	.16	.08	.01
IR	-.07	-.16	-.02	-.35#

# p<.05

Two significant correlations were found: the first between NC and P; the second between L and the IR. Subjects with higher P scores achieved more correct responses, and subjects with higher L scores had smaller IR values.

3.15 Discussion.

3.15.1 The effects of varying the stimulus scaling factor.

One of the main findings in this experiment was the failure of NC to differ when the stimulus scaling factor was altered. Subjects' accuracy did not vary between either group or design, nor did it differ across sessions. On this basis, it was decided that the results should be collapsed across Group and

Design, so that the experiment was treated simply as a repeated measures design. It was found that, overall, NC did not differ across sessions, and was highly reliable ($r=.49$, $p<.01$) with a test-retest separation of one week. Thus the reliability reported in the E-paradigm in Experiment 2 was replicated in the present experiment. In addition, other results from the present experiment are similar to those reported in Experiment 2 and to those reported by Vickers et al. (1985a). In neither of these studies were LAT and NC correlated, which is consistent with the interpretation that the parameter k is not important in this paradigm.

In Design A, LAT did not differ between groups but was found to change across session. The effects found in Design A indicate that subjects' latency is influenced by practice, with subjects responding faster in the second session. The failure to find any group difference in LAT in this design also means that the scaling factor was not associated with a difference in subjects' latency. In light of the results obtained in Design A, it is probably the case that the significant condition effect in Design B is also a practice effect. It was therefore decided that LAT should be also incorporated in the analyses when the entire population was collapsed into one sample. When this was completed there was clear evidence of a practice effect, as LAT remained reliably correlated across sessions ($r=.77$, $p<.01$), while subjects tended to respond faster in the second session ($t(1,35)=5.53$, two-tailed, $p<.01$)

The two experimental parameters used in this experiment had nominally the same value, i.e. $\mu/\sigma=.38$, with the only difference being the scaling factor of the stimulus intensities. The line segments from the stimulus distribution $\mu/\sigma=1.5/4.0$ were exactly half the size of $\mu/\sigma=3.0/8.0$. The failure to find any performance differences suggests that the scaling factor in the present experiment is unimportant. This is consistent with the results of Experiment 1, where subjects saw three μ/σ parameter combinations each equivalent to μ/σ=.50, and where the level of accuracy for each parameter combination was virtually identical. Similar results to those obtained in Experiment 3 were also reported in another E-paradigm experiment conducted by Innes (1987). In Innes' (1987), experiment three μ/σ parameter combinations with the nominal value μ/σ=.38 were also presented. The experimental parameters were μ/σ=3/8, 2.25/6 and 1.5/4.0, and trials from each discrimination level were presented within a single session to each subject. When the variable NC was analysed, there appeared to be no differences between the three parameter combinations.

3.15.2 Individual differences in Performance.

It was predicted that, as introverts had a tendency to augment incoming stimuli (Eysenck & Eysenck 1985), they should have smaller IR's and make more correct responses. It has also been reported that introversion was associated with criterion adjustment in TSD. However, Rawlings (1985) has found that the E dimension is not always the best predictor of criterion adjustment and has found that the dimension of psychoticism can also predict criterion adjustment.

Results for the overall experimental population suggest that high P scorers obtained more correct responses, contrary to Edman et al's (1983) experiment, where high P scorers (EPQ) made fewer correct responses. However, since this was not accompanied by smaller IR values, this finding tends to indicate that individuals higher on the P scale have greater levels of sensitivity to the stimuli. There was no correlation between IR and the E dimension as initially predicted. In particular, it was thought introverts, who generally have greater levels of sensitivity would achieve more correct responses and adopt smaller IR's. The failure to obtain a correlation between IR and E would suggest that this personality dimension is not associated with performance in this particular experimental paradigm. Moreover, the failure of IR to correlate with personality would tend to suggest that the IR is not a sensory parameter.

3.15.3 Performance and the IR.

As discussed in the introduction, it was expected that the IR would predict the number of correct responses. A larger IR would correspond to lower levels of accuracy. However, the IR did not correlate with NC in either Design A or Design B. When the entire sample (N=36), was analysed, IR did not correlate with NC in either session.

The other main prediction was that the imposition of an IR should lead to greater response consistency, i.e. a larger proportion of responses made by the subject would be consistent with the responses produced by the simulation, than when no IR was assumed. When an IR was imposed for the entire experimental population only a negligible improvement in response consistency could be observed.

There were no differences in the number of correct responses between groups in either design. If subjects had employed a constant IR then differences in accuracy should have been found. Either subjects are adjusting the IR differently within the two experimental groups in Design A, or, in Design B, they are setting different values for IR in the two sessions (possibly during the practice session). However, if scaling was varied within one single session, there would be less opportunity for subjects to vary the IR from trial to trial. In Innes' (1987) experiment three different scaling factors were presented. In this experiment there were no differences in the estimates of IR for each subject in the different scaling conditions. Furthermore, IR did not predict the level of accuracy or improve response consistency. On the basis of these results one would have to consider the possibility that observations are lost at random rather than being discarded on the basis of magnitude. It may be the case, for example, that more observations are lost by subjects who have slower rates of information acquisition.

CHAPTER FOUR.
TEMPORAL LIMITATIONS IN PROCESSING.

The failure of the IR to improve response consistency and predict the number of correct responses led to the conclusion that this type of process did not explain information loss in the E-paradigm. As a result, an alternative explanation for information loss is necessary. In Chapter 3, it was suggested that one possible cause of the loss of observations might be the inability of the subject to process and accumulate information as quickly as it was presented.

Past research on temporal limitations in a processing mechanism has been mainly concerned with investigating and explaining the mechanisms responsible for regulating the input of information, e.g. Hoagland (1935). More recent studies have assumed that such a mechanism exists, and have been concerned with finding ways to measure the minimum exposure duration of a piece of information necessary for accurate processing to occur (Nettelbeck 1985; 1982). In addition, most recent studies have been concerned with individual variation in performance indices and with correlating these with other individual differences, such as intelligence.

In this chapter a number of issues will be discussed. First, a brief history will be given of the work associated with temporal limitations in processing. Second, the recent research concerned with the inspection time procedure will be examined. Correspondences between the assumptions underlying the inspection time (IT) procedure and probabilistic models of RT will be discussed. Since the IT methodology has been found to be susceptible to a number of problems, such as the use by certain subjects of apparent motion cues, the comparative advantages of adopting a multiple observations procedure, such as the EJT, will be considered.

The significant correlations obtained between measures such as IT and IQ has been taken to indicate that speed of processing may be a causal factor in intelligence, and there appears to be little interest in personality in this area. However, those few studies which have examined personality as a main source of individual variation will be included in this review.

4.1 Historical perspective and experimental paradigms.

During this century, psychologists have explored the temporal constraints involved in the perception of events. The original impetus for such research was created by James (1890), when he spoke against the concept of time being understood as a series of units, opting instead to speak of a `stream of consciousness'. Some years later Bergson, in 1913, argued that the perception of objects moving in time was best understood in terms of a series of units of duration, or moments. An impression of motion was derived from a series of pictures, similar to those in a motion film.

The principle that perceived time was effectively divided into a number of discrete units became generally accepted, and a number of different theories were put forward to explain why this should be so. Many physiologists adopted a viewpoint, according to which the factors influencing processing were seen as cyclic, and they suggested that the alpha rhythm determined this sampling mechanism. Similarly, cybernetic psychology drew an analogy between the brain and a computer, and concluded that a periodic scanning process must be involved for the brain to handle large quantities of information (White 1963). The question was traditionally studied by employing experimental procedures designed to investigate such phenomena as perceptual simultaneity and apparent movement (Fraisse 1978). However, in later studies, masking techniques were also used to investigate the hypothesis of perceptual discreteness.

The physiological approach was concerned with identifying what physiological processes might be operating to define the units of time. Hoagland (1935), argued in favour of a chemical mechanism rather than motor activity. His argument was based on the finding that individuals with increased body temperature had a different perception of time, and often reported that time passed more rapidly. Pieron (1952) developed this argument further by supposing that time units are affected by the speed of organic processes, such as the propagation of nervous discharges, as measured by the alpha and beta rhythms. If both the alpha rhythm and body temperature define the units of time, then it would be expected that these measures would be interrelated. Experimental evidence provided by O'Hanlon, McGrath & McCauley (1974) and also work cited by Pieron (1952), indicates an association between them.

Other researchers have also argued that the alpha rhythm is an important variable determining the psychological unit of duration (Kristofferson 1967; McFarland 1970; Murphree 1954; Varela, Toro, John & Schwartz 1981). Kristofferson (1967) has suggested that the alpha rhythm is linked to a central processing mechanism, which is responsible for the temporal integration of data. The subject's alpha rhythm determines his/her ability to attend to information that may be entering on different input channels, and also the transmission of messages from one stage of processing to another. Subjects with longer alpha cycles usually have longer estimates for the perceptual moment.

In contrast to the physiological approach, the cybernetic approach incorporated a scanning mechanism. Wiener (1948) concluded that a cyclical scanning process operates like the alpha rhythm. A unit of duration is equivalent to the time taken to complete a single scan. An influential theory incorporating the use of a scanning mechanism was developed by Stroud (1955). According to Stroud (1955), the subject's psychological percept of time T represents physical time t. However, T is not a continuous variable as is t, but is the result of a scanning process, in which, according to Stroud, psychological time is quantized into successive moments of finite length, within which all objective temporal ordering is lost.

Unlike other theorists, Stroud (1955) did not specify any physiological mechanism or process as being responsible for scanning, even though such a mechanism could be incorporated into the system (Murphree 1954). Stroud also used the phrase "perceptual moments" to refer to the hypothetical products of this discrete sampling process.

One variation of Stroud's (1955) hypothesis has been put forward by Allport (1970, 1968). He rejects the notion that information is accumulated discretely, and argues that a more continuous process of accumulation was operating. He referred to this as the Travelling Moment hypothesis. In this hypothesis, events are perceived as simultaneous whenever their temporal separation is less than the width of the travelling moment. Information will then be entering continuously for processing, and, at the same time, other units will drop out of processing. This finding has led to a debate on the nature of the moment (Turvey, 1977). Irrespective of the precise theoretical interpretation, however, it is thought that, on average, the moment or minimal time frame is of the order of 100 msec (Lichtenstein 1961; Murphree 1954; Stroud 1955).

Originally, estimates of the minimum time frame, or perceptual moment, were obtained by employing particular experimental tasks designed to investigate phenomena associated with the perception of flicker and fusion, the perception of simultaneity, and with the effects of backward masking.

4.1.1 The perception of simultaneity.

Experiments on the perception of simultaneity have employed a variety of techniques to examine the notion of a perceptual moment or unit of duration. For example, these experiments have often involved a series of lines or lit bars (Allport 1968), which can be perceived either as moving or as simultaneously present. Other relevant techniques include the successive presentation of the fragmented forms, the successive illumination of parts of a figure, as well as those developed to examine the process of "retinal painting".

In studies which employ experimental techniques used to examine the concept of retinal painting, subjects view a rapidly moving figure through a narrow slit in an opaque screen (Anstis & Atkinson 1967; Haber & Nathanson 1968; cf. McCloskey & Watkins 1978), whereas, in the typical fragmented forms experiment, a picture, word or pattern is subdivided into two meaningless subpatterns. When these subpatterns are presented successively, with a short ISI, the word or picture can be identified (Eriksen & Collins 1967, 1968). Finally, in another set of experiments, subjects view an array or figure. Parts of the figure are lit in succession, and, when the time it takes for the whole figure to be lit is made small, subjects will often report seeing the whole figure illuminated (Allport 1970, 1968; Lichtenstein 1961; McFarland 1970).

From these experiments results have been found to support the predictions made by the perceptual moment hypothesis. For example Eriksen & Collins (1967, 1968) found that the time it takes the subject to accurately identify the integrated stimulus in their experiment, utilizing the fragmented forms technique, was equivalent to the estimate of the perceptual moment (100 msec). In another experiment, conducted by Murphree (1954), in which a similar technique was used, the time it took subjects to accurately identify the integrated stimulus was correlated with the alpha rhythm, a measure also associated with the perceptual moment.

There is also evidence which does not support the perceptual moment hypothesis. Allport (1970, 1968) has argued that the data he obtained in his experiments was best explained by a continuous sampling process, such as the travelling moment model (Shallice 1964), where sensory events are perceived as simultaneous whenever their temporal separation is less than the width of the travelling moment. Allport (1970) also found that the subject's judgement that all parts of the array are simultaneously present changes according to a power function of target intensity. Subsequent analysis by Di Lollo & Wilson (1978) revealed that the duration of the first stimulus is important in perceiving two stimuli as simultaneously present.

The perceptual moment hypothesis and the travelling moment hypothesis assume that the inter-stimulus interval (ISI) is an obvious, crucial factor in temporal integration. Di Lollo (1980) has referred to the ISI as the time between the termination of the first stimulus and the onset of the next stimulus. It is important in these hypotheses as both of them assume that integration occurs when two stimuli are separated by a duration (ISI) less than the perceptual moment. Di Lollo & Wilson (1978) have presented evidence suggesting that the duration of the first stimulus is also important in perceiving integration. When increasing the duration of the first stimulus to 200 msec, and reducing the ISI between the two stimuli to 10 msec, it was found that subjects made more erroneous judgments about the stimulus configuration. They concluded that stimulus onset asynchrony (SOA) is more important in determining integration. The SOA refers to the elapsed time between the onsets of two successive stimuli. Rather than the temporal separation between stimuli, the visible persistence of the first stimulus is important.

Another task which has been designed to examine the the phenomenon of simultaneity uses a flickering (stroboscopic) light as a stimulus. In these experiments the critical time at which the subject notes a transition from the light flickering to the light source being fused provides a measure of the critical flicker frequency (CFF). According to Jensen (1983) an individual has a smaller perceptual moment, or has better temporal resolution, when she/he reports that the stimulus is fused on trials where the cycle rate of the flashing light is fast. However, trials where the light is flashing slower than this critical rate must be reported as flickering. So far, most experimental work concerned with studying temporal patterns of stimulation, using this experimental task, have concentrated on either varying luminance, where increasing stimulus luminance increases the sensitivity to the perception of flashing (Kelly 1961; Nelson & Bartley 1965), or on varying the nature of the pulse train. Although a number of experiments using a two flash procedure (e.g. Dark Interval Threshold DIT, and Two Flash Fusion TFF) have been conducted, it has been found that the eye is more sensitive to a series of flashes than to two flashes (Herrick 1974; Lindsley & Lansing 1956; Nelson & Bartley 1965; Wilkinson 1957; Pollack, Ptashne & Carter 1969). Other variations in the pulse train have included varying the pulse-cycle frequency (PCF) or the amount of time spent in light and darkness (Battersby & Jaffe 1953; Nelson & Bartley 1965). By varying the light-dark ratio it appears that estimates of CFF vary systematically as the exposure time of the pulse train is shortened. Subjects generally reported the appearance of fusion at a higher rate, i.e. more cycles per second, when the time spent in light and darkness was equal and when the exposure of the pulse train was longest. Flicker is seen less readily when the individual flashes are on for longer periods - perhaps because the optical channels need greater time to recover (Nelson & Bartley 1965).

Attempts have been made to explain the phenomenon of perceptual simultaneity as being dependent upon the activation of spatial and temporal processing mechanisms. It has been hypothesized that two separate channels are involved in processing information, with the first channel concerned with pattern information and the spatial structure of the stimulus, and the second channel concerned with motion (Breitmeyer & Ganz 1977; Pantle 1978). The second channel is particularly sensitive to stimulus orientation, such as gratings positioned vertically, horizontally, or at an oblique angle (Schwatz, Winstead & May 1982). It has been found that temporal resolution is inversely related to spatial frequency, and, as a rule, is poorer when the gratings are arranged at an oblique angle (Schwartz et al. 1982) Unlike an array, the use of a single light source, as in the case of the flicker technique, does not engage spatial components, and, certain processing components utilized when arrays are presented may not be utilized when completing a flicker experiment.

4.1.2 The phenomenon of apparent motion.

Historically, the phenomenon of apparent movement owes much to the pioneering work of Wertheimer in 1912, and Korte in 1915. In their early attempts to study the phenomenon a number of important properties were established, such as the distinction between the perception of apparent motion and phi motion (Wertheimer 1912). A number of important relationships between luminance, exposure time and the temporal interval between the stimuli were formulated (Graham 1965). However, these relationships turned out to be complex, and gave rise to a diversity of theories. Kolers (1972) argued that there were three classes of theory. The first, which he labelled as Epiphenomenal theories, were concerned with demonstrating that the perception of apparent motion and real motion are perceptually indistinguishable, and incorporate the same mechanisms (Aarons 1964; Frisby 1972; Gibson 1954; Morinaga, Noguchi & Yokoi 1966; Spigel 1965). The electrophysiological stimulation of direction sensitive neurones does lend some support to this notion (Barbur 1981; Barlow & Levick 1965; Movshon, Thompson & Tolhurst 1978). The second class of models, referred to as Excitation theories, were those where the states of cortical inhibition are responsible for the sensation of movement (Eysenck 1955). The third group, or Figural Theory, applies a more cognitive approach. Here apparent motion is perceived in order to solve the appearance of an object in different places (Muijen 1969; Rock & Ebenholtz 1962). Consequently, such concepts as confidence in judgment (De Silva 1929) and expectancy (Jones & Bruner 1954; Klein & Schlesinger 1950; Toch & Ittelson 1956) are important.

Kolers (1970) has argued that a number of processes are involved in the perception of movement. It is believed that motion and figure are processed at different stages, with motion being processed at an earlier stage than the figure (Kolers 1972; von Grunau 1981). Kolers (1972) has argued that the different forms of motion are perceived such as `phi motion', apparent motion, the perception of stimulus succession and stimulus simultaneity. All of these forms of motion involve either the engagement of different processing stages or combinations of stages. For example, phi motion is reported when the subject needs to process motion but does not identify the figure, whereas apparent motion involves the subject identifying motion as well as the figure. In contrast, reports of succession and simultaneity are based on the subjects processing the figure but not movement.

Within the research conducted on the phenomenon of apparent motion, a number of comparisons have been made between this phenomenon and the effect of masking, especially masking produced by the technique of metacontrast. The comparisons have led a number of researchers, such as Kahneman (1967) to conclude that both metacontrast and apparent motion involve the same type of processing. However, before outlining these similarities various masking techniques will be briefly described.

4.1.3 Masking experiments.

The most common form of masking is `backward' masking, where the masking stimulus (MS) arrives after the target stimulus (TS), and affects the processing of the TS (Haber & Hershenson 1973). In backward masking tasks different masking stimuli have been employed, and have produced different effects. These fall basically into the following groups: masking by light, masking by visual noise, metacontrast, and masking by form. In masking by light, the MS is a large pulse of light presented after a smaller and dimmer TS (Boynton 1961). In masking by visual noise, a display, such as a collection of line segments, is used as the MS (Haber & Hershenson 1973; Sperling 1963). Metacontrast, on the other hand, is concerned with spatial interactions incorporating temporal parameters, and, in this instance, masking is caused by adjacent contours (Kahneman 1968). In this form of masking the TS is generally a geometric shape or letter and is presented for a certain duration. After a variable ISI the MS, which is often identical to the TS, is presented adjacent to the TS. Lastly, masking by form uses a pattern similar to the TS, unlike masking by visual noise, and this pattern is usually superimposed over the TS.

It is assumed that MS either interferes with processing by erasing the TS (Averbach 1963) or interrupting the processing of the TS (Sperling 1963). A contrasting view is offered by Eriksen & Collins (1967, 1968) and Kinsbourne & Warrington (1962a, 1962b) who argue that integration of the TS and MS occurs. However, it is possible that both processes are operating at the same time (Turvey 1973).

A number of models have been put forward to explain masking, and are discussed by Breitmeyer (1984). The models which assume that similar processes are involved in the perception of apparent movement and metacontrast fall under the classification of spatiotemporal sequence models. In these models it is assumed that metacontrast is the result of the perception of impossible motion in the stimuli.

In metacontrast two kinds of masking effects have been identified, one labelled Type A and the other Type B (Kahneman 1968, Kolers 1963). With Type A masking the magnitude of the masking effect has been found to be at its greatest when the SOA is equal to zero and much forward masking occurs. In Type B masking the magnitude of the masking effect is greatest when the SOA is in the order of 50-100 msec, and little forward masking occurs. Type B masking is more readily studied, and has also been studied in relation to apparent movement (Kahneman 1967; Didner & Sperling 1980; Fisicaro Bernstein & Narkiewicz 1977).

Kahneman (1967) has referred to metacontrast as being the result of a reduction in the TS brightness when adjacent stimulation by an MS occurs, while metacontrast suppression occurs when the TS is no longer seen at all (Alpern 1952). One of the most important results found in experiments utilizing this procedure is the U-shaped function obtained when accuracy is plotted against SOA (Kahneman 1968; Didner & Sperling 1980). When the luminance of the mask is increased, the masking effect has been found to increase as well (Alpern 1953). Fisicaro et al. (1977) have argued that the relationship between the SOA and the masking effect exists irrespective of whether subjects are making contour or brightness judgments.

The are a number of similarities in the techniques used to study the phenomenon of apparent motion and metacontrast. Firstly, in both techniques two stimuli are presented successively, with varying intervals between them (Pollack 1966a). As well, factors which are important to masking experiments, such as figure-ground contrast and contour orientation, have also been found to affect the perception of apparent movement (Pollack 1966a; Pollack 1966b)

An important spatiotemporal model put forward to explain apparent motion and masking has been postulated by Kahneman (1967). In his article he points to three similarities between metacontrast and the perception of apparent movement. Firstly, in both instances the perception of motion is reported. Secondly, in regard to temporal separation between the first and second elements of the stimulus display, optimal motion and metacontrst suppression are U-shaped functions. Thirdly, in cases where the temporal difference is too short for complete suppression or optimal movement, the brightness and contrast of the first stimulus is reduced. Kahneman (1967) argued that, if a subject is presented with two brief stimuli, as in the case of techniques developed to induce the appearance of apparent movement, there is a large degree of response overlap, given that a brief stimulus elicits a response longer in duration than the stimulus. The closer the presentation of stimuli, i.e. the shorter the ISI, then the larger the amount of response overlap. Motion is then perceived after the first stimulus has been removed while the second is present, and depends mainly on SOA and the duration of the first stimulus.

Kahneman (1968) also argued that apparent motion was phenomenally similar to perceptual delay. Information pertaining to the first stimulus may be perceptually delayed until information about the second stimulus is available. Matteson and Flaherty (1976) provide data which support this suggestion. In their experiment subjects were required to make temporal order judgments. When analysing the subjects' judgments they found that perceptual delay explained both masking and apparent motion.

Other work in this area has been concerned with examining the idea that the perception of optimal motion and metacontrast may both be explained by a U-shaped function, as reported by Kahneman (1967). Weisstein & Growney (1969) have reported that varying qualities of the stimulus, e.g. stimulus duration, luminance level, visual angle separating the test and mask, and test mask temporal asynchrony, leads to subjects rating the `goodness' of movement and `effectiveness' of metacontrast differently, i.e. the amplitude and shape of the metacontrast function changed with visual angle, while the apparent motion function remained invariant. From this they concluded that there was only a weak association between the two. In contrast, Breitmeyer, Love & Wepman (1974) used a discrimination task which required subjects to judge whether the two stimuli (disks) were the same or different. The two disks could be judged the `same' if both were complete circles or both had contour deletion. They could be judged different if one was a complete circle or one had contour deletion. Similar results were obtained when the stimuli were presented according to both the technique used to study metacontrast and apparent motion. In both, subject accuracy was a U-shape function of temporal delay, suggesting that a similar process may be involved in the perception of motion and in masking. Different results obtained in the experiments conducted by Weissten & Growney (1967) and Breitmeyer et al. (1974) may be due to the use of different types of response measure, i.e. a rating of goodness vs accuracy in same-different judgments, or due to the different judgments subjects made, i.e. brightness vs contour. In an attempt to resolve this issue Fiscaro, Bernstein & Narkiewicz (1977), conducted an experiment concerned with the subject's ability to judge accurately whether the brightness of the test or masking stimulus was set to `bright', `medium' or `dim' condition. Results from this experiment supported the notion that there are similarities between the phenomenon of apparent motion and metacontrast as when the stimuli were presented according to techniques designed to examine these phenomena, a U-shaped function was obtained between accuracy and SOA.

The final point to be made about metacontrast is that it has been used to demonstrate that pattern and motion are processed by separate systems (von Grunau 1981), as consistent with the suggestions made by Kolers (1972) concerning the perception of apparent motion. Masking affects the processing of pattern alone and not movement. Therefore, the actual masking effect may be the result of an interruption of earlier processing stages than those concerned with the perception of movement.

The other interesting masking task which has been developed is masking by form. In this instance, masking is produced by a MS which is similar in appearance to the TS rather than a collection of dots or pattern. The procedure is also distinct from metacontrast in that the MS is usually imposed over the TS. Using this type of task, Turvey (1973) conducted a series of experiments. Basically he compared the effectiveness of noise and pattern masks under a variety of conditions, such as monoptic and dichoptic viewing. The TS used in the experiment was the letter T, and this was followed by a patterned mask, consisting of a series of lines of the same thickness as the target. His study showed that perceptual impairment caused by masking could occur peripherally as well as in the central processor. Masking by a noise pattern was interpreted as peripheral interference under conditions of monocular and binocular presentation, and appeared to be described by Equation 4.1.

TS energy x ISI = k (a constant) 4.1

Operations which are performed by the peripheral system are thus directly influenced by the energy of the stimulus. In contrast, masking by pattern is an example of central processing, where the parameters of duration and intensity produce negligible effects. However, the SOA appears to be an important variable in central processes, and Turvey concluded that the input processing mechanism, or central processor, is more affected by the informational than by the energy characteristics of the stimuli. He concluded that *"the relevance of stimulus onset asynchrony to masking of central origin suggests that the constraint on central processes is simply time elapsed since stimulus onset"* (Turvey 1973 p 19). Equation 4.2 most accurately described his suggestion.

TS duration + ISI = k (a constant).....4.2

This indicates that TS duration, rather than TS energy is a main component of central, as opposed to peripheral, processing.

4.2 The Inspection Time task.

A variation of backward masking by form has been developed by Vickers, Nettelbeck & Willson (1972), and is referred to as the inspection time task. The IT task differs from other masking tasks in two ways. Firstly, the MS is similar in appearance to the TS, and secondly it follows a procedure whereby the ISI is set at 0 msec and the TS duration is systematically varied.

The IT task, was developed from the classical experimental procedures discussed earlier in this chapter. Like these tasks, the IT task was built on the assumption that the sampling of information was conducted discretely (Vickers & Smith 1986). In the previous tasks the hypothesis of perceptual framing (or the perceptual moment) assumed that the perception of stimulus differences, or the perception of a series of events, was constructed from a series of observations made in discrete intervals of time. If two stimuli fell in the same interval, then subjects would perceive only one stimulus as occurring. In order for the subject to be able to distinguish between the two stimuli, they must fall into two distinct sampling intervals. The IT is therefore another experimental task designed to provide evidence that there is some temporal limitation in the rate at which information is processed. The IT is defined as the minimum target duration necessary for accurate discriminatory performance (Nettelbeck 1987).

In the IT task subjects are presented with two vertical lines of different lengths, with the upper ends terminated by a horizontal line. This stimulus is exposed for varying lengths of time, and then masked by a similar stimulus, thereby stopping subjects sampling from information in stored traces. A constant difference between the vertical lines, corresponding to .8°, is maintained so as to be 2.7 times the mean value of internal noise estimated from a psychometric function of the elderly subjects studied by Botwinick et al. (1958). The exposure of the stimulus is commonly varied during the experiment in a series of 20 msec steps according to an adaptive staircase procedure, detailed by Nettelbeck (1987), and referred to as Parameter Estimation by Sequential Sampling (PEST) (Taylor & Creelman 1967). In this procedure the stimulus onset asynchrony between target and mask onset is lengthened or shortened depending upon the individual subject's accuracy level.

Since the task involves discrimination processes it is believed that each inspection of the stimulus is accumulated and a response is made as envisaged by the Accumulator model. In the Accumulator model it was proposed that a decision was dependent upon the accumulation of a series of sensory intensities in a number of separate stores, depending upon the number of response options available. Information for positive stimulus differences is accumulated in one store, t_g, and information for negative stimulus differences is accumulated in another store, t_l. After reaching a threshold, k_g, in the case of a trial where V>S (or k_l, in the case of a trial where V<S), a decision is made in favour of one or the other of the corresponding alternatives. The accumulation process depends upon a series of discrete inspections of evidence. The time taken (T_A) to make a particular response (R_A) has been represented by the function 4.3,

$$T_A = r + \lambda N_A \ldots\ldots\ldots\ldots 4.3$$

where r is the measure of residual or non-decision time, associated with such factors as movement time, N_A is the number of observations required to reach a decision and λ is the time required to take a single observation, i.e., the inspection time (Vickers & Smith 1986). In the IT task it is assumed that the values of k are exceeded on the first observation, so that a decision is made after sampling only one stimulus difference.

As with the discrimination models discussed in Chapter 1, it is assumed that accumulation occurs against a background of neural noise, which may also be estimated. In the study of Vickers et al. (1972 p. 276) experimental noise (σ) was regarded as "the standard deviation of the best-fitting normal ogive, calculated for the psychometric function" obtained in their experiment. The experiment involved a forced-choice discrimination task utilizing the MCS procedure, with the stimuli being presented for 100 msec before backward masking. Like the measure of IT, estimates for σ have been found to be both stable and reliable. Furthermore, estimates of this parameter have been found to vary according to external factors, such as giving subjects painful electric shocks (Nettelbeck 1972), which appeared to raise the level of noise.

Using the 97.5 % level of accuracy it has been found that estimates for IT in normal adult populations tend to approximate the perceptual moment of approximately 100 msec. Longer values for IT, e.g. 200-250 msec have been recorded in retarded populations. A number of studies have incorporated test-retest procedures, and it has generally been found that the measure is highly reliable over time. For example, Nettelbeck & Wilson (1985 study 3) reported a correlation value of r=.90 (N=10) for university students after a re-test session one year later than the initial session, and a correlation of r=.87 (N=10) after a re-test of 2 weeks later. Other studies utilizing larger sample sizes have also reported strong correlations. For example, Longstreth, Walsh, Alcorn, Szeszulski & Manis (1986), reported a correlation value of r=.75 (N=81) and Vernon (1983) reported a correlation or r=.80 (N=50).

4.3 Individual differences in speed of processing.

4.3.1 Intelligence and individual differences in the measure of inspection time.

As outlined in Chapter 1, there has been a considerable amount of research conducted concerned with individual differences in the speed of human reaction, as measured by RT. The main impetus for the study of individual differences in RT came from Galton, who argued that RT should show individual variation according to the individual's mental ability. Following Galton, most early research concerned with individual differences concentrated on intelligence and the speed of reaction. This interest was further stimulated by Hick (1952), who proposed a law relating RT to the number of bits of information processed by a subject in a choice RT experiment. More recently, Jensen (1982a,b) has isolated a number of associations between performance in a Choice RT paradigm and intelligence. Jensen has concluded that individuals with higher IQ scores can process information correctly at a faster rate than subjects lower in IQ.

One such paradigm, known to demonstrate individual differences, is the IT task. One of the earliest studies examining the relationship between IT and IQ (WAIS) reported a corelation of r=-.70 (p<.05) (Nettelbeck & Lally 1976). The magnitude of the relationship between IT and IQ has been found to vary from -.87 (Anderson 1977; cited in Nettelbeck 1987) to a value of r=.10 (ns) (Vernon 1983). Nettelbeck (1987) has listed sixteen studies which have examined correlations between IT and general intelligence measures. Of those studies, a number of them completed some sub-studies, so that, of the 16 research reports, 34 correlations were obtained between IT and IQ. Out of the 34 sub-studies, 21 achieved a significant one tailed correlation value. The significant values were obtained in experiments where different subject samples were used and different psychophysical procedures, such as the method of constant stimuli (MCS) and the PEST procedure were used. Furthermore, the significant correlations were obtained across different sensory modalities. As well as the visual discriminanda commonly used, some of the studies listed have recorded significant correlations between IT and IQ in both the auditory (Irwin 1984) and tactile modalities (Nettelbeck & Kirby 1983).

4.3.2 Personality and individual differences in the measurement of inspection time.

Unlike the research concerned with intellectual differences and RT performance, there has been a more diversified approach with respect to individual differences in personality, particularly as measured by the EPQ. The dimension of P, E and N have been associated with a number of psychological phenomena, including conditioning and various types of after-effects. However with regard to personality differences and RT, no one particular RT paradigm has been used, and no consistent effect has been reported. (The research in previous chapters has also highlighted the problem of consistency in the association between performance in the EJT and personality).

Some research has been conducted with the IT paradigm and the Eysenckian dimensions of personality (Brebner & Cooper 1986). In their experiment they employed a `fast' and `slow' condition of the IT task, which varied the presentation speed of the warning signal. It was found that extraverts had significantly shorter IT's. However, subjects' performance was also dependent upon the condition and upon whether they appeared to be strategy users. Brebner & Cooper (1986) interpreted their results in terms of stimulus analysis and response organisation. According to Brebner & Cooper, introverts find it more difficult to process a stimulus which is presented for short exposures, as they prefer to inspect information for longer periods than extraverts.

4.4 Problems in relating theories of individual difference to inspection time.

4.4.1 Problems with inspection time.

In Chapter 1, a number of important problems in both the interpretation of RT and in theoretical approaches to individual differences were addressed. It was suggested that one of the main problems was the theoretical approach of both individual difference theorists and RT theorists. It was argued that individual difference theorists adopted a physiological approach and interpreted RT as a sensorily determined measure, involving few cognitive components. In contrast, theories which have been devised to explain performance in discrimination and RT paradigms have concentrated on a series of hypothetical mechanisms or stages which are affected by both cognitive and sensory constraints. Individual difference theorists assume that RT is relatively free of `top down' processing components and can therefore be used as a `culture fair' measure of intelligence. The cognitive strategies that could be used by subjects were dependent on the type of RT experiment utilized. For example, in the choice RT paradigm, one strategy that could be used is the transference of practice (Longstreth 1984). Subjects can also use strategies in RT tasks where the combination of a home key and response key is incorporated. Subjects may respond quickly by pressing the response key, and, in that response time, include part of the decision making. Thus the response time not only involves the movement time but also decision time. (Nettelbeck & Kirby 1983; Smith & Carew 1987; Welford 1986).

The IT is also affected by cognitive strategies. However, as the task does not involve measures of RT or MT, the strategies associated with these measures are avoided. However, like the measure RT, it has been regarded as a strategy-free index, with little `top down' interference, and is often regarded as providing a culture-fair index of intelligence. Recently, a number of experiments have claimed that the IT is not free from the effects of strategy use. One of the main strategies employed by subjects is an apparent motion strategy, initially discussed by Nettelbeck (1982). Here subjects have reported that they judge a trial as being `V>S' or `V<S' by relying on a sensation of movement, or a bright flash in the stimulus configuration, when the masking stimulus appears. A number of studies have been conducted examining this strategy, referred to as the use of apparent motion cues, by Mackenzie and associates (Mackenzie & Bingham 1985; Mackenzie & Cumming 1986). In particular, they have found that subjects who appear to use the apparent motion strategy record significantly faster ITs. They also found that the inclusion of cue-using subjects reduces the size of the correlation between IT and IQ. For example, in Mckenzie & Cummings' (1986) experiment, the overall correlation between IT and IQ (Advanced Progressive Matrices) was $r=-.45$ ($p<.01$). For the non-cue-using sample a correlation of $r=-.66$ ($p<.01$) between these two variables was obtained. In contrast, for the cue-using sample a correlation or $r=-.19$ (ns) between IT and IQ was estimated.

There appears to be no other variable associated with cue using. Cue users do not have higher levels of intelligence. In Mackenzie & Bingham's (1985) study cue users did not achieve a significantly different score on the WAIS, full scale, verbal or performance sub-scales. Likewise, cue users do not have greater levels of sensitivity to movement, as measured by apparent motion. Mackenzie & Cumming (1986) showed that subjects' reports of optimal movement in an apparent movement experiment did not correlate with IT. For both cue users and non cue users, optimal motion was reported at approximately 97 msec. Brebner & Cooper (1986) have argued that cue using is related to personality. In the fast condition of their experiment they found that, extraverts who were strategy users ($\bar{X}$=68 msec), reported much smaller values for IT than extraverts who were not strategy users ($\bar{X}$=200 msec). In contrast, introverts who were strategy users ($\bar{X}$=180 msec) were not only slower than extraverts who were strategy users, they were also slower than the introverts who were non strategy users ($\bar{X}$=160 msec). An identical trend was reported in the slow condition of Brebner & Coopers (1986) experiment.

Another strategy that can be used by subjects is discussed by Egan (1986) and Fitzmaurice & Nolan (1983). These authors have argued that subjects use `probabilistic strategies'. It is suggested that certain subjects, particularly those with high IQ's attempt to guess the response and may be aided by systematic runs of repetitions and alterations in the stimulus configuration. To avoid this particular problem a more complicated task may be used, increasing the amount of stimulus information, and thereby limiting the occurrence of repetitions.

Culture-specific activities such as individual skill at computer games, have also been examined as another form of strategy. Mackenzie & Cumming (1986) have argued that previous experience with computer games may be associated with better performance in the IT task. At face value, the results from their study suggested that subjects who regularly played video games had faster ITs, reported apparent movement at smaller values for ISI, and were generally younger. Subsequent analysis revealed that the differences produced were an artifact of the differences between the groups in age and APM scores. While this study disconfirms the effect of certain culture-specific activities, such as computer games, more investigations are needed. One problem with analysing differences within Western cultures is that rapid display of visual information on screens is common. Computers are used frequently in work as well as in a leisure context. As a result it would be very difficult to obtain a control group.

Nettelbeck (1987) has also suggested that different types of experimental samples will use different types of strategy. He has noted that RT distributions, recorded by certain populations used in the IT/IQ research, such as retarded and non retarded adults, are different. Evidence for these differences was found in an experiment conducted by Lally & Nettelbeck (1977), and also in one by Nettelbeck, Kirby, Haymes & Bills (1980). For non-retarded adults, RT conforms to the predictions made by the Accumulator model. Correct response times for normal subjects are found to be faster with increased SOA. Error response times are longer than correct response times. In contrast, retarded adult samples have been found to record more or less constant RTs across all TS durations for both correct and incorrect responses. Nettelbeck (1987) and Smith (1986) have argued that this style of performance is indicative of deadline responding. However, an alternative explanation is that these subjects have adopted very low sensory thresholds, in which case the difference between mean reaction times for correct and incorrect responses becomes negligible (Smith & Vickers 1988).

In addition to strategy use, perceptual adaptation may also affect the estimate of IT. As outlined in the previous chapters, the IR may also be a parameter sensitive to adaptation. The IR was regarded as a sensory referent responsible for the classification of evidence. Depending on the size of the IR, information of varying intensities could either be accumulated or disregarded. In the case of IT, the IR may affect subjects' accuracy. If the IR is large, more trials will be rejected, or judged incorrectly, as the V-S difference may not exceed the IR. When subjects are performing at the level of a single inspection, an increased error level would be expected if a larger IR value was employed. In both the PEST procedure and MCS, a large IR causes an inflation of IT (Vickers & Smith 1986; Nettelbeck 1987).

4.4.2 The EJT a replacement for IT?

Evidence has been provided showing that the IT task can be affected by strategy use, and by adaptation, and is also dependent upon the response threshold. In view of these problems it is important to examine other experimental procedures which also provide estimates of discriminative performance. In order to qualify as a substitute, the other experimental task must be able to limit strategy use and adaptation. One task which can simultaneously control strategy use and provide estimates of subjects' discriminative performance is the EJT. In the EJT subjects cannot use apparent motion cues to facilitate performance, as multiple stimuli are presented within an experimental trial. Furthermore, as the stimulus information pertaining to a V>S or a V<S response is presented randomly within each trial, and V>S and V<S trials are presented randomly, it is very difficult for subjects to rely on some sort of inferential strategy within or between trials. It has also been found that adaptation, as measured by the IR, does not determine subjects' accuracy. This is particularly the case in tasks where the amount of information presented within a trial is pre-determined, such as the E-paradigm.

In most RT tasks, a single stimulus is presented to the subject in each trial. It is assumed in most Probabilistic models of RT, that the subject samples a series of covert observations or makes a series of internal inspections of this stimulus. The EJT attempts to externalise these internal observations by presenting a series of stimuli within a trial. The task is similar to a behavioural decision making task where the subject views a sequence stimuli (Sanders & Ter Linden 1967). In the EJT it is assumed that each line segment should ideally correspond to the time it takes to make one covert inspection. The subject makes a series of inspections. While it was argued in Chapter 1, that this appeared to be the case, a number of qualifications have to be made. The common estimate for IT is about 100 msec, making it equivalent to the perceptual moment. The time representing the subjects' IT represents the time it takes for the subject to accurately perform a simple discrimination. It is also believed that only one covert observation is sampled. The EJT is somewhat different. In this task one piece of information has been presented for 175 msec, and a gap of 150 msec exists before the next line segment within that trial is presented. As the information is not masked immediately, the subject is still able to sample information from stored traces. As each line segment is not immediately masked, subjects with small ITs will be able to take more internal observations of the information, and gather more information about the stimuli. In cases where a fixed number of line segments is presented, as in the E-paradigm, subjects with smaller inspection times are expected to have higher levels of accuracy, as the number of covert observations taken within that trial will be greater. Using the rate of stimulus presentation used in previous E-paradigm experiments it would be useful to examine whether an association between accuracy, latency, IT and IQ is apparent. The next step could be to modify the presentation rate. If the presentation rate was increased to one stimulus (line segment) every 40 msec or 80 msec the number of covert observations the subject could sample would be limited, as in the IT task. If this were done, a larger degree of individual variation in a homogeneous population like university students could be obtained.

As subjects are making a series of inspections in the EJT, subjects who have a poor accuracy level may be losing observations at random, or utilizing the information less efficiently. Performance in the EJT may therefore be a measure of the rate of information acquisition. The early studies concerned with the information acquisition were conducted by Cheatham & White (1952) and White (1963). In Cheatham & White's (1952) experiment, subjects were presented with a train of visual stimuli consisting of a flashing light set at varying rates of 10, 15, 22.5 and 30 per second. The subjects had to report how many flashes they saw. The results indicated that, when 5 flashes at 30 per second were presented, the subject perceived 2 flashes, and, when 10 flashes at the rate of 30 per second were presented, subjects saw 3 flashes. When the perceived number of flashes was plotted as a function of time, a plateau in the function was found to occur at the point of about 300 msec from the time of onset. This was then followed by an increase in the function. The slope of the function was found to correspond to a rate of about 6-7 pieces of information per second before the plateau and about 10-12 items beyond the plateau (White 1963). The conclusion White drew from this experiment and others, was that a cyclical process in the CNS interacted with afferent neural activity, which resulted in limitations in the perceptual system when examining a series of events. The two different rates were thought to correspond to two different processes. White (1963) argued that the function represents the activity of peripheral processes, and that at the point of 300 msec, a central process is engaged, which determines the maximum rate at which perceived units can be added.

For the EJT, it is expected that there will be a distinct limitation as to how many samples can be accumulated. The limitation will depend upon the subject's inspection time. The strong correlation between IT and IQ suggests that certain subjects, with higher levels of intelligence can accumulate information more efficiently. In the EJT it would be expected that subjects with higher IQs would achieve more correct responses because of their ability to process information more efficiently.

CHAPTER FIVE.
THE EXPANDED JUDGMENT TASK AND PERCEPTUAL INTERMITTENCY.

5.0 Introduction.

The EJT is a task in which the rate of information processing clearly appears to play an important role. Specifically, as argued in Chapter 3, accuracy of performance in the EJT appears to be limited by the rate at which the sequence of stimuli can be registered and perceived as input to a decision mechanism. If performance measures linked to periodicity are obtained from classical experimental tasks, such as apparent motion, and CFF, then it would be expected that they should correlate with measures such as IT and accuracy scores in the EJT.

In this chapter, two experiments have been designed to examine this possibility. In the first experiment, which was a pilot investigation, measures of psychophysical thresholds for the perception of flicker and fusion, apparent motion and simultaneity, IT, and accuracy in the EJT were inter-correlated. In the second experiment, the rate of information presentation in the EJT was increased, and a larger subject sample was drawn so as to analyse individual differences more adequately.

A. EXPERIMENT 4. Temporal intermittency, IT and the EJT: a pilot investigation.

5.1. Method.

5.1.1 Subjects.

Thirteen undergraduates enrolled in Psychology II participated in this experiment as subjects. All had normal or corrected vision and were naive with respect to the aims of the experiment.

5.1.2 Apparatus: presentation and registration of responses.

The five experimental tasks completed by subjects in this experiment were controlled by computer programs run on Northstar Advantage computers.

(a)The EJT.

For the EJT a series of green horizontal line segments of varying lengths were displayed. The stimuli used in this experiment were identical to those reported in section 2.5.2 The line segments were drawn from one of two distributions with a μ of 2.33 or -2.33 and a common σ of 6.0. The procedure detailed in section 2.5.5 was employed. Subjects were told that they would observe a number of line segments in a trial, and that the number of line segments would vary from trial to trial. They were instructed to observe the display and determine whether on average the end point of the line segments fell to the left or right of the mid-line. When the trial terminated they were told to respond immediately by pressing one of two microswitched keys. To start the next trial subjects pressed the home key. All responses were made with the index finger of the preferred hand. Furthermore, they were informed that the a priori probability of a right or left trial was .50. Subjects completed 20 practice trials, and then 1 block of 200 trials with 100 trials having a right endpoint and 100 trials having a left endpoint.

(b) Inspection time (IT).

For the IT the stimulus shown in Figure 5.1 was utilized. In the case of the target stimulus one of the vertical lines measured 11.00 mm in length and the other 31.90 mm, and a distance of 9.39 mm separated them. Both vertical lines had their upper ends terminated by a horizontal line. The difference between the vertical line lengths corresponded to 0.8 degrees of visual angle. This difference was chosen to minimize the probability of error following one inspection of sensory input. The target stimulus was followed by a masking stimulus which lasted for 1000 msec. Figure 5.1 illustrates the temporal sequence of events. To obtain an index of inspection time an adaptive computer program employing the PEST procedure (Taylor & Creelman 1967) was utilized. The level of accuracy the subject had to reach was set at 97.5%. Subjects were instructed to observe the display and to determine which vertical line of the stimulus appeared to be the shortest. They were also instructed that the appearance of the shortest line on the left or the right of the display was random. Subjects completed 40 practice trials before the experimental session.

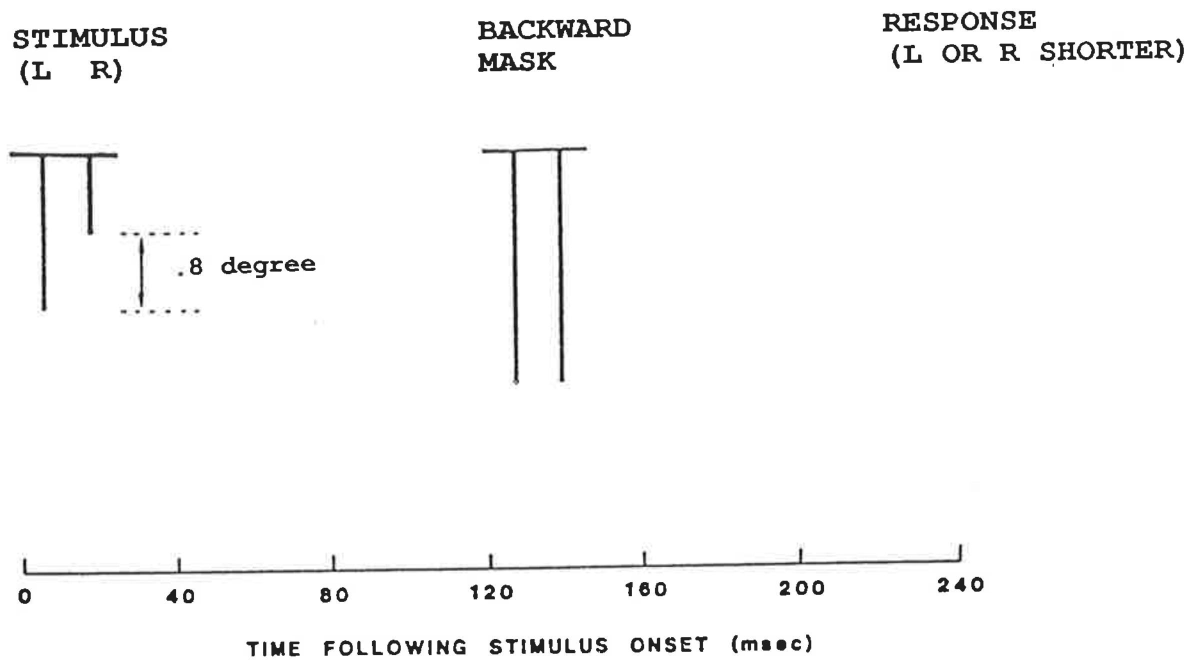

Figure 5.1 *The temporal sequence of events in a typical inspection time task trial. The target stimulus (TS) is followed by the backward masking stimulus (MS). (From Vickers & Smith 1986).*

(c) Apparent Motion (AM).

The apparent motion (AM) experiment employed two rectangular shapes that were sequentially presented on the computer screen. Each rectangular shape measured 26.14 mm by 5.84 mm, and was separated by a distance of 26.14mm. The interstimulus interval between the presentation of each shape was programmed to be either 20, 40, 60, 80, 100, 120, 260, or 320 msecs. In this experiment, the estimation of the movement threshold was made by the method of constant stimuli, where a fixed number of trials for each inter-stimulus interval are exposed randomly during an experimental block.

Subjects were told to inspect the stimulus on each trial and determine whether the display appeared to be simultaneous, moving or discrete. "Simultaneous" was described as the appearance of two simultaneously present stimuli, "moving" as the movement of single stimulus from one position to the other, and "discrete" as two stimuli appearing successively in two different positions. Subjects responded by pressing one of three microswitched keys labelled as `discrete', `moving' and `simultaneous'. Subjects completed 36 practice trials before completing one experimental block of 140 trials.

(d)Critical flicker fusion (CFF).

For the CFF experiment the observed stimuli was a red stroboscopic light measuring 43 mm in diameter. This was flashed at various rates determined by an adaptive computer program employing a PEST procedure (Taylor & Creelman 1967). The accuracy level was set at 50%. Therefore subjects had to respond consistently 50% of the time for a given cycle rate. For each trial, subjects were told to decide whether the display appeared to be fused or flickering. "Fused" was described as a light which was continuously present in appearance, whereas "flickering" was described as a light which intermittently flashed. Subjects responded by pressing one of two microswitched buttons marked either `flicker' or `fused'. Subjects were given 25 practice trials before completing the experimental session.

(e) The perception of simultaneity (SIM).

For the simultaneity experiment (SIM) the stimuli consisted of a grating, comprised of 12 red horizontal bars each measuring 53 mm across by 3 mm. The bars were successively lit at a cycle rate controlled by a computer program. Like the CFF experiment, the estimated threshold value was obtained by the PEST program with an accuracy criterion set at 50%. Subjects were instructed to view the display, and to determine whether the display was simultaneous or successive in appearance. Subjects responded by pressing one of two microswitched keys marked either `successive' or `simultaneous'. Subjects were presented with 25 practice trials.

5.1.3 Tests and measures - The Standard Progressive Matrices.

The written test given to the subjects in this experiment was the Standard Progressive Matrices (PM 38). The PM 38 is a non-verbal intelligence test originally designed by Raven (1938).

The test involves completing 5 sections, A,B,C,D,E, each containing twelve problems, which vary according to difficulty. A time limit of 2 minutes for Set A, 3 minutes for Set B, 4 minutes for Set C, 5 minutes for Set D, and 6 minutes for Set E, is recommended. The raw scores can be converted to an I.Q. range as outlined in the Test Manual.

5.1.4 General Procedure.

All subjects completed the Standard Progressive Matrices, according to the procedure outlined in the test handbook. Following this, subjects then completed the CFF, SIM, AM, and IT experiments in random order. Each experiment was conducted in a darkened room. The EJT was completed approximately one week later by all subjects.

5.2 Results.

In this experiment performance measures from each of the experimental tasks was obtained. For the EJT, the measures of mean post summative decision latency in msecs (LAT), and accuracy (NC) were recorded. For the IT task a measure of the minimum stimulus duration (msec) at which subjects achieved 97.5% level of accuracy represented the index IT. The measure that represented the perception of apparent motion (AM) was the inter-stimulus interval (in msec) that the subject classified most frequently as moving. The measure that represented the threshold for perception of fusion (CFF) was the duration (msecs) of a single flash. Likewise the measure that represented the threshold for the perception of stimulus simultaneity (SIM) was the time it took for one cycle (msecs). Results from the PM 38 were also obtained.

In the results section the means and standard deviations for all the measures are presented first, followed by an analysis of the E-paradigm variables and their association with estimates of intelligence, IT and the perceptual threshold measures.

5.2.1 Means and standard deviations.

Means and standard deviations for all the experimental measures are presented in Table 5.1.

Table 5.1 *Means and standard deviations for all experimental measures. The measures LAT, CFF, AM, SIM and IT are in terms of msecs. NC was the number of correct responses obtained in the EJT, and PM 38 was the raw score for the standard progressive matrices.*

	Mean	SD	N		Mean	SD	N
LAT	1721.5	347.0	13	NC	163.1	3.6	13
CFF	23.7	2.1	11	SIM	100.6	32.6	13
AM	107.6	35.1	13	IT	119.0	44.1	13
PM38	50.2	4.0	13				

An examination of these experimental measures shows that the perceptual thresholds representing perceptual simultaneity (SIM) and apparent motion (AM) approximate 100 msec. The index for IT approximated this value as well, but CFF was quite different.

5.3 The EJT.

Consistent with previous experiments there was no correlation between LAT and NC ($r=-.10$ $p=.38$), suggesting that variation in subjective caution had no systematic influence in this experiment.

5.3.1 The EJT and its relationship to other experimental measures.

Intercorrelations between experimental measures, as presented in Table 5.2, showed that only one significant correlation was obtained. The only correlation was between the measure of IT and the number of correct responses in the EJT ($r=-.61$ $p<.01$). In this case, subjects who have large inspection times

Table 5.2 *Pearson correlation coefficient matrix of all of the main variables measured in this experiment. For each correlation the sample size equals 13 except for those involving CFF where the sample size equals 11.*

	SIM	AM	IT	LAT	NC	PM38
CFF	.05	-.43	-.01	-.13	.19	.40
SIM	-	.35	.20	-.01	-.25	-.26
AM		-	-.20	.32	-.09	-.35
IT			-	.02	-.61*	.13
LAT					-.10	-.04
NC						-.26

* p<.01

tend to produce fewer correct responses.

There were also no significant correlations between performance, threshold and intelligence measures.

5.4 Discussion

5.4.1 Periodicity.

The main purpose for conducting this study was to investigate whether limitations in processing might be due to a limitations in a temporal processing mechanism. It was hypothesized that periodicity should affect the accumulation of evidence, with those subjects having longer estimates for the perceptual moment being able to accumulate less information within a given time, and generally having poorer temporal resolution. Evidence from a large number of experiments, including studies concerned with masking, simultaneity and apparent motion, indicates that the perception of stimuli as occurring discretely or successively depends upon the stimulus exposure rate and upon the inter-stimulus interval. For example, the work of Kahneman (1967) demonstrated that, if two events occurred in a time span less than the critical duration of the perceptual moment, then they would be perceived as occurring simultaneously. Subjects' inability to accurately discriminate in the IT paradigm also depends upon the duration of a TS before masking (Nettelbeck 1982, 1987; Vickers et al. 1972), indicating that there is a minimum duration required for stimulus presentation before the subject can make accurate judgements. Temporal limitations in processing may also be assumed to affect the perception of a series of stimuli. For example White's (1963) work on temporal numerosity indicated that there is a distinct limit in the rate of processing and acquisition of information.

If thresholds for the perception of motion, flicker and simultaneity are limited by temporal resolving capacity, and hence by the rate at which information can be processed, then it would be expected that the measures of the various perceptual thresholds should be correlated. While the experimental sample size was quite small, there was no correlation between any of these measures. The estimates for the perceptual thresholds of motion, simultaneity and flicker were not consistent across tasks. That is, low threshold estimates in one task were not accompanied by low threshold estimates in another.

The failure to obtain significant intercorrelations might indicate that the tasks used involve different processes. This may be so particularly in the case of the CFF, which not only failed to relate to other indices, but also exhibited a vastly different mean estimated threshold. Murphree (1954) also found that subjects' estimated threshold for fusion was quite different to estimates of the perceptual threshold for apparent motion. The main difference between the CFF and the other tasks is that the CFF requires virtually no processing of pattern information, since a very simple stimulus consisting of a single light is employed. In addition, when compared to AM, there is no demand for movement processing, as the stimulus has little appearance of actual movement.

Subjects' reports of apparent motion have been found to correlate with metacontrast performance (Kahneman 1967). While this relationship was not tested in this experiment, the relationship between the threshold for apparent motion and estimates of inspection time was tested. An association between these two measures was expected, as both were assumed to be related to the duration of the perceptual moment. Furthermore, intercorrelations were expected, as recent research indicates that apparent motion is a type of cue used by subjects in the IT task (Mackenzie & Cumming 1986). However, an insignificant correlation between IT and AM obtained in this experiment. For a more detailed examination of this issue it would be necessary to employ a larger sample, separating cue-users from non cue-users, and to examine the relationships between AM and IT within each sub-sample, as was done by Mackenzie & Cumming (1986).

The absence of a significant correlation may be due to the fact that the IT experiment involves subjects making a simple (V-S) discrimination, whereas, according to Kolers (1972), apparent motion is a complex phenomenon, requiring the subjects to process both motion and features of the stimulus. In Kolers' view, apparent motion is different from masking in that it is an information-building activity, involving multiple stimulus presentations in one trial, whereas masking is an information-destroying activity.

Another possible reason for the failure to obtain a significant correlation is that different estimation criteria are used for IT, CFF, SIM, and AM. While IT, CFF and SIM all utilized the PEST procedure (Taylor & Creelman 1967), based on the methods of limits, the procedure is somewhat different for IT, since, for IT, a stringent accuracy criterion is set. By imposing a strict accuracy criterion, the subject is obliged to perform accurately and consistently. In the other tasks, such as the CFF, SIM and AM, subjects have simply to be consistent in their responses.

One of the main findings of this experiment was the correlation between IT and the number of correct responses in the EJT. In both tasks, subjects perform a simple (V-S) discrimination, and subjects who can accurately discriminate in a task involving a single observation, can also accurately discriminate in a task involving multiple observations. This significant correlation indicates that further experimentation examining the relationship between IT and the number of correct in the EJT is necessary, and that accuracy in the E-paradigm can also be used as an index of processing speed in addition to IT.

5.4.2 Individual Differences.

Finally, in this experiment, measures of IQ were obtained. It was hypothesized that individuals with a smaller perceptual moment would have higher levels of intelligence, and have the ability to accumulate more information. Experimental evidence reviewed by Nettelbeck (1987) demonstrated that strong negative correlations between IT and IQ have been reported. The association between IQ and CFF, and IQ and AM is less clear. For CFF, contradictory results have been reported. For example, Barratt, Clark & Lipton (1962) reported a significant correlation ($r=.43$, $p<.01$) between IQ

(Culture Fair Intelligence Scale) and the fusion threshold. On the other hand, Jensen (1983) reported no correlation between IQ (Concept Mastery Test and Raven's Standard Progressive Matrices) and CFF. For apparent motion, contradictory results have also been reported. Pollack (1966) reported significant correlations of $r=.25$ and $r=.24$ ($p<.05$) between IQ (Lorge-Thorndike Scale) and the thresholds of the perception of apparent motion and stimulus simultaneity, and the perception of stimulus succession and apparent motion. In contrast, Hamilton (1960) and Mackenzie & Cumming (1986) failed to find any correlation between subjects' reports of apparent motion and intelligence.

The failure to report significant correlations between IQ and performance may be due to the fact that only a small sample size was utilized.

B: EXPERIMENT 5. Individual differences in the EJT and IT.

5.6 Introduction.

In Experiment 4 a positive correlation between subjects' inspection time and the number of correct responses recorded from the EJT was obtained. The correlation between these two variables was expected, and suggests that similar discrimination processes may be involved in both experimental tasks. Performance in neither of these tasks correlated with other experimental tasks which have been used in research on periodicity, such as apparent motion, critical flicker frequency and the perception of simultaneity. As a result, these paradigms are not included in the following experiment.

In this experiment, the speed of information presentation was altered. The duration of each line segment, and the interval between each line segment (inter-line interval) was reduced. Results from masking experiments, particularly the IT task, indicated that subjects can make accurate V-S discriminations when the stimulus is present for approximately 100 msec. In the EJT, the stimuli, or each line segment were present for the subject to process for 325 msec before the next line segment was presented. Reducing the exposure duration of the stimulus will reduce the availability of information for processing, and may also help differentiate subjects who normally perform accurately in an EJT task. In addition, previous research concerned with the perception of sequentially presented information, such as White's (1963), has indicated that subjects are limited to perceiving and accumulating approximately one piece of information every 80 msec. As the EJT involves the sequential presentation of information, it is possible to present information for this length of time, and then to examine subject's rate of information acquisition.

In this experiment, a larger population of subjects was sampled and a measure of intelligence obtained. A larger sample size should facilitate a preliminary investigation into the association between intelligence and the EJT. It was expected that a positive correlation between IQ and the number of correct responses in the EJT would be found. This association was expected, as it is assumed that subjects who obtain a higher level of correct responses in the EJT can accumulate information at a greater rate, and have a higher level of intelligence.

5.7 Method.

5.7.1 Subjects.

Seventy six undergraduate students enrolled in Psychology II at the University of Adelaide were used as subjects in this experiment. All had normal or corrected vision and were naive with respect to the aims of the experiment.

5.7.2 Stimuli.

For the EJT a series of horizontal line segments of varying lengths were displayed on a grey Cleveland (IBM compatible) computer screen. Each line segment was presented either for 20 msec, followed by an interval of 20 msec before the presentation of the next line segment, or for 40 msec, followed by an interval of 40 msec. The line segments were drawn from two normal distributions, with one having a mean of μ=-2.00 and the other having a mean of μ=2.0. A common standard deviation of σ=8.0 was used.

For the IT, the stimuli presented were similar to that reported in section 5.1.2. The figures in the present experiment consisted of a solid circular cue, which was presented for 500 msec, followed by the stimulus figure, which was presented for varying durations, and finally the masking stimulus, which was presented for 360 msec. The stimulus was represented by the letter pi, as in Experiment 4, with one of the vertical lines (v) having a length equivalent to 25 mm in length, and the other, the standard (s), being 35 mm in length. There was a constant difference of 10 mm between the variable and the standard. The uppermost ends of both the variable and the standard were terminated by a horizontal line measuring 10mm, equivalent to the horizontal separation between the lines.

5.7.3 Apparatus.

The EJT used the same response keyboard as described in an earlier section (2.1.3). The subject responded to each trial by pressing one of two microswitched keys marked L or R. A Cleveland computer was used to run the experimental program.

In the IT task, the same apparatus as described in section 5.1.3 was used. The stimulus was generated on a Northstar Advantage computer screen, and the subject's responses recorded by pressing one of two microswitched keys.

5.7.4 Tests and measures.

Scores were obtained from the Standard Progressive Matrices (PM 38) as described in section 5.1.3.

5.7.5 Design and Procedure.

At the beginning of each session, subjects completed the Standard Progressive Matrices. Following that, subjects were randomly assigned to one of two Conditions. In Condition 1, subjects were presented the slower speed of stimulus presentation, where each line segment was presented for 40 msec with an inter-line interval of 40 msec before the presentation of the next line length. In Condition 2, subjects viewed the fast presentation of line segments, where each line segment was presented for 20 msec, with an inter-line of 20 msec. In both conditions, subjects viewed one block of 12 practice trials, half of which had a left average and the other half a right average. Following practice, subjects were presented with one block of 240 trials at one level of discriminability. As in the practice trials, half of the trials, i.e. 120, had a right average, and the other half had a left average. The probability that a trial was either right or left was equal to .50. Unlike previous experiments, the number of line segments presented was n=5,10,15,20,25, or 30. There were 40 trials for each value of n.

More line segments were presented to subjects in this experiment as stimulus exposure time was shortened.

The procedure described in section 2.5.5 was followed. Subjects were informed that there was an equal probability for a trial to be left or right, that the line segments were generated randomly, and that the number of line segments they would view was pre-determined by the computer program. They were instructed to respond immediately at the end of each sequence of line segments.

For the IT, a similar procedure to that outlined in Experiment 4 Section 5.1.2 was followed. Subjects viewed 15 practice trials before completing the experimental phase. In five of the practice trials the stimulus exposure duration was 200 msec, followed by 5 practice trials with an exposure duration of 100 msec, and finally by 5 practice trials at an exposure duration of 60 msec. In the experimental session, the PEST procedure was employed, and, as in Experiment 4, the stimulus exposure duration was adjusted according to a staircase procedure, depending upon the percentage of correct responses. In this experiment, the accuracy criterion was set at 90%. The stimulus exposure duration began at 200 msec, and was adjusted in steps of 20 msec to a smaller or a longer duration, depending on the subject's level of accuracy.

Since the subject's consistency determined the rate which this process was completed, subjects did not view a set number of trials. When completing the task, they were instructed to examine the stimulus, and determine which vertical line was the shortest. The subjects were discouraged from looking for any stimulus pattern.

All subjects, irrespective of which condition they were assigned to, completed the IT, However, in each condition, exactly one half of the subjects completed the IT before completing the EJT, whereas, in the other half, the subjects completed the EJT before the IT. Consequently, in both Conditions there was a different Order of task completion.

5.8 Results.

In both Conditions of this experiment the mean overall latency (LAT), and the total number of correct responses made (NC) were recorded. In addition to these measures, scores for IT and the Standard Progressive Matrices (IQ) were also calculated.

5.8.1 Means and standard deviations.

Means and standard deviations for the entire experimental population and for each experimental Condition are presented in Table 5.4. For the entire sample, a wide range of scores was recorded for the IT. However, a smaller range was obtained for IQ. The range for IQ in this population varied from a raw score of 37 (corresponding to an IQ range of 87-99), to a raw score of 58 (corresponding to 130+), out of the maximum of 60.

Table 5.4 *Means and standard deviations for the variables LAT, NC, IT, and IQ. The measures LAT and IT are in msecs, NC the number of correct responses and IQ the raw score from the PM38.*

Condition	Variable	Mean	SD	N
Entire Sample	IQ	50.3	4.0	76
	IT	68.6	25.4	
Condition 1	IQ	51.2	3.5	38
	IT	71.4	27.9	
	NC	186.4	6.7	
	LAT	2577.9	272.4	
Condition 2	IQ	49.3	4.4	38
	IT	65.9	22.6	
	NC	181.0	7.8	
	LAT	1758.8	269.0	

The random assignment of subjects to either Condition of the EJT produced a problem with respect to IQ. Those subjects that were assigned to Condition 2 tended to have a significantly lower value for IQ ($t(1,74)=2.13$, two-tailed, $p<.05$). There was, however, no mean difference in IT between the different Conditions ($t(1,74)=0.95$, two-tailed, ns).

5.8.2 Main effects of Condition and Order on the overall performance measures.

To examine whether Condition and experimental Order affected the results, an analysis of variance (ANOVA) was conducted. For LAT, the effect of Condition was significant ($F(1,72)=170.4$, $p<.01$), whereas experimental Order did not affect LAT ($F(1,72)=.05$, ns). There was no interaction between Condition and Order ($F(1,72)=.37$, ns)

For NC, there was a significant effect for Condition ($F(1,72)=10.96$, $p<.01$), but not for Order ($F(1,72)=2.51$, ns). There was no interaction between Condition and Order ($F(1,72)=2.31$, ns).

For IT, there was no significant effect for Condition ($F(1,72)=0.89$, ns) or Order ($F(1,72)=0.06$, ns). Similarly, there was no interaction between these effects ($F(1,72)=1.05$, ns).

For IQ, there was a significant effect for Condition ($F(1,72)=4.44$, $p<.05$). However, there was no difference for between subjects assigned to the different Orders ($F(1,72)=0.16$, ns). There was no interaction between Condition and Order ($F(1,72)=0.47$, ns).

5.8.3 IT and EJT.

It was expected that subjects' performance in the IT task would correlate with their performance in the EJT. To examine this, Pearson correlations between NC and IT, and between LAT and IT were conducted for each Condition, and are presented in Table 5.5. Here it can be seen that the only significant correlation was reported in Condition 2, i.e. a negative correlation between LAT and IT.

Table 5.5 *Pearson correlation coefficients between the experimental variables LAT, NC, IT and IQ.*

		IT	IQ
Condition 1	LAT	.08	-.25
	NC	-.17	.32#
	IT		-.52*
Condition 2	LAT	-.54*	.17
	NC	-.04	-.06
	IT		.17
	* p<.01 # p<.05		

5.8.4 Individual differences.

A number of correlations between intelligence and performance were expected. Overall, for the entire population, a Pearson correlation between IT and IQ of r=-.14 (ns) was estimated. The individual difference analyses were then divided according to Condition. Table 5.5 shows that in Condition 1 two significant correlations in the expected direction were obtained. Those subjects with higher IQ scores had shorter IT's and recorded more correct responses in the EJT. No significant correlations were reported in Condition 2.

5.9 Discussion.

5.9.1 Speed of Processing the EJT and IT.

This discussion will cover a number of issues. Firstly, the results obtained from the EJT will be discussed, followed by the results from the IT. Secondly, the discussion will focus on the EJT as a substitute for the IT.

5.9.1.1 The EJT.

In this study, a Condition effect for both the subject's latency and accuracy was reported. This effect was apparent for both latency (LAT) and accuracy (NC). Overall, subjects that were assigned to Condition 1, where the speed of information presentation was slower, i.e. 1 line segment every 80 msec, were more accurate, and had longer latencies. This result indicates that, when the presentation rate is slower, subjects can accumulate more information, and make more accurate judgments. When the rate of information presentation is increased, the subjects' accuracy level is lower, and latency is shorter. This suggests that subjects are accumulating fewer observations.

5.9.1.2 The IT.

In this experiment, a lower mean value of msec for IT was recorded by subjects. While the sample was composed of University students, other studies using this type of sample have recorded mean ITs roughly equivalent to the perceptual moment of 100 msec. For example, the mean IT for University students in Experiment 4 was 119.00 msec. The main reason for the mean difference between the experiments is that a different accuracy criterion was employed in both. In Experiment 5 a 90% level of accuracy was imposed, as compared to a level of 97.5% in the previous experiment. However, lower criterion values are expected to give sounder estimates of IT (Irwin 1984). Irwin argued that, if the accuracy criterion is too high, there would be large changes in IT as the psychometric curve is relatively flat at this level. The 90% level of accuracy was adopted as it has been found to produce greater reliability in performance, and require fewer trials, thereby reducing the variability in individual performance (Nettelbeck, conversation 1987).

5.9.2 The relationship between IT and EJT.

Results from this experiment demonstrated that, unlike Experiment 4, IT correlated with LAT, but not with NC. A number of other unpublished studies have also reported insignificant correlations between IT and the number of correct responses recorded from an EJT task. In the first experiment, conducted by Nicholls (1988), insignificant correlations between IT and NC were also reported. In Nicholls' (1988) experiment, subjects completed two experimental sessions. In both of these sessions they completed an IT and EJT task. The IT task was identical to that outlined in Experiment 5. The EJT was similar to Condition 2 in Experiment 5, with identical experimental parameters. The number of line segments in the EJT was 5,10,15,20, or 25. The correlation between IT, averaged across both sessions, and average NC was r=-.29 (ns). The sample of adults was further divided according to those classified as cue-users and non cue-users. In both sub-samples an insignificant correlation between NC and IT was reported.

In a second experiment, conducted by McDowell (1989), subjects were once again required to complete two experimental sessions. In both sessions, the subjects (8-10 year old children) completed an IT task and a modified form of the EJT. The IT task was identical both to that used by Nicholls (1988) and to the one presented in Experiment 5. However, the EJT was modified, with two horizontally separated red lights replacing the line segments extending to the left or the right. Like the line segments, the lights were presented as a train of flashes. The number of flashes per trial was 19 and the probability that a trial was either left or right was .50. Once again the results from McDowell's experiment showed an insignificant correlation between IT and the number of correct responses in both sessions. The subject sample was also divided into two sub-samples, i.e., cue-users and non cue-users. For neither of the sub-samples, was there a significant correlation between IT and the number of correct responses.

In Condition 2 of Experiment 5 a significant correlation between IT and LAT was reported. However, Condition 1 failed to yield a similar correlation. Nicholls and McDowell also failed to obtain correlations between IT and subject's latency. It is possible that the negative correlation between IT and response time in Condition 2 of the EJT is an isolated finding. At this stage, little further comment seems warranted, except that further experimentation is necessary.

Overall, the results from Experiment 5, and from McDowell's and Nicholl's study indicate that there is little association between the number of correct responses in the EJT task and IT. A number of factors may have been instrumental in producing these negative findings. First, in Nicholl's experiment the line segments were presented at a fast rate (like Condition 2). It could be that the rate of 25 line segments per second is too fast for accumulation. If the accumulation of evidence is correlated with IT, then it would be expected that this correlation would be stronger in cases where the presentation rate was equivalent to the subject's IT. However, if this is strictly true, then it would be expected that a correlation between IT and the EJT should be evident in

Condition 1. Second, Nicholls allowed his subjects to practice until a certain level of accuracy was obtained in both experimental tasks. However, subjects who can practice more may reach an artificial level of performance, making them appear as efficient and as accurate as those who did not need as much practice. As a consequence, individual differences between subjects may be reduced.

McDowell's experiment may have failed to find the expected correlation due to the subject population studied. To date, this experiment is the first involving an EJT task with children as subjects. It is possible that developmental differences may affect performance. While there is no evidence to suggest that this is the case with the EJT, there is evidence to suggest that developmental differences exist in the IT task (Anderson 1986). For example, Hulme & Turnbull (1983), using school children aged between 6-7 years old as subjects, reported an average IT of 164 msec. In contrast, Smith & Stanley (1983) reported an average IT of 104 msec in a sample consisting of children aged between 12-13 years old. Nettelbeck & Wilson (1985) have concluded that IT decreases between the ages of 7 and 11 years, and that there is less change in IT after 11 years of age. In addition, McDowell used a modified form of the EJT. In both the IT task and the original form of the EJT task, subjects make subjective judgments about line lengths. Judgments are dependent upon a magnitude of difference between V and S. As the subjects' judgments are not based on magnitude of stimulus difference, counting strategies can perhaps be used more readily when the number of stimuli or light flashes is important.

Finally, the failure to find the expected correlation between IT and NC may indicate either that other processes may be involved, or that a different kind of processing is required for each task. As the IT is a task involving only a single observation, discrete processing may be utilized. However unlike the IT, the EJT involves sequential presentation of information, and, in this situation, subjects may employ a continuous processing strategy. The Accumulator model assumes that discrete processing occurs even when information is presented sequentially. However, other researchers have suggested that both elements of continuous and discrete processing can occur in such tasks (Miller 1988; Townsend & Ashby 1983).

5.9.3 Individual differences.

Some support was obtained in Experiment 5 for the suggestion that performance is associated with intelligence. In Condition 1, a negative correlation between IT and IQ was obtained. However, this correlation was not found in Condition 2. There was also a significant correlation between IQ and NC in Condition 1. In this instance, those subjects who had higher levels of intelligence also obtained more correct responses. It was found that the Conditions were significantly different with respect to IQ. Those subjects allocated to Condition 2 were significantly lower in their IQ, as measured by the Standard Progressive Matrices, and it is possible that the difference in this sample may have been responsible for producing nonsignificant results.

While there are many studies reporting significant correlations between IT and IQ (Nettelbeck 1987), there are very few studies reporting correlations between EJT performance and IQ. Both McDowell (1989) and Nicholls (1988) reported correlations between these two variables. In McDowell's (1989) study a significant correlation between IQ (WISC-R, full scale IQ) and the number of correct responses was obtained in the modified EJT task, for both the first and for the second experimental session ($r=.62$ $p<.01$, $r=.57$ $p<.01$) respectively. In contrast, Nicholls (1988) reported a significant correlation between the number of correct responses and IQ (Standard Progressive Matrices) for the first experimental session only ($r=.49$, $p<.01$). In the second session, a non significant correlation between the number of correct responses and IQ of $r=.25$ was reported. Correlations obtained between subject's latency and IQ, reported in Experiment 5, cannot be compared to McDowell's (1989) and Nicholls' (1988) studies, as they did not report correlations between these two variables. Overall, therefore, there appears to be some evidence supporting an association between intelligence and performance in the EJT.

It is assumed that the EJT provides an index of information acquisition. If intelligence is associated with the speed of processing, as hypothesized by Brand & Deary (1982) and Eysenck (1987), it would be expected to correlate with the EJT, since subjects who exhibit more efficient processing should achieve more correct responses in the EJT. It may also be assumed that these subjects have superior retention.

CHAPTER SIX.
CONCLUSIONS.

6.1 Experiment 1.

In Chapter 2 it was argued that the processes involved in the EJT should not differ in any important respect from those involved in traditional RT experiments. In order to test this it was necessary to assume that the processing of an overt observation in the EJT is analogous to that of a covert observation in a conventional RT task. The main purpose of the first experiment therefore, was to demonstrate that the relationships between stimulus discriminability, accuracy and response time were the same in the EJT as they are in conventional RT tasks. Discriminability was adjusted by varying the parameters μ and σ, which determined the distribution from which the line segments or observations were drawn. Another aim of the initial experiment was to investigate the relationships between measures of individual difference and parameters characterising the decision process. In the EJT the rate of information presentation is constant, and is normally less than the average value of 10 items per second, assumed to be associated with processing limitations in the discrete sampling hypothesized to take place in traditional psychophysical judgments. As a consequence, it was assumed that individual differences associated with the acquisition of information and speed of processing such as intelligence should be reduced. Instead, it was hypothesized that relationships between personality differences and EJT performance measures would be found. Research using TSD methodology has indicated that introverts are generally more cautious than extraverts, and usually make more correct responses. It was therefore assumed that introverts would make more correct responses in the EJT.

In Experiment 1 subjects completed an S-paradigm EJT where the number of observations (line segments) that could be sampled was determined by the subject. Discriminability was varied throughout the experimental session. In addition to varying discriminability by altering the μ/σ ratio, the stimulus scaling was also manipulated. In these instances, the values for μ and σ were altered, but the μ/σ ratio always resulted in the same nominal value of .50. When smaller values for μ/σ such as 2/4 were employed, discrimination was expected to be more difficult than when larger values, such as 4/8, were presented. Measures of psychoticism, extraversion, and neuroticism (EPQ) were also obtained.

The results from Experiment 1 confirmed that alteration in μ and σ affected subjects performance. As in traditional psychophysical tasks, it was observed that, when discriminability was reduced, subjects' achieved fewer correct responses and had longer response times, whereas, when discriminability was made easier, more correct responses and shorter response times were recorded. When the discrimination levels had the same nominal value only RT varied in the expected direction. A positive correlation between E and RT, and E and NC was recorded. The positive correlation between extraversion and performance was contrary to the expected result, and it was concluded that this finding was probably caused by the random variations in discriminability and the employment of stimuli characterised by a high degree of random variability. Both of these may have caused an increase in the level of cortical arousal.

6.2 Experiment 2.

The main aim of the second experiment was to asses the reliability of performance measures obtained from both the E- and S-paradigm EJT. The E-paradigm differed from the S-paradigm in that it controlled the number of observations subjects could take, thereby limiting the quantity of information. Experiment 2 was also designed to determine whether measures of latency and accuracy were consistent across experimental paradigms, and to examine whether individual differences in performance could be found in experimental conditions when only one discrimination level was used.

In Experiment 2 subjects completed two sessions of both an E-paradigm and an S-paradigm EJT. In both paradigms the same discrimination level was employed. The mean test separation between the completion of the first and second S-paradigm session was 91 days whereas the mean test separation between the first and second E-paradigm was 81 days. As in Experiment 1, measures of psychoticism, extraversion and neuroticism were also obtained. For both the E- and S-paradigm there were high correlations between latency and accuracy measures in the first and second sessions. As a consequence of this finding, the measures of latency and accuracy for each paradigm were averaged across sessions and correlated. The results from this analysis indicated that neither latency nor accuracy correlated between paradigms. Neither was there any correlation between personality measures and performance measures from either the E- or the S-paradigm.

The main conclusion drawn from this study was that subjects' performance within both the E- and S-paradigm is reliable over sessions. However, there does not appear to be any cross-paradigmatic consistency in performance. The failure to obtain cross-paradigmatic consistency does not necessarily imply that different accumulation processes are involved in each paradigm. Nevertheless, as a consequence of this finding, only one of the experimental paradigms was utilized in the remaining experiments. Another conclusion drawn in this experiment was that the previous finding of personality differences in the EJT performance in Experiment 1 may have been facilitated by the use of multiple discrimination levels.

6.3 Experiment 3.

The main aim of Experiment 3 was to investigate the possibility that measures of sensory adaptation, such as the IR, are associated with the level of accuracy in the EJT. The IR was assumed to be determined by the stimulus sequence and to be a consequence of adaptation to the distribution of sensory intensities which the subject experiences. In the E-paradigm, it was hypothesized that larger values for the IR would result in more observations being lost and as a consequence, lower levels of accuracy would be recorded. It was also hypothesized that individual differences in the measure IR would be found. The research concerned with individual differences in vigilance performance and the perception of after-effects indicated that introverts may be more ready to make criterion adjustments based on the stimuli and that they also tend to augment stimuli. Therefore, not only was it expected that introverts would make more correct responses, it was also expected that they should have smaller IR values.

In this experiment, subjects were assigned to one of two experimental designs. In both designs an E-paradigm EJT was employed, and two scaling levels, which had the same nominal value (μ/σ=.38), were utilised. In Design A, subjects were assigned to one of two experimental groups, and completed either two experimental sessions where μ/σ was set at 3.0/8.0 or two sessions where μ/σ=1.5/4.0. In Design B, subjects were assigned to one of two experimental groups. In both groups both scaling levels were presented. However, one group was presented with the level 3.0/8.0 in the first session and 1.5/4.0 in the second session, whereas in the other group the reverse order was chosen.

The results from this experiment indicated that latency was generally faster in the second session than in the first and was not affected by the scaling level. For NC there was no difference either within the experimental designs or between designs, indicating that variations in scaling did not affect accuracy. Like Experiment 1, in cases where the same nominal scaling level is utilized, results tend to suggest that the difference in the scaling of the stimuli does not alter subjects' performance. The measure IR varied according to the scaling of the stimulus, but it did not predict the level of accuracy. Furthermore, the imposition of an IR failed to significantly improve the level of response consistency in comparison to an IR=0. There were two significant correlations between measures of individual difference and performance. The first correlation demonstrated that high P scorers obtained more correct responses and the second correlation suggested that subjects with higher L scores had smaller values for IR.

The main conclusion drawn from this experiment was that observations are more likely being lost at random rather than being discarded on the basis of magnitude as the concept of an IR implies. Accuracy in the E-paradigm is more likely to be affected by the P scale, indicating that higher P scorers may have higher levels of sensitivity to the stimuli. There were no correlations between the personality dimensions P, E and N and the IR, which indicates that the IR does not appear to be a sensory parameter linked to personality.

6.4 Experiment 4.

Since the IR did not explain information loss in the E-paradigm, other ways of explaining subjects' accuracy were examined. In Chapter 4 it was suggested that subjects' performance depended upon the rate of processing, with superior performance expected from those subjects who could process information at a faster rate. EJT accuracy appears to be limited by the rate at which the sequence of stimuli can be registered and perceived as input to a decision mechanism. In the EJT it was argued that subjects were taking a series of discrete observations of sensory difference. To examine the rate of processing in this task it was necessary to obtain a measure of the minimum time it took subjects to accurately take a single observation. The IT task was used in this thesis to obtain such a measure. Subjects with shorter ITs should then make an accurate inspection in less time. When multiple stimuli were presented, as in the EJT, it was assumed that subjects with shorter ITs would be able to accurately accumulate more information, make more correct responses, and respond faster.

The purpose of Experiment 4 was to determine whether measures linked to periodicity obtained from classical experimental tasks designed to measure the perception of apparent motion, the perception of flicker, and simultaneity are correlated with IT and accuracy in the EJT. The review of the studies concerned with inspection time and intelligence demonstrated that subjects' ability to make an accurate discrimination of sensory input is correlated with intelligence. Likewise, for the EJT it was expected that accuracy would also correlate with intelligence. In this experiment, subjects completed an E-paradigm EJT at one level of discriminability. Subjects also completed an inspection time task, and tasks designed to yield a threshold measure for the perception of flicker, simultaneity and apparent motion. Measures of IQ were also obtained.

The results from this experiment indicated that the number of correct in the EJT correlated with IT. Subjects with shorter ITs made more correct responses. Threshold measures for the perception of flicker, simultaneity and apparent motion did not intercorrelate, nor did any of these measures correlate with IT and EJT performance.

It was concluded that the failure to obtain significant correlations between thresholds for the perception of motion, simultaneity and flicker indicated that the tasks may involve different processes. However, it would appear that similar processes were involved in both the EJT and IT, as a highly significant negative correlation between IT and EJT accuracy was found. It was concluded that further experimentation examining the association between these two tasks is justifiable. Conclusions concerning the relationship of IQ to performance indices and the relationship between the perception of apparent motion and IT were not possible due to the small sample size.

6.5 Experiment 5.

The main aim of the final experiment was to examine the relationship between IT and EJT performance. The exposure duration of the stimulus in the EJT was reduced, and it was assumed that by reducing the availability of information more variation in accuracy levels could be obtained. Furthermore, previous research concerned with the perception of sequentially presented information indicated that subjects are limited to perceiving and accumulating approximately one piece of information every 80 msecs. A larger sample size was also drawn to examine the relationship between intelligence and performance.

In Experiment 5 subjects completed an E-paradigm EJT and an IT task. They were assigned to one of two experimental conditions. In Condition 1 the line segments in the EJT were presented at the rate of 12.5 segments per second, whereas in Condition 2 a rate of 25 line segments per second was programmed. The results from this experiment indicated that in neither condition was there a correlation between IT and NC. In Condition 1, correlations between IT and IQ, and NC and IQ were recorded. A number of conclusions were drawn from this experiment. EJT performance was affected by the presentation rate, with a faster presentation rate resulting in fewer correct responses. There appeared to be only a limited association between IT and accuracy in the EJT when the rate of information presentation was reduced. It was suggested that a different kind of processing may be involved in the two tasks. In the IT task it is possible that discrete processing is required due to the fact that a single observation is presented. In contrast, in the EJT, multiple observations are presented and continuous processing may be required. It was also concluded that there was some support for the contention that EJT accuracy is affected by speed of processing measures such as intelligence.

6.6 Conclusions.

From the series of experiments that have been conducted in this thesis a number of general conclusions can be made. Results from Experiment 1 tend to indicate that EJT performance is similar to performance measured in conventional RT tasks, and alterations in the stimulus distribution from which the observations are drawn affect measures of latency and accuracy. However, adjustments in performance were not observed in experiments, such as Experiment 1 and Experiment 3 where the same nominal discrimination level was used but scaling level was manipulated.

Another important conclusion that can be drawn was that measures of latency and accuracy recorded in both paradigms are reliable, since highly significant test-retest correlations were found. However, latency and accuracy in the E-paradigm did not correlate with measures of latency and accuracy recorded in the S-paradigm. While it was argued that this finding did not necessarily imply that different accumulation processes were involved in both paradigms, it was decided that only one paradigm would be employed in the remaining experiments.

Experiment 3 demonstrated that subjects' accuracy in the E-paradigm was not related to measures of sensory adaptation such as the IR, which assumes that observations are lost on the basis of magnitude. Rather, it was argued that observations may be lost at random. One possibility is that accuracy may be determined by the subjects' ability to accumulate information and may therefore depend on the speed of processing. To assess this proposition, Experiment 4 and Experiment 5 were conducted. In these experiments performance in experimental tasks also believed to be associated with speed of processing such as IT, were correlated with EJT performance. Like the EJT, the IT task involved subjects making a V-S discrimination and may also involve the same decision processes. The results from Experiment 4 and Experiment 5 demonstrated that the strength of the association between IT and accuracy in the EJT is affected by the presentation speed of the line segments. The strongest correlation coefficient between IT and accuracy was found when the presentation rate of the line segments was approximately 3 line segments per second rather than when the presentation rate was speeded to 12.5 and 25 line segments per second. It was concluded that the strongest correlation between these two tasks appears to occur in instances where the stimulus presentation in the EJT is slower, possibly enabling subjects to sample and accumulate multiple observations.

With respect to individual differences and performance the results from these experiments suggest that there was only a limited association between the two measures. Personality differences in performance were recorded in Experiment 1 and Experiment 3. In Experiment 1, positive correlations between extraversion and latency, and number of correct were recorded, and it was concluded that the variations in discriminability may have facilitated this association. In Experiment 3 the dimension psychoticism was associated with accuracy, perhaps indicating that subjects with higher scores on the P scale have greater levels of sensitivity to the stimulus. The results from these experiments may also suggest that certain personality dimensions are more likely to correlate with performance measures obtained from particular experimental paradigms. For instance, it may be the case that extraversion is more likely to be associated with S-paradigm latency and accuracy, whereas the dimension psychoticism may be associated with accuracy in a data-limited situation such as the E-paradigm.

The failure of the IR to predict accuracy and correlate with personality tends to suggest that subjects' performance in the EJT does not appear to be influenced by arousal, but is more likely to be determined by speed of processing. If this is the case, then it was argued that intelligence may be a more suitable measure of individual difference. Previous research has indicated that higher levels of intelligence are associated with shorter times to make an accurate discrimination. The results from Experiment 5 and other studies such as those of Nicholls (1988) and McDowell (1989) indicate that intellectual differences are correlated with E-paradigm accuracy.

6.6.1 Postscript: further experimentation

Following the examination of this thesis the possibility was raised that a further study investigating the relationships between IT, EJT and intelligence might be conducted. Specifically it was suggested that EJT parameters might be systematically varied and the subject's accuracy from this test should be correlated with IT and scores obtained from a more comprehensive intelligence test than the Ravens Progressive Matrices as used in Experiment 4 and Experiment 5. The purpose of this section is to address this suggestion.

In Chapter 3 it was suggested that subjects may be losing observations at random rather than discarding observations on the basis of stimulus magnitude. One possible cause of this loss of observations might be the inability of the subject to process and accumulate information as quickly as it was presented. As a result, experiments examining the relationship between EJT accuracy, IT and IQ were conducted. The significant correlation between IT and EJT accuracy obtained in Experiment 4 indicated that further experimentation utilising these tasks was justified. On the other hand, results obtained in Experiment 5 did not support an association between IT and EJT accuracy. McDowell's (1989) study was an extension of Experiment 5. However, major modifications were made to the EJT in order to simplify the task.

McDowell's (1989) study was discussed at length in Chapter 5 of this thesis (see pages 158 & 159). In this study 28 subjects aged between 8 - 10 years of age completed two experimental sessions. In both sessions subjects completed an IT task and a modified form of the EJT. As stated in Chapter 5 the EJT was simplified by replacing the line segments extending to the left or the right of a midline with two horizontally separated lights. In each trial one light had the probability of flashing equal to .65 and the other had the probability of flashing equal to .35. Each light flash was displayed for 70 msec, with an inter-flash interval of 70 msec. After a trial was completed subjects had to indicate whether more flashes occurred to the left or the right of the horizontal midline. To obtain a measure of intellectual ability McDowell (1989) administered the WISC-R. A good dispersion of scores ranging from 91 to 133 was obtained. The sample mean was IQ=111, with a standard deviation of 11. The sample was further divided into two groups, namely cue-users and non-cue-users.

The substantial modification to the EJT was made for two reasons. Firstly, if observations are lost at random and not discarded on the basis of magnitude then the length of the line segments should not be an important factor in the subject's decision making. Rather the subject's accuracy will be determined solely by his/her speed of processing. If this is true, then a simple procedure using lights instead of line segments would yield an index of speed of processing. Secondly, the failure to find a correlation between EJT accuracy and IT in Experiment 5 promoted McDowell's (1989) modification to the EJT task. The task was simplified and the rate of presentation was slowed.

The results obtained from McDowell's (1989) study answer questions raised by one examiner. In particular, they showed that there are distinct advantages in using the modified form of the EJT task as a measure of speed of information processing. The EJT did not appear to be influenced by practice effects, was reliable, and, in contrast to the IT task, was not influenced by cue-using. The study also obtained correlations between EJT accuracy and measures of IQ obtained from a comprehensive, standardised intelligence test.

In this study IT was subject to practice effects: a 6 msec improvement by cue-users and a 40 msec improvement by non-cue-users was recorded. The number of strategy users increased from 8 in session one to 16 in session two. For the entire sample a correlation of $r=.30$ (ns) between IT in session one and IT in session two was reported.

EJT accuracy was not effected by practice and was consistent across sessions ($r=.69$ $p<.01$). Measures of IT and EJT accuracy for the entire sample did not correlate highly (session one $r=-.25$ ns: session two $r=-.32$ $p<.05$). Non-significant correlations between IT and EJT accuracy were also found for the sub-sample classified as cue-users (session one $r=-.36$ ns: session two $r=.41$ ns). Likewise, non-significant correlations between IT and EJT accuracy were found for the sub-sample classified as non-cue-users (session one $r=-.36$ ns: session two $r=-.38$ ns). The failure to find significant correlations between these two experimental tasks suggests that speed of processing is not being measured by both tasks. Results from Experiment 5 also support this conclusion. As concluded from Experiment 5, it is possible that different types of processing are occurring or that the tasks are measuring different processes. Vernon (1983, 1986) has suggested that IT may actually be a measure of attention.

The correlation between IT and IQ for the entire sample in session one was $r=.19$ (ns), and, in session two, the correlation obtained between these two variables was $r=-.08$ (ns). When cue-users were removed an improvement in the correlation between IT and IQ as found (session one $r=-.83$ $p<.001$: session two r=-.66 p<.01). Non-significant correlations between IT and IQ were found in both experimental sessions for cue-users (session one r=.19 ns: session two r=-.14 ns). In contrast, EJT accuracy correlated highly with IQ in both experimental sessions (session one r=.62 p<.001: session two r=.57 p<.001) indicating that accuracy, and hence, by implication, speed of processing, is correlated with the subject's intellectual ability.

The results from this study indicate that there are a number of advantages in using the modified form of the EJT to explore individual differences in speed of processing. Indeed the results would support the use of the modified EJT to provide an index of speed of processing rather than the IT. Firstly McDowell's (1989) results provide evidence to suggest the EJT is not influenced by strategy use. The EJT limits strategy use as it does not incorporate a backward mask. Furthermore the EJT avoids the arbitrariness of speed of processing in terms of a predetermined accuracy level as is the case with the PEST procedure. In the EJT only the subject's accuracy is free to vary and the exposure duration and the number of trials is constant for all subject's (McDowell 1989). This is not the case with the PEST assessment of the IT task which produces variations in the number of trials dependent upon the subject's response consistency and performance on previous trials.

The identification of cue-users is also problematical. As McDowell (1989) demonstrated, subjects can possibly learn to use strategies. (The number of cue-users doubled in the second session). The IT task would not be a suitable task to use in an experiment incorporating a repeated measures design. Overall, the IT task is prevented from assessing true and reliable differences in the rate of processing because of the problem associated with strategy users. There is also the possibility that cue-users did not inform the experimenter that they actually used cues. Subjects often find it very difficult to explain how they completed the IT task and they may not adequately convey whether they utilised cues or not.

The results from McDowell's (1989) study indicate that further research examining the role of individual differences in the modified form of the EJT task could usefully be conducted. However a parametric study is required before conducting a study concerned with validating the modified EJT as an index of mental speed. A parametric study would help to establish the optimal conditions that provide clear differentiation between individuals.

A number of parameters need to be manipulated. These include parameters that determine the nature of the stimulus display, the length of the experimental session, and the sample size. Firstly, the probability of a trial being right or left needs to be altered. This would provide information on if and how bias affects EJT accuracy. Secondly, the duration of each flash and the inter-flash interval need to be varied. This would help to determine whether variations in the duration of the flash have a greater effect on accuracy than variations in the inter-flash interval. Thirdly, parameters that determine how the flashes are sampled could be varied. Alterations to the probability that a light will flash to the left or right of the midline need to me made. In McDowell's (1989) study the probability that a light would flash to the right of the midline in a right trial was .65. Alterations making discriminability less difficult (e.g. setting the probability to .8), and making discriminabiltiy more difficult (e.g. setting the probability to .6), need to be conducted. In addition, the sampling of the flashes could also be explored. Flashes could be sampled with or without replacement. The optimum number of light flashes within each trial, the number of trials and the number of subjects are also important factors that need investigation.

A validation study could then be designed utilising the EJT parameters identified in the parametric study that provide clear differentiation between individuals. However, depending upon the experimental design a large number of subjects would be required. If the study involved between-groups testing more subject would be necessary. Secondly, a more comprehensive test of intelligence than the Progressive Matrices would need to be used. For an adult population the Advanced Progressive Matrices or the WAIS could be used. Thirdly, the problems associated with the measurement of IT, together with the non-significant correlation between EJT accuracy and IT means that further research investigating the relationship between them is fraught with difficulties.

The parametric and validation studies would require several hundred subjects and multiple testing sessions, and would take approximately 2 years to complete. Although such studies would doubtless increase our knowledge about the relationship between intelligence and EJT accuracy. They would constitute a substantial addition to the thesis rather than an improvement.

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APPENDIX A.

Tables for the Repeated Measures Analysis of Variance (MANOVA) conducted upon RT and NC in Experiment 1.

Table A.1 *Analysis of variance for RT.*

	SS	MS	DF	F	Sig.
Between Ss					
within cells	2756136346.0	81062834.0	34		
constant	6641122892.0	6.64E+09	1	81.93	.000
Within Ss (mean)					
within cells	27889749.7	410143.0	68		
mean	35828074.9	17914037.0	2	43.68	.000
Within Ss (sd)					
within cells	20900288.2	307357.1	68		
sd	6980417.5	3490208.8	2	11.36	.000
Within Ss (mean x sd)					
within cells	23966837.1	176226.7	136		
mean x sd	957021.3	239255.3	4	1.36	.252

Table A.2 *Analysis of variance for NC.*

	SS	MS	DF	F	Sig.
Between Ss					
within cells	1161.9	34.1	34		
constant	347404.8	347404.8	1	10165.41	.000
Within Ss (mean)					
within cells	246.8	3.6	68		
mean	638.0	319.0	2	87.90	.000
Within Ss (sd)					
within cells	315.4	4.6	68		
sd	576.7	288.3	2	62.16	.000
Within Ss (mean X sd)					
within cells	341.8	2.5	136		
mean x sd	111.3	27.8	4	11.07	.000

Table A.3 *Analysis of variance for RT when μ/σ=.50*

	SS	MS	DF	F	Sig.
Between Ss					
within cells	850158109.4	25004650.0	34		
constant	2156759980.0	2.16E+09	1	86.25	.000
Within Ss (parameter)					
within cells	8352875.3	122836.4	68		
parameter	4240133.3	2120066.7	2	17.26	.000

Table A.4 *Analysis of variance for NC when μ/σ=.50*

	SS	MS	DF	F	Sig.
Between Ss					
within cells	456.9	13.4	34		
constant	120226.7	120226.7	1	8946.34	.000
Within Ss (parameter)					
within cells	142.1	2.1	68		
parameter	3.2	1.6	2	.77	.000

APPENDIX B.

Tables for the repeated measures analysis of variance (MANOVA) conducted upon the variables LAT, NC, IR in Experiment 3, Design A.

Table B.1 *Analysis of variance for LAT Design A.*

	SS	MS	DF	F	Sig
Between Ss					
within cells	1960331.4	122520.7	16		
constant	90648383.1	90648383.0	1	739.86	.000
grp	46656.0	46656.0	1	.38	.546
Within Ss (sess)					
within cells	346078.5	21629.9	16		
sess	246071.1	246071.1	1	11.38	.004
grp x sess	8504.94	8504.9	1	.39	.539

Table B.2 *Analysis of variance for NC Design A.*

	SS	MS	DF	F	Sig.
Between Ss					
within cells	440.0	27.5	16		
constant	1363056.2	1363056.3	1	49565.68	.000
grp	90.2	90.3	1	3.28	.089
Within Ss (sess)					
within cells	211.1	13.1	16		
sess	4.6	4.6	1	.36	.559
grp x sess	26.6	26.6	1	2.02	.174

Table B.3 *Analysis of variance for IR Design A.*

	SS	MS	DF	F	Sig.
Between Ss					
within cells	139.9	8.7	16		
constant	479.4	479.4	1	54.82	.000
grp	85.7	85.7	1	9.80	.006
Within Ss (sess)					
within cells	62.2	3.8	16		
sess	16.2	16.2	1	4.17	.058
grp x sess	.3	.3	1	.08	.786

APPENDIX C.

Repeated measures analysis of variance (MANOVA) tables for the variables, LAT, NC, IR in Experiment 3 Design B.

Table C.1 *Analysis of variance for LAT Design B.*

	SS	MS	DF	F	Sig.
Between Ss					
within cells	3047635.0	190477.1	16		
constant	83330526.5	83330527.0	1	437.48	.000
order	174028.0	174028.0	1	.91	.353
Within Ss (condit)					
within cells	337222.3	21076.4	16		
condit	385434.0	385434.0	1	18.29	.001
order x condit	14081.7	14081.7	1	.67	.426

Table C.2 *Analysis of variance for NC Design B..*

	SS	MS	DF	F	Sig.
Between Ss					
within cells	866.8	54.2	16		
constant	1335180.2	1335180.3	1	24643.16	.000
order	23.3	23.3	1	.43	.521
Within Ss (condit)					
within cells	273.1	17.0	16		
condit	14.6	14.6	1	.86	.367
order x condit	.6	.6	1	.04	.843

Table C.3 *Analysis of variance for IR Design B.*

	SS	MS	DF	F	Sig.
Between Ss					
within cells	223.4	13.9	16		
constant	397.3	397.3	1	28.46	.000
order	.9	.9	1	.07	.796
Within Ss (condit)					
within cells	68.7	4.3	16		
condit	2.6	2.6	1	.62	.442
order x condit	24.0	24.0	1	5.59	.031

APPENDIX D.

Repeated measures analysis of variance (MANOVA) tables for the variables, nLAT, nNC, in Experiment 3, Design A vs Design B.

Table D.1 *Analysis of variance for LAT.*

	SS	MS	DF	F	Sig.
Between Ss					
within cells	5228650.5	153783.8	34		
constant	173901925.1	173901925.1	1	1130.82	.000
design	76984.5	76984.51	1	.50	.484
Within Ss (sess)					
within cells	705887.6	20761.4	34		
sess	623720.4	623720.4	1	30.04	.000
design x sess	7784.7	7784.7	1	.37	.544

Table D.2 *Analysis of variance for NC.*

	SS	MS	DF	F	Sig.
Between Ss					
within cells	1420.5	41.7	34		
constant	2698164.5	2698164.5	1	64581.20	.000
design	72.0	72.0	1	1.74	.198
Within Ss (sess)					
within cells	511.6	15.0	34		
sess	18.0	18.0	1	1.20	.282
design	1.39	1.39	1	.09	.763

APPENDIX E.

Analysis of variance (ANOVA) for overall latency, number of correct, inspection time and intelligence for Experiment 5.

Table E.1 *Analysis of variance for overall latency by Condition and Order.*

	SS	MS	DF	F	Sig
Main effects	12750709.30	6375354.6	2	85.1	.
cond	12747052.6	12747052.6	1	170.1	.000
order	3656.6	3656.6	1	0.05	.862
Interaction	27696.	27696.3	1	0.37	.545
cond x order	27696.3	27696.3	1	.37	.545
Explained	12778405.6	4259468.5	3	56.8	.000
Residual	5394372.9	74921.8	72		
Total	18172778.5	242303.7	75		

Table E.2 *Analysis of variance for overall number of correct (NC) with experimental condition and order as main effects.*

	SS	MS	DF	F	Sig
Main effects	692.8	346.4	2	6.73	.002
cond	563.8	563.8	1	10.96	.001
order	128.9	128.9	1	2.51	.118
Interaction	118.7	118.7	1	2.31	.133
cond x order	118.7	118.7	1	2.31	.133
Explained	811.5	270.5	3	5.26	.002
Residual	3703.7	51.4	72		
Total	4515.	60.2	75		

Table E.3 *Analysis of variance for inspection time (IT) with experimental condition and order as main effects.*

	SS	MS	DF	F	Sig
Main effects	627.2	313.6	2	.48	.622
cond	586.6	586.6	1	.89	.347
order	40.6	40.6	1	.06	.804
Interaction	689.5	689.5	1	1.05	.308
cond x order	689.5	689.5	1	1.05	.308
Explained	1316.7	438.9	3	.67	.573
Residual	47178.1	655.3	72		
Total	48494.8	646.6	75		