AN EXPERIMENTAL INVESTIGATION OF SOME PARAMETERS AFFECTING INDIVIDUAL DIFFERENCES IN PERCEPTION

T. Nettelbeck

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Department of Psychology
University of Adelaide
South Australia

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SUMMARY

The initial experiment was concerned with an examination of subliminal perception. Critics of this concept have attributed the effect to two main sources biasing response processes; (a) fragments of the stimulus, and (b) uncontrolled situational cues which convey the experimenter's intentions. However, neither of these explanations is altogether satisfactory, so an attempt was made to re-examine some of the questions associated with the perception of subliminal stimulation.

This approach proved disappointing, and the research programme was therefore directed towards a more fundamental concern with the conditions of discrimination. From this three main determinants of perceptual organisation were identified: (1) *inspection time* λ, governing the rate of accumulation of sensory data, (2) *noise* in the visual system s_D, and (3) *the degree of caution* adopted as a criterion for responding. The development of the theoretical recognition of these variables is traced, and an index of noise suggested, which is closely related to traditional psychophysical measures, being distinguished by the detailed conditions under which it is obtained.

Results suggest that 100 msec provides an approximate estimate of λ, while measures of noise are higher than estimates obtained from the data of earlier experiments. Values, however, are of an order expected on the basis of the proposed rationale, having regard for the different conditions

applying to the work of previous authors. The mean overall latency of responding *L* appears to provide a satisfactory indirect index of caution. The index of noise s_D is sensitive to increased anxiety, even though this does not produce consistent or significant changes in heart rate, or in the degree of caution adopted by O. Differences between individuals in the descriptors λ, s_D, and *L*, together with an index of the use made of *immediate memory* δ, are compared with personality, measured by the M.A.S. and the E.P.I. Results confirm the independence of λ, s_D, *L* and δ as indicators of individual differences. The relationships between these measures and scores on the personality scales are clear, but not always straightforward. They are examined in terms of interactions between the processes underlying the measures. The perceptual indices developed appear to be stable and consistent descriptors of performance.

Consistent support is found for a model of the perceptual decision process, which proposes that O *accumulates* statistical information over time concerning the state of the discriminanda, in accordance with an *optional stopping* strategy for examining the sensory data. Results from a final experiment support the proposal that this model might be extended beyond simple psychophysical judgements, to account for the more complex perceptual phenomena of *emergence* and *alternation* in ambiguous figures.

The final chapter outlines further applications of these perceptual indices of performance, particularly in the areas of intellectual retardation and vocational rehabilitation. The concept of subliminal perception is re-evaluated in the light of this new approach to discrimination, and an explanation of some effects associated with this concept sought in terms of the optional stopping accumulator process.

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, it contains no material previously published or written by another person, except when due reference is made in the text.

Signed ....

T. Nettelbeck

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PREFACE & ACKNOWLEDGEMENTS

In the course of the research, and during the preparation of this dissertation, I have been helped by many people. I should like to thank Dr. D. McNicol who supervised my first year until his departure from Adelaide. My special thanks are due to Dr. D. Vickers, who supervised the research reported in Chapters III, IV, V, and VI, for his sound advice, warm encouragement, and guidance throughout. I am extremely grateful to Professor A.T. Welford for his generous help when critically commenting upon the entire manuscript. I should like also to express my gratitude to Mr. R.J. Willson, who wrote the programs for the generation of stimuli and the measurement of responses, to Mrs. Margaret Blaber who has typed the final manuscript, and to Mrs. Judy Hallett and Mrs. Helena Lomax who helped in preparing the figures. My greatest debt is to my wife, Esme, without whose support and understanding this dissertation could not have been undertaken.

The experiments reported in Chapter III, together with much of the theoretical and analytical discussion, have already been jointly published as:

VICKERS, D., NETTELBECK, T., and WILLSON, R.J., 1972, "Perceptual indices of performance: the measurement of 'inspection time' and 'noise' in the visual system", *Perception, 1*, 263-295.

The experiments reported in this paper were carried out entirely by myself. The writing of the paper involved such a close degree of collaboration between the first two authors that it is not possible to distinguish individual contributions precisely. However, Dr. Vickers must be credited with the fundamental ideas, and the development of the traditional psychophysical procedures, from which the experiments were derived.

Part of the findings of Chapter IV appear as:

NETTELBECK, T., 1972, "The effects of shock induced anxiety on noise in the visual system", *Perception, 1*, 297-304.

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CHAPTER I.

GENERAL INTRODUCTION

The initial experiment in this thesis was suggested by the controversy which has long surrounded the proposition that a person's behaviour may be influenced by stimulation presented at low intensity below the level of awareness. In discussing this issue, Neisser (1967) has emphasized his opposition to the possibility of subliminal perception, maintaining that all apparent demonstrations of discrimination in the absence of awareness can be regarded as artifactual.

In developing a model of cognition, in which the percept is actively constructed from both sensory and stored information in accordance with an internalized hypothesis, Neisser acknowledges his debt to Bartlett (1932). However, by precluding the possibility of perception at any level other than that of conscious phenomenal representation, Neisser implies that awareness is a necessary correlate of cognitive analysis. This proposal would appear to go beyond both Bartlett's insistance that perception involves 'an effort after meaning', and current theories concerning the basis of 'selective attention' (Egeth, 1967; Moray, 1969; Norman, 1969; Treisman, 1969). Whilst these emphasize that, at any given time, the organism is directly affected by only a very limited range of the available sensory information, they do not imply that information cannot be synthesized at preconscious levels of analysis. In fact, these models assume that the conscious percept is preceded by a great deal of cognitive processing, in which all features of incoming stimulation, other than the particular structures consciously perceived, are 'filtered' out at various levels within a hierarchical system of analyzers.

Neisser's objections to the hypothesis of subliminal perception apply equally to situations in which stimuli exposed briefly, or presented at levels of intensity below awareness, appear to affect behaviour, and those in which variations in the recognition threshold are held to be linked with the emotional content of threatening, taboo, or anxiety-provoking stimulus material. His criticisms are drawn from a number of sources, and are particularly directed towards those experiments employing a metacontrast technique in which the sensory effects of a test signal are erased by a masking stimulus which follows the test stimulation. In each case, Neisser insists that an interpretation in terms of subliminal perception is invalid, and that the percept has occurred either because the stimulus was seen by the observer, or because of the operation of particular biases, influencing the observer to respond in a certain way. This emphasis upon the biasing of response processes as an alternative and sufficient explanation for discrimination in the apparent absence of awareness is not altogether consistent with his attempt elsewhere (1967, p.119) to avoid formulating a dichotomy between sensory and response systems. Nor would it appear to rule out the possibility that sensory processing may occur at levels of activity below consciousness.

Let us first consider Neisser's assumption that an alternative explanation for some reports of subliminal perception is that the stimulus has been partially seen by the observer, and that cues obtained in this way have resulted in a bias to respond in a particular fashion. This explanation does not explain why fragmentary cues of this kind should not be erased by the backward masking procedure, or how they may enter into cognitive processing without the observer becoming aware of their influence. Transferring the influence from the full thematic implications of the hidden stimulus to its figural properties does not explain how the structure of the stimulus is able to influence behaviour, in the absence of subjects' reports that they were aware of these cues. Dixon (1971) has recently and independently made similar criticisms of Neisser's position.

A second explanation put forward by Neisser is that, in many of the investigations concerned with subliminal phenomena, insufficient controls in the experimental situation have enabled the observers to obtain unintentional cues about the task required of them. Although it is now well established that an experimenter may inadvertently convey the experimental hypothesis to his subjects, and that subjects may introduce unexpected sources of error by responding in accordance with pre-conceived ideas about the experimental situation, Neisser's explanation is untenable unless we can assume that the observers are aware of these biasing factors.

Neisser points out that most investigators have failed to question subjects explicitly concerning their awareness of cues in the experimental situation. The first experiment was therefore designed to examine the role of fragmentary cues in perception, and the possible influence of situational cues in biasing judgements. Further, a programme of carefully phrased questions, administered at the conclusion of the experimental session, was intended to establish whether any such influence had occurred in the absence of awareness.

This approach, however, proved disappointing. Although some evidence was found to support the hypothesis that situational cues may influence behaviour, the form of the bias produced was unexpected, and not obviously related to the independent variables in the experimental situation. Thus although observers shown words before rating emotional facial expression made significantly different judgements than observers not shown this verbal material, ratings were not found to be consistent with the functional meaning of the words. Moreover, the results of this experiment clearly demonstrated the difficulties that one might expect to encounter, in following Neisser's (1967, p.121) proposal that the phenomenal report of a co-operative subject should be relied upon, since judgements here were so clearly dependent upon what had occurred beforehand.

It had now become clear that this fairly orthodox approach to the study of subliminal perception, and the related concept of perceptual defense, was unlikely to prove successful. Two essential questions had been left unanswered by this experiment. First, the role that consciousness or awareness plays in discriminative judgement had not been clarified. Second, no line of enquiry had been suggested which might eventually lead to the delineation of the mechanisms by which emotion and stress influence perceptual decision. It appeared that these questions might be more fruitfully approached by a careful examination of some of the more fundamental conditions governing discrimination.

The problems encountered while attempting to interpret the data obtained in this first experiment emphasized the need for rigid control procedures, together with accurate measurement carried out on individual observers under carefully specified conditions. It was also clear that verbal stimulus material and response measures dependent upon language might best be avoided at this stage, despite their wide application in research of this type, because of difficulties in defining the parameters involved with sufficient precision. Instead, it was decided to direct the research programme towards an immediate concern with the factors limiting simple two-choice psychophysical judgements about lines of different length.

It was fortunate that ideas in this area were extant within the Adelaide Department of Psychology at this time. The change in orientation was reinforced in part by a change in supervision. This brought me into closer contact with a related, but apparently more comprehensive theoretical framework, involving the analysis of perceptual discrimination as mediated by an *optional stopping process*. This type of model assumes that before reaching a decision about a perceptual discrimination, the observer accumulates the outcome of a series of *inspections* of the sensory input, made at a steady rate, until some predetermined *criterion* or level of *caution* is satisfied. Despite differences between the detailed properties of a number of different optional stopping models, several provide a reasonable account of the general features of perceptual discrimination, which are that both error rate and response latency increase as the discriminability of the stimuli is made more difficult, and that, for any given level of difficulty, observers adopt a *speed-accuracy compromise*, by which they may decrease the time taken to make the discrimination, but only at the cost of making more errors (Audley, 1970; Vickers, 1970, 1972a). A detailed account of these processes is included in the introduction to Chapter III.

In addition to the factor of inspection time, which determines the rate at which sensory input is acquired, and that of caution, which governs the amount of information upon which a decision is based, recent models of the discrimination process recognize the importance of *noise* as the third main determinant of perceptual judgement. Such noise is conceived as providing the ultimate limit to discriminative capacity, and is generally supposed to be caused by unpredictable variability and random disturbances, both external to the observer in the sources of signals, and internal in the sense-organs, sensory pathways, and the brain. Although there has been considerable discussion in the literature concerning the various sources and nature of noise, the separation of different types is seldom clear, and certainly far from easy. In this thesis, therefore, an operational measure will be used which includes all sources of variability within the perceptual process. In fact, the measure of noise has inevitably included any contribution from the motor system involved in responding, and although experimental tasks were designed to minimize this contribution, the measure developed should be regarded as a comprehensive index of all factors limiting the accurate prediction of visual performance.

As discussed in Chapter IV of this thesis, an estimate of noise might be used to monitor relative changes in the individual, under circumstances designed to enhance or impair performance. It might equally be applied within the areas of retardation or ageing, where efficiency is already impaired or in the process of deterioration, or in the study of personality and individual differences. In addition, a reliable, independent measure of noise should remove what has so far been a major limitation on the development of a satisfactory model of the fundamental process of perceptual discrimination. Thus, although the predictions of a model proposed by Laberge (1962) have appeared to be in general agreement with experimental results, it has not been possible so far to examine the model stringently, principally because of difficulty in estimating the noise in the perceived signal.

In developing his 'accumulator' model, Vickers (1970) sought to avoid this difficulty by assuming that noise is a function of the signal value and, further, that the criterion adopted by the observer is linearly related to noise. This strategy side-steps the theoretical difficulties of describing the 'accumulator' model mathematically, and has enabled Vickers to derive predictions about the patterns of errors, and the latencies for correct and incorrect responses at different criterion levels, by using a computer simulation of the process. The approach has met with some success, and the simulated functions for these and related behavioural descriptors bear a close resemblance to empirically determined estimates. His results have enabled Vickers to extend the model with some confidence beyond simple psychophysical judgements, in an attempt to account for the emergence of complex perceptual organisations, and the alternation between one organisation and another that occurs when certain figures are viewed for a prolonged period. A more thorough discussion of these phenomena, and their relation to the fundamental perceptual indices proposed and to other measures of individual difference, is to be found in Chapters V and VI of this thesis.

These successes not withstanding, the 'accumulator' model would benefit from an independent measure of noise, since without such an estimate it is not possible to distinguish reliably between the effects of noise, on the one hand, and changes in the observer's degree of caution in making a judgement, on the other. Although it is customary to attribute the increase in errors found to accompany reduced discriminability to the influence of noise, the same effect would be produced if the criteria adopted were subject to change, or fluctuated within a trial, as suggested by Pike (1968). The effect of such variability would become more severe as discriminability was reduced. Without an independent estimate of noise, however, it has not been possible to explore this possibility.

It is hoped that the index of noise developed in this thesis will prove to have considerable applicability to the investigation of the discrimination process. The results obtained from the experiments reported in Chapter V, however, have emphasized the importance that a precise measure of inspection time holds for a reliable estimate of noise. There are grounds for optimism that research, in the immediate future, will further define some of the parameters of these potentially useful behavioural descriptors.

Meanwhile, the model of discrimination that emerges from these studies appears to provide a new and surprisingly simple theory of how perception might indeed be influenced by stimuli of which the observer was not aware.

CHAPTER II.

DISCRIMINATION WITHOUT AWARENESS

INTRODUCTION

Psychological interest in discrimination without awareness may be traced back to a series of experiments performed by Suslowa in 1863 (Calvin et al, 1961). Working with the two point threshold for tactual stimulation, he found that when forced to guess about difficult discriminations, subjects made significantly more accurate judgements than chance would allow as to whether stimulation involved one point or two, even though they had no confidence in their decisions. Peirce and Jastrow (1885) were able to demonstrate essentially the same result in an experiment involving discrimination between lifted weights.

The generality of the finding was early established for a wide variety of stimuli, including alpha-numeric characters (Sidis, 1898), auditory material (Dunlap, 1904; Dunlap and Wells, 1910) and geometric shapes (Williams, 1938). Re-examining an earlier controversy (Dunlap, 1900; Titchener and Pyle, 1907), Bressler (1931) reported that observers experienced the Muller-Lyer illusion, although the arrows were presented at levels of intensity previously established to be subliminal. Moreover, the magnitude of the illusory response varied directly with stimulus intensity, a finding, frequently reported by later workers, which suggests that perceptual accuracy increases as stimulation approaches a supraliminal level (McConnell et al, 1958). Early investigators relied upon low intensity to produce subliminal stimulation, but the development of reliable tachistoscopic techniques provided the alternative method of brief exposures.

Many response indices have been employed to demonstrate discrimination without awareness, including fantasy production (Perky, 1910), specific dream experiences subsequent upon subliminal stimulation during normal waking periods (Poetzl, 1917), reports of after-imagery following the removal of subliminally presented material (Newhall and Dodge, 1927), and reports of contrast between colours, themselves too weak to produce a response (Ferree and Rand, 1934). Others have been the establishment of association between nonsense syllables previously paired with shock, and autonomic responding (McLeary and Lazarus, 1949), the effect of subliminal shock upon later judgements of shock intensity (Black and Bevan, 1960), the initiation of reactions and changes in reaction time (Fehrer and Biederman, 1962; Fehrer and Raab, 1962), improvement in problem solving ability (Beier and Donoviel, 1963), and classically conditioned differential blocking of the alpha rhythm (Barratt and Herd, 1964).

Several experiments have used verbal reinforcement techniques to demonstrate that this may modify behaviour in a variety of situations including the increased use of pronouns (Cohen et al, 1954), plural nouns (Greenspoon, 1955), and statements of opinion (Verplanck, 1955). Controversy has existed as to whether awareness of the reinforcing stimuli is a necessary condition for facilitation of performance (Spielberger, 1962; Spielberger and De Nike, 1966), but there appears to be sound evidence that it is not (Kennedy, 1970, 1971). The implications of this type of research for social interaction have been emphasized by Abrahamson (1966), in his discussion of various forms of covert communication.

Because of the vast number of experiments directed towards the investigation of discrimination and learning without awareness, discussion here has been necessarily selective. The reader is referred to a number of extensive reviews provided during the course of experimental concern with the topic by Collier (1940), Miller (1942), Lazarus and McCleary (1951), Lazarus (1956), Adams (1957), Eriksen (1956, 1960, 1962), McConnell et al (1958), Bevan (1964), and Dixon (1971).

In addition to the possibility that information may be obtained from subthreshold stimulation, it has long been acknowledged that variations in an individual's threshold may be due to numerous physiological and psychological factors, such as fatigue, acuity, interest or attention (Jastrow, 1888; Cattell, 1893). More recently, a great deal of research has been directed towards possible relationships between the attributed properties of ambiguous stimulation and underlying psychological determinants such as motivation (Sanford, 1936, 1937; Levine et al, 1942; McClelland and Atkinson, 1948; Lazarus et al, 1953), familiarity and expectancy (Engel, 1956; Johnson et al, 1960;

Stricker, 1961), culture, environment and training procedures (Toch and Smith, 1968) and emotion (Bruner and Postman, 1947; McGinnies, 1949). The rationale underlying this type of investigation is that perception is selective and, under conditions of ambiguous stimulation, the effects of perceptual preferences will be heightened. Thus, some material will be processed more readily and therefore have a lower threshold.

Whilst clearly related to subthreshold discrimination, the investigation of variations in the differential threshold represents an independent body of experimentation. Such changes have been termed "perceptual defense" (Bruner and Postman, 1947; McGinnies, 1949), "perceptual sensitisation" (Bruner and Postman, 1947), or "vigilance" (Brown, 1961). A complete review of work on perceptual defense and vigilance is inappropriate here, since comprehensive reviews are provided by Eriksen (1954), Blum (1955), Brown (1961), Minard (1965), and Dixon (1971).

While there is now general agreement that, under certain conditions, the perceptual system may utilize information without apparent awareness on the part of the observer, considerable controversy has existed as to how this might occur. Criticism of the concept of perception without awareness can be categorized under two general headings;

(a) *logical objections*

Some opponents have argued that negation of particular stimulation implies prior recognition, and have criticized vague attempts to define what constitutes "subliminal perception" and "perceptual defense" (Howie, 1952; Eriksen, 1960; Gibson, 1968).

(b) *alternative explanations*

Many critics have emphasized that differences in recognition threshold might be accounted for by differences in the familiarity, or expectancy, associated with stimulus material (Solomon and Howes, 1951; Freeman, 1954, 1955), or by the voluntary suppression of verbal responses regarded as unacceptable (Whittaker et al, 1952). McConnell et al (1958) have stressed that the phenomenological limen is a statistical concept, and that material presumed to be subthreshold may be operating directly in the perceptual process.

More recently, Neisser (1967) has cited evidence from Sperling (1960), and Averbach and Coriell (1961), for the existence of a transient, rapidly decaying short-term trace, located very early in the perceptual process, from which information may be synthesized after exposure has ceased. He has emphasized that stimulus presentation of a brief duration in many of the earlier tachistoscopic studies would not necessarily limit cognitive processing to an equally brief period.

Neisser (1967) has suggested that apparent perception without awareness is accounted for by supposing that the observer makes use of partial information, available either from the source of stimulation, or from the experimental situation. He pays particular attention to a methodological class of experiments involving metacontrast (Werner, 1935), wherein a briefly exposed stimulus is followed by a prolonged exposure of different material. Although the initial stimulus is presented at above threshold level, it produces no phenomenological effect at the time of presentation, because the subsequent stimulation acts as a backward mask, effectively erasing it from short-term memory. Using this technique, a number of investigators have obtained results which they interpret as demonstrating that the masked, undetected stimulus material has influenced the observer's later judgements about the masking stimulus.

One such experiment is that of Eagle (1959), in which 30 Os rated a neutral figure using 63 pairs of antonyms, having viewed the figure in a situation where it masked briefly exposed scenes composed of either "aggressive" or "benevolent" material. Exposures were of short duration, ranging from 60% to 200% of the individuals' threshold level and O received 2 exposures at each of 8 levels. In general, Os made more negative personality judgements about the neutral figure when it masked an aggressive scene, than when it was preceded by benevolent material. Eagle attributed this effect to the unconscious perception of the hostile content in the aggressive scene.

Neisser (1967), however, proposes an alternative explanation in terms of partial cognitive processing, a hypothesis derived from the explanation that Solomon and Postman (1952) advanced to account for the word-frequency effect (Howes and Solomon, 1951; Solomon and Howes, 1951). They suggested that stimulus fragments might be effective in biasing response towards word alternatives sharing those fragments. This "partial cue" hypothesis has since been elaborated and developed by Eriksen and Browne (1956), Wiener and Schiller (1960), Newbigging (1961a, 1961b), Savin (1963), and Kempler and Wiener (1963). The subject is held to perceive fragments of the total stimulus array and to infer, on the basis of past experience, the nature of the whole.

In support of fragment theory, Neisser (1967) cites a series of three experiments by Guthrie and Wiener (1966). Using a methodology derived from Eagle, these authors had observers make mood and personality judgements about a neutral figure, drawn in broken contour, after it had been preceded by one of four briefly exposed figures of a similar kind. The masked figures were, however, either angular or contoured, on the one hand, and aggressive or nonaggressive (as determined by the presence of a gun), on the other. Guthrie and Wiener established that it was the relative angularity of the masked figure, and not the presence of the gun, which determined judgements of hostility. Furthermore, since they were able to establish independently in additional experiments using different Os that angularity is systematically associated with negative reactions, and that Eagle's aggressive drawing was judged to be more angular than his benevolent picture, they concluded that the figural properties of the preceding material, and not its thematic content, influence cognitive processing. This result is perhaps surprising since Kempler and Wiener (1964) had earlier suggested that Os may reveal individual differences in their responses to the *same* fragmentary cues because of characteristic variance in the fluency and use of language, or even personality traits. Evidence exists, however, to support the hypothesis that structural attributes of line and contour may result in widespread attribution of stereotyped meaning, the association presumably depending upon the existence in the language of common descriptive qualities that are culturally determined (Osgood, 1953).

A second experiment criticized by Neisser is that by Smith et al (1959), in which words rather than pictorial material were used as the inducing stimuli. Subjects made descriptions, which were later classified for expressive qualities and physical features, about a drawing of a male face, presumed to be neutral and expressionless. The face was presented in a backward masking paradigm, following brief tachistoscopic exposures of the words "Happy" and "Angry". All exposures of the words were well below the individual's determined threshold and any trial in which a response was made following recognition of the verbal material was excluded from analysis. Smith et al reported a significant tendency for descriptions of the face to be more pleasant when it was preceded by the word "Happy", than by "Angry". The effect, furthermore, was as marked at an exposure duration of 4 msec (modal value) as at 20 msec. The authors propose that the absence of any increase in the effect with increasing exposure duration renders an explanation in terms of partial awareness unlikely. Instead, they conclude that the meaning of the words had been unconsciously perceived.

Neisser (1967) prefers an alternative explanation, suggesting that, because Smith et al did not employ a double blind technique, the unintentional provision of cues within the experimental situation could have conveyed their hypothesis to their subjects. Such sources of experimental error have been termed "demand characteristics" (Orne, 1962; Rosenthal, 1963). Neisser advances essentially the same argument when discussing the results obtained by Dixon (1958a), whose subjects were shown prolonged exposures of verbal material, superimposed on an illuminated screen at intensities far below the threshold of awareness.

Neisser's alternative explanation, however, fails to account for the fact that Guthrie and Wiener's (1966) subjects were able to make discriminations between subtle compositional differences in figures already erased by the masking procedure. Nor does it explain how the structural attributes of the stimulus material, as opposed to the thematic content, can influence behaviour in the absence of awareness. Finally, whilst the importance of adequate controls against artifacts arising from subjects' expectation or covert cues provided by the experimenter must be acknowledged, cues of this kind do not provide an alternative explanation to perception without awareness unless it is established that observers are, in fact, aware of these factors.

In a recent review of this area, Dixon (1971) has made similar criticisms of Neisser's position. Dixon further argues that, in most situations, the effect of partial cues concerning the experimental hypothesis would not be robust, and that where subjects are not even aware that they are being stimulated at all (Dixon, 1958a,1960; Dixon and Haider, 1961), the possibility of covert communication is extremely remote.

When the principal experiments upon which the controversy above is based are examined, a number of additional considerations are raised. Firstly, many experiments in this area have failed to establish whether or not O was aware of the masked stimulus or of a portion of it. In his discussion of the distinction between perception and response, Neisser (1967, p.118 ff) argues that "if a carefully interrogated and cooperative subject says that he really saw the word in question, he is to be believed" (p.121). Secondly, there are instances of weaknesses in experimental design: both Eagle (1959) and Guthrie and Wiener (1966) may be criticized for combining responses, made to descriptive dimensions which are possibly not independent; e.g. by adding together responses on the dimensions of "pleasant-unpleasant", "helpful-harmful", and "cruel-kind" which would seem likely to be substantially correlated. Thirdly, on close examination, Eagle's results are not uniformly convincing, and among female subjects, for example, are actually in the opposite direction to his hypothesis. Fourthly, in some research, the classification and quantification of responses depends upon psychodynamic assumptions the validity of which many psychologists would query (Klein et al, 1958; Dixon, 1956; Smith et al, 1959).

However, despite the attraction of a parsimonious explanation for subliminal perception in terms of response rather than sensory processes, the results of a number of experiments, designed to distinguish between sensory and response processes, suggest a genuine sensory effect. Neisser (1967) has not attempted to account for these findings.

Worthington (1964a), and Wallace and Worthington (1970) have used rate of dark adaptation as the dependent variable in a situation where, because of the extremely low intensity of stimulus presentation, O remains unaware that verbal material is being presented. Results indicate that, following light adaptation, the time required to report the presence or absence of a test nonsense shape, which accompanies a stimulus of much lower intensity, is significantly longer for emotional material than for the same words inverted, for structurally similar or neutral words, or for nonsense material. Worthington (1964b, 1969) has developed a technique involving paired comparison judgements of the relative brightness of emotional and neutral verbal stimuli, under conditions involving both simultaneous and successive presentation at very low intensity. No difference in judged brightness was found for the simultaneously paired comparisons but, under the successive condition where changes in sensitivity should be stimulus specific, systematic differences favouring a 'perceptual defense' explanation were found.

Sales and Haber (1968) report similar findings that although the rate of increase in "perceptual clarity" following repeated presentation is invariant for high and low frequency words, and for socially taboo words, the degree of clarity for letters of frequent words exceeds that for rare words, which, in turn, exceeds that for taboo words. Following Haber (1967), they argue that although the perceived clarity of the verbal material can be affected by a wide range of stimulus variables, including word frequency, language, expectation, familiarity, length of word and exposure duration, the fact that the *rate* of increase in clarity remains the same for a variety of material implies that the effect is not mediated by response mechanisms, but affects sensory processes directly. In support of this view, they also find no systematic difference between Os who were required to name only the letter, and those required to name letters and then guess the word, or simply guess the word only.

Finally, some investigators have examined the question of discrimination without awareness by using the methodology of signal detection theory (Green and Swets, 1966). At least four experiments have shown a change in sensitivity (d') following the presentation of emotional stimulus material, although the effect is not uniform. Sensitivity was found to increase in two studies, and to decrease in two.

Dorfman et al (1965) appear to be the first investigators to apply signal detection theory directly to the problem of perceptual defense. They found that for exposure durations of 30-60 msec, accuracy in identifying emotionally neutral words was significantly higher than for socially taboo words, but that at longer durations this was reversed, even when the word had to be uttered publicly. In contrast, a second experiment found higher accuracy for frequent, as opposed to infrequent, words at all durations, a result which supports earlier proposals of a bias against infrequent stimuli in the absence of any stimulus, but under conditions where stimuli are believed to be presented (Goldiamond and Hawkins, 1958; Zajonc and Nieuwenhuyse, 1964). Dorfman et al suggest that the interaction between emotionality and duration may be accounted for by their additional finding that discriminability (d') was higher for taboo stimuli at all exposure durations, and that the difference in discriminability between taboo and neutral words increased with duration. No such consistent trend was found with frequent-infrequent words. Using the same stimulus material, in a study designed to examine the common finding (e.g. Green, 1960) that response bias is a function of the a priori probability of the signal, Dorfman (1967) obtained results confirming this hypothesis, accuracy of taboo versus neutral words increasing with a priori probability. Once again, however, it was found that taboo words were significantly more discriminable at all three exposure durations of 30, 50 and 70 msec, than neutral words, and examination of individual data confirmed that this applied for 42 out of the 60 female Os.

On the other hand, Hardy and Legge (1968) applied signal detection procedures to a task involving the detection of a faint auditory signal while being simultaneously presented with either emotional or neutral words in the visual modality. Sensitivity, as measured by d', was lower during emotional stimulation for 12 out of 14 Os. However, β, calculated from pooled data, showed no evidence to suggest that emotional stimuli were affecting decision making criteria.

Again, results from an experiment by Broadbent and Gregory (1967), in which socially acceptable words, but having different degrees of emotionality, were embedded in white noise and presented to 32 Cambridge housewives, suggest that, although there were more correct responses to neutral than to emotional words, this was not determined by a bias against emotional words but, apparently, because of the failure of stimulus information to reach the perceptual mechanism. As the authors emphasize, this was an unexpected finding, since Broadbent would predict that any effect would show as a change in β, not d'.

Zwosta and Zenhausern (1969) have reported that a subliminal stimulus of white noise increases d' as opposed to β, for detection of a faint light signal imposed on an illuminated masking field. Paradoxically, their results also suggest a curvilinear relationship between sensitivity and the level of stimulation, facilitation being greater both well above (+ 15db) and well below (- 15db) the auditory threshold, a finding which appears to contradict the commonly described inverted U relationship between arousal and performance (Malmo, 1959; Welford, 1968). Zwosta and Zenhausern's suggestion that the activating properties of supraliminal stimulation might be offset by its distracting properties, does not, as pointed out by Dixon (1971, pp.281-284) explain the U shaped relationship. Dixon's explanation for the supraliminal section of the curve, that sensitivity is a function of concomitant non-specific activation, is satisfactory if one assumes that O is, in fact, under-aroused within that range of stimulation, and moving towards maximum efficiency.

As a possible explanation for the subthreshold part of the curve, Dixon suggests a hypothetical mechanism for which he advances some evidence. Specific and non-specific cortical activity resulting from near threshold signals are held to summate, producing interference, whereas for definitely subliminal stimulation which is not linked to specific cortical effects, the non-specific activity facilitates sensitivity for concurrent visual stimulation. Regardless of whether the model provides a sound physiological basis for the results described, this experiment suggests the intriguing possibility that sensitivity may be either increased or decreased, depending upon the kind of stimulation and general level of arousal already existing in the perceptual system.

EXPERIMENT 2.1:

This investigation represents an attempt to re-examine some of the questions associated with the perception of subliminal stimulation within an experimental situation derived from the principal studies discussed above. Observers viewed a man's face, previously established to have a neutral expression with respect to the emotions of happiness or anger. The face was preceded by a briefly exposed word, which was either *Happy*, or *Angry*, or a structurally similar nonsense syllable, and the lettering was in each case either angular or contoured. Os remained unaware of the word's presence.

It was therefore possible to establish whether subsequent judgements about the emotional expression in the face were directly influenced by the semantics of the masked word since, if this were the case, then judgements should coincide with the word present, regardless of its figural properties. If, on the other hand, Os made judgements consistent with some stereotyped meaning derived from the structural attributes of the letters in the word, then impressions of anger might be expected in the presence of angular lettering, while those of happiness should occur where the word was constructed from contoured letters. Finally, following a technique used by Rooney (1969) who succeeded in evoking emotionally toned responses in the absence of direct stimulation, an attempt was made to bias Os' expectations concerning the aims of the experiment by previously showing them words synonymous with the meaning of either *Happy* or *Angry*, in the guise of a visual acuity test. If this technique proved successful then subsequent judgements of the emotional expression in the face should reflect the influence of these situational cues, and be independent from the various attributes of the word itself.

A number of response measures, including rating scales designed to avoid items responses to which were likely to be correlated, were used in an attempt to uncover whether the verbal material was indeed unseen, and if it had produced a detectable cognitive effect. The experimental design therefore enabled the effects of bias, fragmentary cues, and subliminal stimulation to be examined independently and further provided for the possibility of interaction between these factors.

Preparation of stimulus material and response measures

1. Selection of verbal material designed to bias Os' expectations.

Words considered functionally similar to *Happy* and *Angry* were derived from Roget's Thesaurus and the 10 most frequent in both categories (Thorndike and Lorge, 1944) included with 10 high frequency neutral words (Broadbent and Gregory, 1967, Table 2). The association between each of these 30 words and the dimensions *Happy-Unhappy* and *Angry-Not angry* was rated by 23 male and female students, enrolled in the first year Psychology course at the University of Adelaide, on a scale ranging from 1 to 7. It was emphasized that a score of 4 represented the point of neutrality for both dimensions. The order of word presentation was varied for each judge as a control against response set.

Although results suggested that judgements using the two dimensions were closely inter-related (Spearman r_s = -0.98; $p < 0.001$; two tails), both were retained for later use, and a final list of 12 words, as set out in Table 2.1, selected according to ranked mean ratings. Each word was formed in both angular lettering (Letraset, No.285, capitals), and contoured lettering (Letraset, No. 318, 48 point Berling italics), and, after matching the two forms for height and length, transferred to 35 mm transparencies. Examples of verbal material, in different forms, are shown in Appendix 2.1.

2. Preparation of response sheets

The aim was to develop a series of response dimensions unrelated to those associated with happiness and anger, so that presenting these two within the total context should prevent awareness that they were of special significance.

Twenty five adjectives considered to be functionally dissimilar to either *Happy* or *Angry* were included with 15 thought to have a high semantic association with these two, and converted to 40 pairs of antonyms. As a control against response set, the word pairs were presented in the same order to 12 judges, this order being reversed for the remaining 11. Judges were the same 23 students used in the previous task. Each rated every word pair on a scale from 1 to 5 in accordance with its functional similarity to the dimensions

		"*Happy-Unhappy*"		"*Angry-Not angry*"	
		Mean rating	Rank	Mean rating	Rank
Happy, Not angry words	rejoicing	1.26	1	6.69	29
	joyful	1.30	2	6.83	30
	delighted	1.35	3	6.61	28
	laughing	1.61	4	6.35	26
Neutral words	foot	3.96	14.5	3.91	15
	run	3.96	14.5	3.83	12
	far	4.04	16	4.35	19
	stop	4.09	17	3.87	13.5
Unhappy, Angry words	furious	6.04	27	1.04	2.5
	fuming	6.09	28	1.09	4
	enraged	6.26	29	1.04	2.5
	seething	6.30	30	1.00	1

Table 2.1: Mean ratings on a scale from 1 to 7, and corresponding rank order of 12 stimulus words, selected from a list of 30, as most strongly reflecting specified conative relationships with the descriptive dimensions *Happy-Unhappy* and *Angry-Not angry*

Happy-Unhappy and *Angry-Not angry*, a score of 1 indicating that the dimension implied by the word pair was completely synonymous with the critical dimension, and a score of 5 indicating the absence of any relationship. The 10 antonym pairs judged to be least related to the critical dimensions are shown in Table 2.2.

3. Selection of a face, neutral with respect to the dimensions *Happy-Unhappy* and *Angry-Not angry*.

Photographs of 14 male and 8 female faces considered to be relatively expressionless, together with 6 male and 6 female faces where the person was smiling, were selected from among psychology students entering first year courses four years previously. All photographs were full face with the shoulders partially visible.

The 34 photographs, together with the drawing of a male face used by Smith et al (1959) were shown to the same 23 students used above, who rated the expression on each face on each of the descriptive dimensions in Table 2.2, and also the critical dimensions of *Happy-Unhappy* and *Angry-Not angry*. Judges used a scale from 1 to 7, the score of 4 indicating a neutral expression. Lists were arranged so that the word pairs were reversed for about half of the judges. The order of presentation was also reversed in half the cases, as a control against response set. Judges indicated whether the person photographed was known to them and where this was so, the data were discarded.

	Happy-Unhappy		*Angry-Not angry*	
	Mean rating	Rank	Mean rating	Rank
religious-irreligious	4.43	1.5	4.35	1
educated-uneducated	4.35	3.5	3.96	8
realistic-superstitious	4.35	3.5	4.00	6
studious - not studious	4.30	5.5	3.87	10.5
naive - sophisticated	4.22	8	4.09	2
tidy - untidy	4.13	9	4.04	3.5
ostentatious - unpretentious	4.09	10.5	4.00	6
concise - verbose	4.00	12	4.00	6
courageous - cowardly	3.87	15.5	3.87	10.5
discreet - indiscreet	3.83	18	4.04	3.5

Table 2.2: Mean ratings on a monotonic scale from 1 to 5 and corresponding rank order of 10 descriptive dimensions, selected from a list of 40 antonyms as being relatively independent to the dimensions *Happy-Unhappy* and *Angry-Not angry*.

The stimulus used by Smith et al (1959) was examined separately and found to be unsatisfactory, since the mean ratings of 2.74 (*Happy-Unhappy*) and 5.70 (*Angry-Not angry*) depart significantly from neutrality (single sample $t = 5.32$ and 6.87 respectively; d.f. = 22; $p < 0.001$; two tails). Judgements concerning the final choice showed least variance in both dimensions when compared with three possible alternatives, and mean ratings showed no significant departure from neutrality on either dimension.

	Happy-Unhappy	*Angry-Not angry*
Mean ratings (N = 23)	4.39	4.26
Standard deviations	1.27	1.51
Single sample t (df = 22)	1.48	0.83
p (two tails)	0.15	0.58

The male face selected is shown in Appendix 2.2.

Despite a highly significant correlation between mean ratings of the 35 faces on both dimensions (Spearman r_s = -0.80; $p < 0.001$; two tails), it seems possible that some judges used the *Angry-Not angry* dimension as a monotonic scale, reserving the score of 7 to indicate a completely neutral expression. Thus, although all 17 photographs categorized to some degree as *Happy* had mean ratings in the direction of *Not angry*, of the 18 photographs categorized to some extent as *Unhappy*, 13 had mean ratings in the direction of *Not angry*, whilst only 5 were in the direction of *Angry*.

This question was examined further by categorizing each face according to its rating (1-7) on the *Happy-Unhappy* dimension. Mean ratings on the *Angry-Not angry* dimension were then calculated for all photographs in each category on the *Happy-Unhappy* dimension. These results are included in Appendix 2.3. Although the clear linear trend obtained suggests a strong interdependence between the two dimensions, the markedly larger dispersion in category 7, *Unhappy*, indicates marked individual differences in the interpretation of facial expressions seen as "Unhappy", with respect to *Angry-Not angry*. This conclusion is supported by the finding that variances in Categories 1 and 7 of the *Happy-Unhappy* dimension are significantly different ($F_{max} = 3.26$; $df = 15,20$; $p < 0.01$).

Because, however, it could not be satisfactorily determined from the data whether the facial expressions were directly responsible for this result, or whether some judges had used the *Angry-Not angry* dimension in a way other than instructed, it was decided to include both in the experiment, since the two dimensions did not necessarily reflect each other in some circumstances.

4. Letter slides and stimulus film-loops.

Two sets of stimulus material were prepared, in addition to the words shown in Table 2.1.

(i) The letters Z, B, E, W, Q, K, M, X were formed with letraset, No. 285, capitals, and individual slides prepared for projection in a Carousel projector.

These letters were chosen since they do not occur in the words "happy" and "angry".

(ii) Film has been used to produce tachistoscopic exposure conditions, with backward but without forward masking, which are usually only available on a 3 field tachistoscope.

Seven film loops were made, each containing 290 frames, subdivided into 5 identical stimulus sequences. Each sequence consisted of 46 blank frames, 1 frame containing a word, and 11 frames the face, so that when the loop was in operation, the word was followed and masked by the slightly darker face.

The word was photographed so that it appeared to lie across the eyes of the face, extending from ear to ear without passing beyond the facial outline. Of the 7 films, 2 contained the word "happy", 2 the word "angry", and 2 the nonsense syllable "yagph" composed from letters in the other two words. In one of each pair the lettering was angular, and in the other contoured. The seventh film contained no word or syllable, and the frames, corresponding to those in which the words or syllable appeared in the other films, were left blank.

The time for which a frame was exposed could not be accurately determined since this projector makes 3 separate exposures of a single frame and the precise parameters of the mechanism were not available. However, if the intermediate 'blanks' are disregarded, the approximate exposure for the verbal material was 40 msec.

To confirm that verbal material was visible when not followed by the face, a film loop containing the 6 stimulus forms was prepared and each word exposed separately to the same 23 Os mentioned previously under conditions equivalent to the experimental situation. Results, which are presented in Appendix 2.4, leave no doubt that the words were clearly visible when exposed for the duration of one frame without masking.

Apparatus

The experimental room adjoined that housing the apparatus, and from which lighting and a warning buzzer were controlled. Slides were projected approximately 10 feet onto a screen in the experimental room by means of a slide-projector, fitted with an electronically timed mechanical shutter. Films were similarly projected, using a 16 mm cine projector, running at 24 frames per sec.

Experimental design

Observers were randomly allocated to 1 of 28 groups in accordance with a three factorial design as set out in Table 2.3. There were 10 Os in each group. To induce different expectations concerning the experimental aims, 4 treatments were employed. In three of these, Os saw words previously established as functionally similar to either "happy" or "angry", or as neutral in either respect. Os allocated to a fourth control condition were not shown words during this stage.

GROUP	Stage 1 (manipulation of Os expectations about experimental aims)				Stage 2 (film masking verbal material in either angular (A) or contoured (C) lettering)						
	Happy words	Angry words	Neutral Words	NO TREATMENT	"Happy" A	"Happy" C	"Angry" A	"Angry" C	"Yagph" A	"Yagph" C	BLANK
1	✓				✓						
2	✓					✓					
3	✓						✓				
4	✓							✓			
5	✓								✓		
6	✓									✓	
7	✓										✓
8		✓			✓						
9		✓				✓					
10		✓					✓				
11		✓						✓			
12		✓							✓		
13		✓								✓	
14		✓									✓
15			✓		✓						
16			✓			✓					
17			✓				✓				
18			✓					✓			
19			✓						✓		
20			✓							✓	
21			✓								✓
22				✓	✓						
23				✓		✓					
24				✓			✓				
25				✓				✓			
26				✓					✓		
27				✓						✓	
28				✓							✓

Table 2.3: The design of Experiment 2.1. Groups were first shown words selected as likely to bias expectations about the experimental aims. Groups then watched a film in which a face masked verbal material which was formed from either angular or contoured lettering. Appropriate control groups were included.

Each of three film loops included either the word "happy" or "angry" or "yagph", whilst no word appeared in a fourth film. There were therefore 4 levels concerned with the meaning of the masked word.

Finally, for each of 3 conditions in which a word was included in the film, the structural attribute of that word was defined as either angular or contoured. The factorial design was therefore incomplete, since the factor concerned with word structural properties could not be applied to those control groups viewing a film in which no word was present.

Procedure

Observers attended in groups, sitting at desks between 7 and 9 feet from the screen. Communication with the experimenter and within the group was restricted, all instructions being on printed handouts, or projected onto the screen.

Stage 1 was concerned with manipulating expectations about the aims of the experiment. Initial instructions included in Appendix 2.5 prepared Os for a test of visual acuity and eye dominance. Os were required to identify the letters Z, B, E, W, using the left eye only, and Q, K, M, X, with the right eye, each letter being exposed for 50 msec. The four words previously selected to bias O's expectations concerning the experimental aims followed, each being exposed twice for 500 msec in both angular and contoured lettering in a predetermined order.

Each exposure was preceded by a 5 sec warning buzzer during which lights were extinguished. Following exposure, lights were restored for 20 sec enabling Os to indicate the verbal material seen on the response sheets provided. At the conclusion of stage 1 projected instructions asked Os to remain seated and refrain from talking. The experimenter entered the experimental room briefly, to collect response sheets and distribute instructions and response sheets for Stage 2. These are included in Appendix 2.5. Different response sheets were designed, as described above, to provide controls against response set.

During stage 2 the film loop was run, the sequence of the word masked by the face appearing 16 times, after which Os rated the expression of the face on the 10 dimensions shown in Table 2.2 together with those of *Happy-Unhappy* and *Angry-Not angry*. When all the stimuli had been given, Os answered 3 questionnaires A, B and C, included in Appendix 2.5, which were designed to reveal if masking had been successful, whether O had been aware of partial cues, and to distinguish between visual processes underlying the certain recognition of the word in the film, and inferential processes by which O might arrive at a "best bet" concerning the word. This distinction has been emphasized by Neisser (1967, p.121), who terms the former process "figural synthesis", while reserving the term "auditory synthesis" for the latter which he regards as an inferential verbal process. The questionnaires were designed in such a way as to prevent answers being biased by earlier questions and answers.

The 24 adjectives in Questionnaire C were derived from the 12 pairs of antonyms used to rate the expression of the face in the film. Once again, the design of the questionnaire included a control for response set. Thus, the words were presented in two different orders, one being the reverse of the other, and 5 Os in each group answered one form, while 5 answered the other.

Observers

108 male and 172 female students, with a modal age of 18 years, and enrolled in first and second year psychology courses at the University of Adelaide and the South Australian Institute of Technology, served as Os. All were naive with respect to the aims of the experiment. Two additional Os were rejected after correctly identifying the word in the film. 273 Os reported that they did not know the person in the film and it has been assumed that he was unknown to the 7 failing to answer this question.

RESULTS AND DISCUSSION

An examination of responses following stage 1 reveals that, of the 210 Os undergoing these conditions, only 4 made errors in reporting letters (1 error each), 6 reported 1 word incorrectly, and 1 failed to identify 2 words. These Os were not distributed among groups in any discernible pattern and it may therefore be concluded that Os recognized the verbal material initially presented.

Responses to questionnaires A and B clearly demonstrate that the great majority of Os did not experience any change in facial expression, and remained unaware of the word's presence - only 27 considered that a change of expression had occurred, and only 45 reported the detection of additional material in the film. Observers who did this were widely distributed throughout the 28 groups and reference was invariably directed towards non-facial characteristics, e.g. film blemishes and items of clothing. 4 Os indicated that they saw letters but, since they were unable to identify any of them correctly, their results were retained for analysis.

These findings completely discount the possibility that O obtained fragmentary information at levels of conscious awareness, and confirm the effectiveness of the backward masking procedure. The tendency, reported by Smith et al (1959), for Os to experience change in facial expression is clearly not evident here. However, since the instructions given by Smith et al specifically suggested the possibility of such a change (p.169), it seems probable that the effect was artifactual.

The frequency with which the 24 adjectives listed in questionnaire C were selected, regardless of rank, as being most probably exposed during the film, departs significantly from chance (single sample $\chi^2 = 528.9$; d.f. = 23; $p < 0.001$; two tails), 16 of them making contributions to the overall

χ^2 which exceed the critical value for the 5% level. These are from 10 descriptive dimensions, and include "happy" (χ^2 = 25.2), "unhappy" (χ^2 = 202.5), and "angry" (χ^2 = 42.3). An examination of the distributions of "unhappy" and "angry" responses, however, finds no evidence for a relationship with any of the independent variables (analyses are included in Appendix 2.6 (i) and (ii)). However, a comparison of choice in questionnaire C, with ratings of facial expression on the two critical dimensions during stage 2, reveals a significant relationship for both *Happy-Unhappy* (χ^2 = 59.9; df = 15; $p < 0.001$; two tails), and *Angry-Not angry* (χ^2 = 74.2; df = 10; $p < 0.001$; two tails). The principal contributions to these results indicate that Os judging the facial expression as "happy" have avoided the choice of "unhappy", whilst those previously registering judgements of "unhappy" have subsequently chosen this to a significant degree. Similarly, those judging the face to be "angry" have subsequently included this as a highly probable masked word, while those recording "not angry" judgements have omitted "angry" from their choices, to a significant degree (refer Appendix 2.6 (iii)).

These findings clearly demonstrate the operation of a response set: Os' subsequent opinions about what words might have appeared in the film were largely determined by their earlier judgements of facial expression. This, in turn, suggests that an experimenter might expect to encounter difficulties if he should rely ultimately, as Neisser suggested (1967, p.121) on the phenomenal report of even the most cooperative observer. The question of the use made of phenomenal reports in experimentation has been widely discussed (Waters, 1958; Corso, 1967), and it is not the intention here to suggest that an O's introspections should be inadmissible as experimental data. The present results, however, do emphasize the need for caution when attempting to interpret these data.

The results further suggest that the expressive qualities reported are actually present in the face. However, the single group (N = 10) which did not take part in stage 1, and which viewed the film in which no verbal material was present (group 28 in Table 2.3), made judgements of facial expression closely resembling those made prior to the experiment. (A comparison is provided in Appendix 2.7 (i)). This suggests that judgements of facial expressions have been affected by some as yet unidentified variable in the experimental situation.

It was not expected that adjectives other than "happy", "unhappy", or "angry", "not angry" would be selected from questionnaire C at greater than chance level. Words from the 8 descriptive dimensions shown in Appendix 2.7 (ii) were, however, chosen either more or less frequently than would be expected by chance, and the manner in which these particular dimensions had been previously applied to the same face in the pre-experimental session was therefore examined. Despite the much smaller sample (N = 23), earlier ratings differed significantly from neutral in the direction predicted by present results in 4 cases ($p \leqslant 0.03$; one tail), were marginal in 2 ($p \lesssim 0.07$; one tail), and doubtful in 1, although this was in the predicted direction ($p = 0.14$; one tail). In the case of the dimension *cowardly-courageous*, from which *both* adjectives were chosen significantly *less* than chance, it was expected that earlier ratings would not differ significantly from neutral. This was found to be the case ($p = 0.26$; two tails).

Taken together, these findings suggest that although the choice of some adjectives departs significantly from chance, this is not related to factors related to the experimental treatment. Rather, the biases shown in selecting these adjectives as applicable to the facial expression, are probably a function of the words used to form the descriptive dimensions. The alternative explanation, that these characteristics might be seen to be inherent in the facial expression, would seem unlikely, since, with the possible exception of *tidy-untidy*, the dimensions in Appendix 2.7 (ii) are more appropriately applied to the description of behaviour than to facial expression.

Because the four groups viewing the no-word film can not be included under the condition examining the structural relevance of verbal material, rating data, for both *Happy-Unhappy* and *Angry-Not angry* dimensions, have been analyzed by 3 separate multi-factorial, orthogonal analyses of variance, included in Appendix 2.8.

Happy-Unhappy ratings.

Treatment in stage 1 produced an unexpected bias effect: all groups shown words prior to viewing the film, tended, regardless of the meaning of the words they had been shown, to rate the facial expression as more unhappy than did the groups not undergoing treatment (Table 2.4; $F = 2.65$; $df = 3, 216$; $p = 0.049$). However, $F_{max(4,59)} = 1.99$, indicating that variance is significantly non-homoscedastic ($1-\alpha = 0.95$), and there has been some tendency for scores to bunch at the top end of the rating scale. Following a 2 arcsine $\sqrt{x}$ transformation, where x represents a proportional score, the effect is less marked ($F = 2.10$; $df = 3,216$; $p = 0.099$). The meaning of the verbal material in the film has had no effect ($F < 1.0$), but the structural attributes of the lettering has produced a significant effect ($F = 3.81$, d.f. = 1,216; $p = 0.049$; transformed data), angular attributes resulting in higher *Unhappy* ratings. The significant interaction between verbal material in Stage 1 and the structural attributes of the verbal material in the film ($F = 2.82$, $df = 3,216$, $p = 0.039$; transformed data), is caused by the effect of angularity being less marked in groups not taking part in stage 1 (Table 2.4). No other interactions approach significance at the 5% level.

		Words, presented during Stage 1, being functionally similar to defined meanings (Factor A)				
		Angry	Happy	Neutral	No treatment	TOTALS
Structural properties of words in the film, Stage 2 (Factor C)	Angular	5.80	5.77	5.73	4.83	5.53 (1.37)
	Contoured	5.43	4.70	5.50	5.30	5.23 (1.35)
	TOTALS	5.62 (1.19)	5.23 (1.49)	5.62 (1.11)	5.07 (1.56)	

Table 2.4: Means and standard deviations (in parentheses) for ratings of facial expression on the *Happy-Unhappy* dimension. Analysis of variance summary table is included in Appendix 2.8, 1 (i).

Separate analyses, included in Appendix 2.8, (2) and (3), enable the comparison of groups seeing films in which the masked word is constructed from angular letters, and groups seeing those in which lettering is contoured, with groups viewing the film in which no word is present. These confirm that the bias towards *Unhappy* judgements, which appears above to be attributable to the prior exposure of any words, regardless of their emotional tone, is confined to groups viewing films in which the masked word is of angular appearance ($F = 3.49$; df = 3,144, $p = 0.017$). No significant effect is evident when the lettering of the masked word is contoured ($F = 1.53$; df = 3,144, $p = 0.207$).

It should not be concluded, however, that the angular properties of the masked word are a contributory factor to this outcome, *since the presence or absence of a word in the film produces no significant effects on judgements*, regardless of whether the word, when present, is angular ($F = 1.14$; df = 3,144; $p = 0.336$), or contoured ($F = 1.45$; df = 3,144; $p = 0.229$). Clearly, if the angular property of the masked word was a factor influencing judgement, then we should expect to find that the angular structural attributes produce significantly higher *Unhappy* judgements than are found when no word is present in the film. As may be seen from Table 2.5, this has not been found to be the case. It is concluded, therefore, that judgements of facial expression have been influenced by the presence of verbal material presented prior to the judgemental situation, irrespective of its meaning.

		Words presented during Stage 1, being functionally similar to defined meanings (Factor A).				
		Angry	Happy	Neutral	No treatment	TOTALS
Structurally angular words in the film, Stage 2, (Factor B).	"Angry"	5.80	5.80	6.10	4.20	5.48 (1.45)
	"Happy"	6.00	5.80	5.40	5.00	5.55 (1.30)
	"Yagph"	5.60	5.70	5.70	5.30	5.38 (1.39)
	No word present	4.50	5.40	5.60	4.80	5.08 (1.51)
	TOTALS	5.48 (1.40)	5.68 (1.29)	5.70 (1.22)	4.83 (1.62)	

Table 2.5: Means and standard deviations (in parentheses) for ratings of facial expression on the *Happy-Unhappy* dimension. Analysis of variance summary table is included in Appendix 2.8, 2(i).

Angry-Not angry ratings.

The conclusions above receive some support from responses made on this dimension. No factors or interaction produce differential effects significant at the 5% level. However, the treatment in stage 1 has produced a difference between those groups that were shown words regardless of meaning, and those control groups that were not. This difference, although not significant (F = 1.92, d.f. = 3,216; p = 0.126), is consistent with the findings discussed above, and as may be seen from Table 2.6, judgements in all groups previously exposed to words show slight biases towards *Not angry*, whereas the bias is towards *Angry* in those control groups not undergoing treatment during Stage 1. No evidence is found for an effect arising out of structural differences in the masked verbal material.

There is some suggestion that the use of *Angry-Not angry* has not been uniform. When ratings on this dimension are categorized according to *Happy-Unhappy* ratings, variance between Os increases as judgement of *Happy-Unhappy* increases from 1-7 (Spearman r_s = 0.79; p = 0.048; two tail). However, as may be seen from Table 2.7, there is no clear evidence that the *Angry-Not angry* dimension has been generally interpreted in a manner inconsistent with use of the *Happy-Unhappy* scale.

		Words, presented during Stage 1, being functionally similar to defined meanings (Factor A)				
		Angry	Happy	Neutral	No treatment	TOTALS
Structural properties of words in the film, Stage 2 (Factor C).	angular	4.73	3.83	4.17	3.80	4.13 (1.76)
	contoured	4.37	4.63	4.00	3.93	4.23 (1.49)
	TOTALS	4.55 (1.48)	4.23 (1.67)	4.08 (1.58)	3.87 (1.74)	

Table 2.6: Means and standard deviations (in parentheses) for ratings of facial expression on the *Angry-Not angry* dimension. Analysis of variance summary table is included in Appendix 2.6, 1 (ii).

Rating on *Angry-Not angry* dimension		Rating categories on *Happy-Unhappy* dimension						
		1	2	3	4	5	6	7
	Mean	4.75	5.00	5.57	4.30	4.55	4.18	3.58
	n	4	11	7	50	60	89	59
	Standard deviation	0.96	1.34	1.62	1.43	1.53	1.55	1.81

Table 2.7: Means and estimated population standard deviations for ratings of *Angry-Not angry* falling within all categories of the *Happy-Unhappy* dimension.

CONCLUSIONS

Under conditions where the possibility of bias caused by situational cues is reduced by isolating Os from experimental apparatus, and minimizing contact with the experimenter, the phenomena often reported as supporting a hypothesis of discrimination without awareness, have not appeared. This lends support to the alternative viewpoint, that raising or lowering of threshold to emotional material result from response bias, and are not due to any change in sensory processes (Goldiamond, 1958). It is clear, furthermore, from the absence of an obvious relationship between the functional meaning of the words shown to Os in stage 1, and the subsequent ratings made by these Os of the extent to which the face they saw revealed the emotions of anger or happiness, that the attempt to manipulate Os expectations directly has not succeeded. Response bias has evidently occurred, however, as demonstrated by the significantly less *unhappy* judgements made by Os not previously shown verbal material of any kind, a paradoxical finding for which no explanation can be offered here.

The finding that responses to various questionnaires administered at the end of the experimental session are in line with earlier judgements concerning facial expression made during the session, may also be interpreted as evidence for response bias of an unexpected kind. This result points to the difficulty of placing much reliance upon phenomenal reports which, after the event, are unlikely to be independent of earlier patterns of responding.

Although there appears to be some *prima facie* evidence that previous exposure to words of any kind may lead to an increased sensitivity to partial cues concerning the structural attributes of masked stimulation, this must be discounted in the light of evidence that the effect occurred, even when no word was present in the film. It should be noted that, lacking the control effected by this final condition, which is seldom encountered in the literature, this finding would have been attributed to the angularity of the masked stimuli, and seen, therefore, to support fragment theory.

The difficulties encountered in attempting to interpret these data underscore the necessity of adequate control procedures, particularly where a number of conditions are involved. Of equal importance, however, is the choice of stimulus and response measures. The ambiguity of these experimental findings suggest that, despite wide application in research of this type, verbal material and verbally dependent scales may best be avoided at this stage, in favour of variables for which the parameters may be more accurately specified.

CHAPTER III.

THE MEASUREMENT OF 'INSPECTION TIME' AND 'NOISE' IN THE VISUAL SYSTEM

INTRODUCTION

In 1760 Bouguer reported that when two candles of differing brightness are placed so that one casts a shadow obliterating that from the other, the ratio of the two intensities remains constant with variation in the brightness of the lights (cited by Barlow, 1957a). This would appear to be the earliest attempt to measure the discriminatory limitations of receptor organs utilizing the differential threshold. During the next hundred years a number of workers, including the German physiologist E.H. Weber, confirmed that the least detectable increment in intensity increases as a direct function of the standard or background intensity to which the organism is adapted. This concept ($\Delta I/I = C$) was found to hold reasonably well within wide limits of intensity, despite individual differences, not only for vision but also for other sense modalities.

Fechner (1966) assumed the Weber fraction to be true, and used it in attempting to demonstrate a lawful relationship between stimulation and sensation. He further assumed that any difference threshold is subjectively equal to any other, deriving, by integration, his "psychophysical law";

$$\text{sensation} = K \log I + C$$

The adequacy of the Weber fraction was challenged from the outset, a number of workers demonstrating its breakdown at low and high intensities and some inaccuracy in the intermediate range. Others questioned the validity of the underlying assumptions, particularly those concerning the quantification of a sensation (Henmon, 1906, pp.5-11). Fechner, however, considered that the absolute threshold provided the limiting case of the differential threshold.

Thus Fechner's theory stressed that the organism's capacity to respond to stimulation was limited. The level of the absolute threshold was held to be determined by the "Augenschwarz", an intrinsic residual activity existing in the organism's nervous system. Essentially, Fechner's rationale was that because the brain and its receptor systems are already in a state of neurological activity, excitation resulting from a physical stimulus must sufficiently exceed the level of excitation already present. Unless this occurred, the organism could not experience sensation and was not, therefore, capable of detection or discrimination.

Since that time the differential threshold has provided a fundamental behavioural descriptor, used extensively in comparing the relative sensitivity of different sense modalities, measuring the effects of fatigue, anxiety, sensory deprivation, and the influence of drugs and alcohol, establishing the perceptual capacities of species other than man, and detecting changes resulting from development and ageing. Although controversy has existed since the earliest studies, as to whether sensory discrimination actually involves an underlying, abrupt, qualitative change at the threshold, as held by Fechner, or whether there is no threshold in a literal sense and that "sensation and stimulation each forms a continuum" (Jastrow, 1888, p.284), it may be illustrated by the method of constant stimulus differences (Corso, 1967) that response probability, in a situation involving two discriminanda, may be plotted as a *psychometric function* of the stimulus differences (Urban, 1910). Peirce and Jastrow (1885) found no evidence for discontinuity as implied by Fechner's position, reporting that the function took the shape of a continuous sigmoid curve.

Jastrow (1888) proposed that the form of this function was caused by "lapses of attention, slight fatigues and all the other psychological fluctuations that go to make us now better and now worse judging agencies than our average selves" (p.284). Cattell (1893) made similar suggestions linking variation in sensation, and hence responding, to variance in stimulation and to internal fluctuations "in attention, fatigue, interest, inhibition" and other numerous "sources of variation" (p.297). The ideas of these early workers provide parallels with more recent interest in "neural" or "internal noise". The "Augenschwarz" may be seen as the precursor to maintained activity in the central nervous system, whilst early concern with variance provides the basis for present day signal/noise discrimination and detection theory.

Recordings from single sensory neurones have almost invariably revealed a continuous, irregular activity, even in the absence of any direct stimulation. This low frequency discharge was attributed to methodological sources of error by early workers but, following Granit (1941), it has been widely recognised that factors like mechanical stimulation, electrode pressure and anaesthesia are not responsible for the background, maintained activity. Maintained activity has been recorded in single ganglion cells in the cat's retina, even in complete darkness and after full adaptation, (Granit, 1955; Arduini and Pinneo, 1962, 1963; Levick and Williams, 1964; Rodieck, 1967; Barlow and Levick, 1969(a), 1969(b)), and in unanaesthetized preparations (Kuffler, et al, 1957).

In addition, it has been recognized that variability in stimulus energy, absorbed from a nominally constant source, limits the accuracy of intensity judgements (Rose, 1948; de Vries, 1943; 1956). Hecht et al (1942), in fact, considered the effects of biological noise to be negligible, arguing that statistical fluctuations in detection could be entirely accounted for by variance in the number of quanta absorbed by the photo-receptors during a single, brief flash of light of near-threshold intensity. More recently, however, it is most commonly held that, whilst stimulus variability is undoubtedly a contributing factor, the absolute limit to discrimination is ultimately determined by random biological activity in the central nervous system (Denton and Pirenne, 1954; Barlow, 1956, 1957a, 1957b), which may be the consequence of ongoing cortical processes, or the aftereffects of previous activity (Hebb, 1961; Treisman, 1964; Welford, 1965a, 1968).

Arduini (1963) and Pinneo (1966a) have criticised energy level theories on the grounds that they regard spontaneous, random discharge of neurones as noise and, therefore, disruptive. These authors argue, on the contrary, that both phasic and tonic activity convey information of specific functional value to the organism, emphasising the essential role of variable stimulation in maintaining normal perceptual function (Arduini and Pinneo, 1962, 1963). They point to evidence of a direct relationship between parameters associated with impulse frequency and varying conditions of stimulation (Kuffler, 1953; Bullock and Diecke, 1956) and to evidence that programming highly specific discrete stimulation may produce integrated sequences of motor activity, which are the combination of several different behavioural fragments (Pinneo, 1966b).

However, without denying the significance of such activity to discrimination and learning, there is also evidence that irregularity in the timing of the occurrence of impulses from receptor organs may limit sensitivity in the processing system (Barlow and Levick, 1969a). Furthermore, it is felt that Pinneo's (1966a) criticisms of Hebb and Treisman are, in part, based upon a misinterpretation of their positions, which are concerned with the consequences of interaction between intrinsic cortical activity, arising from stimulation which is irrelevant to the task, rather than with the parameters of specific task-linked activity. A reasonable compromise would seem to be that a unique probability distribution function, determined by a specific signal, may become increasingly disrupted as it is swamped by an increasing number of irrelevant functions.

In a series of investigations concerned with spatial summation, Gregory and his associates have produced psychophysical estimates of noise in the visual system, attempting to distinguish between retinal noise, added to the system before transduction, and neural noise, arising from variation in impulse rate subsequent to transduction (Gregory and Cane, 1955; Gregory, 1955, 1956; Cane and Gregory, 1957). Although these measures have shown promise in studying perceptual changes with age (Gregory, Cane and Wallace, 1957; Gregory; Gregory and Kendon, cited by Welford, 1958, pp.156-160), a number of criticisms have been raised (Barlow, cited by Gregory, 1956; Barlow, 1957b; Bulmer and Howarth, 1957), and as the authors themselves acknowledge, the values obtained are highly reliant upon the goodness of fit derived from the empirical data.

Barlow (1956) describes a procedure for estimating both the mean maintained retinal discharge and the ratio of rod excitations to quanta falling on the cornea from a flash of light at threshold intensity. The dark-adapted subject looked at brief light flashes of varying intensity under conditions ensuring scotopic stimulation, and, in addition to recording when he saw a flash, indicated "possible" flashes. The experimental design included a number of "zero intensity flashes" which occurred in the same context as stimulus flashes, thereby providing an indication of false-positive rate. Although it is possible in principle to derive a best-fitting cumulative Poisson distribution from the empirical data, where slope at threshold provides an indicant of noise and the 50% threshold represents the ratio of rod excitations to quantal stimulation, the technique relies upon an accurate 'false-positive' measure and this was not obtained in practice. Barlow concludes that the allowable range of parameter values obtained is so large as to render other methods of determination necessary. A more successful procedure (Gregory, 1959; Barlow, 1957a) involves first establishing the relationship between ΔI and I over a range where the contribution of noise is negligible, and then extrapolating this relationship to the absolute threshold, where the only noise is assumed to be intrinsic retinal activity. Although dependent upon a large number of empirically specified parameters, this technique yields values of 'dark light', which appear to receive some corroboration from available evidence concerning maintained activity in the visual system.

M. Treisman (1964) presents no new data but uses the signal detection model to apply Weber's law parsimoniously to a wide range of threshold discriminations. It is postulated that the central effect of incoming stimulation is a linear function of stimulus intensity and may be represented by a normal distribution, the variance of which (termed 'neural noise') will be positively correlated with the initial sources. Given these assumptions, it is possible to define the Weber fraction in terms of a continuous transition, from a square root law at low stimulus intensities, to a linear law at high intensities, thus accounting for both the approximations to Weber's law so frequently encountered for mid-range stimulus dimensions and the departures reported for low values of I. The Weber function that Treisman derives includes a number of parameters which take account of the effects of different sources of noise, and Treisman discusses possible techniques for isolating four of the parameters in some detail. However, the difficulties encountered by Gregory and his associates and by Barlow, described above, remain. Also there is evidence that sensory coding is multidimensional (Uttal, 1969). While, therefore, speculation concerning the details of complex neural integration and function provides an impetus to the discussion and clarification of ideas, and may help establish guidelines for the plausibility of hypotheses, a single behavioural measure of *noise*, in the most comprehensive sense, seems to be the mose useful at the present time.

THE PSYCHOMETRIC FUNCTION AND THE PHI-GAMMA HYPOTHESIS

Although the distribution of effect from some sources may be more appropriately characterized by a Poisson distribution (Pirenne, 1951; Barlow, 1956; Welford, 1968) it has been widely accepted that the combined effects of all sources of random variation should be closely approximated by a normal curve (Jastrow, 1888; Cattell, 1893; Boring, 1917; Thurstone,1927a, 1927b; Cartwright and Festinger, 1943; Tanner and Swets, 1954). As pointed out by Swets et al (1961), although the assumption of normality simplifies matters, it is sufficient that the distribution be such that it can be transformed into the Gaussian form.

Two signals X and Y of different magnitude may therefore be represented by two uncorrelated normal distributions of sensory effect having equal variance, as shown in Figure 3.1. Following Thurstone (1927a), fluctuations in sensory effect are held to occur *from one judgement to the next*, so that each judgement is a function of the "discriminal difference" (X - Y) between X and Y on that trial. Over a series of trials the distribution of (X - Y) differences will have a mean $\overline{(X - Y)}$ equal to $\bar{X} - \bar{Y}$ and a standard deviation $\sigma_{(X-Y)} = \sqrt{\sigma_X^2 + \sigma_Y^2}$ (or $\sqrt{2\sigma_X^2}$ where $\sigma_X = \sigma_Y$), as illustrated in Figure 3.2. According to the

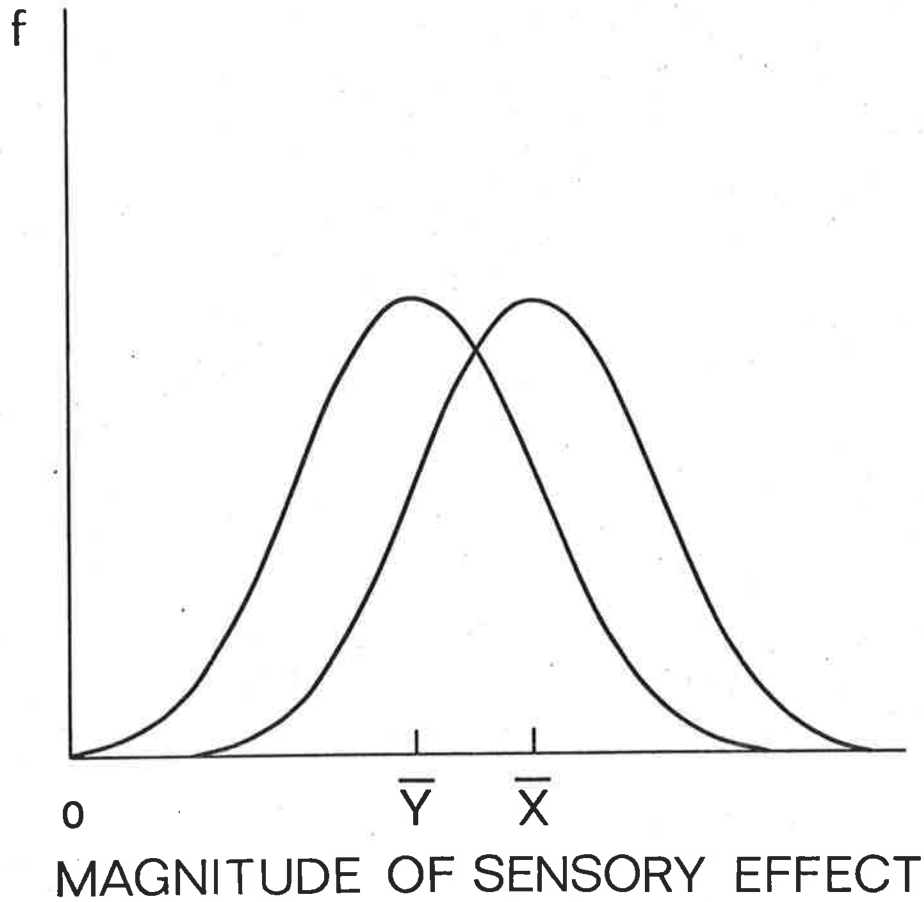


Figure 3.1:

Hypothetical frequency (f) distributions of the magnitude of sensory effect corresponding to two signals X and Y. The distributions are normal, with means $\overline{X}$ and $\overline{Y}$, and $\sigma_X = \sigma_Y$.

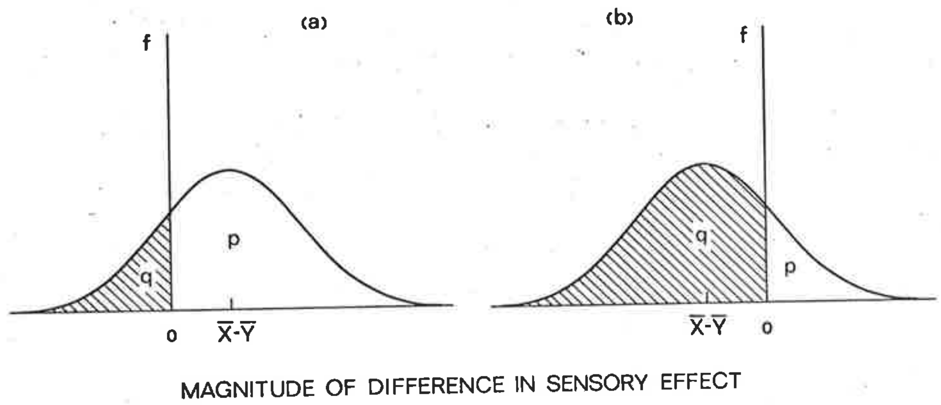


Figure 3.2:

Hypothetical frequency distributions of (X-Y) differences in the magnitude of sensory effect between the signals X and Y: (a) the case where $\bar{X} > \bar{Y}$; (b) the case where $\bar{X} < \bar{Y}$. The probability of a positive difference corresponds to the area p, while that of a negative difference corresponds to q, with $p + q = 1$.

phi-gamma hypothesis, the probability ϕ of making a response of the form 'X > Y' to a given stimulus difference γ should correspond to the proportion p of the distribution of (X - Y) differences falling above 0, where γ is measured in units of $\sigma_{(X-Y)}$. The corresponding psychometric function takes the form of a cumulative normal ogive (Boring, 1917; Corso, 1967). It is therefore possible, by observing the proportion of responses of one kind made over a range of $(\bar{X} - \bar{Y})$ differences, to chart out the hypothesized distribution of differences, and to calculate its standard deviation $\sigma_{(X-Y)}$ in terms of the physical units in which the signals are measured (Guilford, 1954).

There is perhaps some restriction on the generality of the phi-gamma hypothesis in cases where the variance in the distribution of sensory effect is directly related to its mean value (Solomons, 1900), or if the magnitude of sensory effect were found to be related to relative stimulus differences, as implied by Weber's Law, rather than to absolute difference. In the first case, deviation from the phi-gamma hypothesis should be shown by inequality between a measure of $\sigma_{(X-Y)}$ calculated from responses of the form 'X > Y' and one based on those of the form 'X < Y'. In the second, any deviation would result in skewing of the psychometric function. However, a study of 630 differential thresholds by Fernberger (1949) found virtually no difference between values of $\sigma_{(X-Y)}$ calculated for the two alternative responses. Furthermore, there seems to be no unequivocal evidence that the psychometric function departs systematically from a normal ogive or is better described, as proposed by Stevens et al (1941), by a rectilinear form (Urban, 1910; Guilford, 1954; Barlow, 1961; Corso, 1967). Indeed, at the small absolute magnitudes required for the measurement of thresholds, it has been recognized that the relative magnitudes of stimulus differences may be less important than absolute differences (Crossman and Szafran, 1956; Welford, 1960). In an unpublished experiment by Vickers and Binns, using differences in line length ranging from 0.01 deg. of visual angle to 0.14 deg., it was found that response latencies and errors each formed two separate functions when plotted against relative stimulus difference. When plotted against absolute difference, however, each could be described by a single, continuous curve, suggesting that absolute difference was the principal factor determining performance. Even if relative difference were operative, deviation of the psychometric function from a normal ogive would be negligible unless the Weber fraction approached 0.2 (Thurstone, 1928), which might be predicted for taste, but is 10 times higher than the expected value for the visual modality (Boring, Langfeld and Weld, 1948, p.268). Within the present context, therefore, the assumptions of normality, constant variance, and a linear relation between stimulus difference and sensory effect, would appear to be satisfactory approximations for the restricted range of values used in determining a threshold (Treisman and Watts, 1966), and the phi-gamma hypothesis

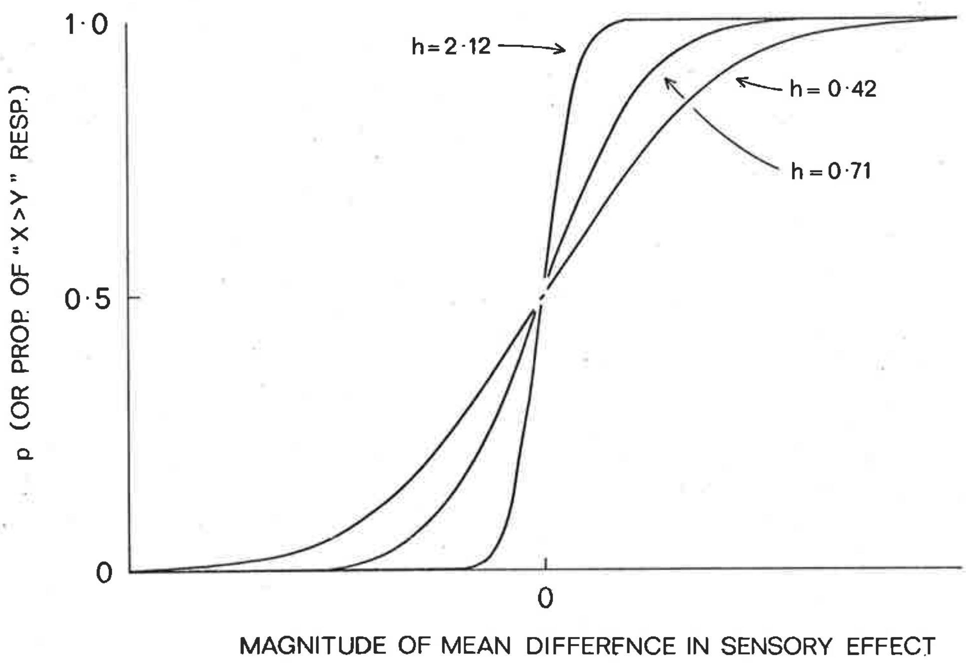


Figure 3.3:

Cumulative normal ogives representing the proportion p of responses of the form "X > Y", as a function of mean difference in sensory effect. As the precision *h* increases from 0.42 through 0.71 to 2.12, the value of $\sigma_{(X-Y)}$ is reduced from 1.67 through 1.0 to 0.33.

seems to provide a tenable explanatory model for the processes involved in sensory discrimination.

It has been widely accepted that $\sigma_{(X-Y)}$, or the related measure of *precision*, given by $h = 1/\sigma_{(X-Y)}\sqrt{2}$, will vary directly with differential sensitivity, as illustrated in Figure 3.3 (Culler, 1926; Kellogg, 1930; Woodworth, 1938; Guilford, 1954; Fechner, 1966; Corso, 1967; Siegel, 1969). However, whereas classical psychophysics has emphasized the importance of precise threshold measurement, obtained under conditions as free of constraints as possible, (Kellogg, 1931; Corso, 1967), Vickers (1972a) has proposed that the parameters of error in performance under carefully specified conditions might provide a measure of the fundamental limitations in sensory motor performance. It is therefore suggested that $\sigma_{(X-Y)}$ might furnish a useful index of noise, provided that it is measured under conditions free from the effects of *bias* and under which the *caution* of O is controlled and *data accumulation* prevented.

DECISION MODELS OF SENSORY JUDGEMENT

A major difficulty for the classical model of psychophysical judgement is that the absolute threshold has been found to vary with changes in observer *bias*. Studies of the absolute threshold for flicker fusion, for example, have drawn attention to errors of "habituation" and "anticipation" (Hake and Rodwan, 1966), whilst instructions designed to facilitate or inhibit the perception of flicker have been found to affect the critical cycle time (Knox, 1945; Landis and Hamwi, 1954; Clark, 1966). Boring (1920) has proposed that determining the *a priori* probability of making one response rather than another should affect the psychometric function, a suggestion supported by evidence that, when differential thresholds are determined using an intermediate response category to allow for 'doubtful' or 'equal' judgements, the standard deviation of the psychometric function of one response may differ from that for the other, because of a bias towards a particular response in the doubtful cases (Culler, 1926).

Signal detection theory (Tanner and Swets, 1954) provides a possible solution to this difficulty, since it distinguishes between O's *sensitivity* and his *bias* towards making one or the other response, and the model has been applied to the measurement of absolute thresholds (Swets et al, 1961; Hake and Rodwan, 1966; Corso, 1967) and differential thresholds (Treisman and Watts, 1966). In the latter case, where O is presented with a discrimination task identical to that illustrated in Figure 3.2, it is proposed that O adopts a cutoff, x_c, along the dimension of differences, classifying as 'greater' all observations above it, and as 'lesser' those below it, as shown in Figure 3.4a. Whereas in terms of threshold theory, a bias towards one alternative would result in a lowered threshold for that response, leaving $\sigma_{(X-Y)}$ unchanged, within the context of the signal detection model, bias is reflected by a shift in x_c. The model copes with the additional complication of an intermediate category by supposing that O adopts two cutoffs x_c and x_g, observations below x_c being classified as 'lesser', those above x_g as 'greater', and intermediate judgements as 'doubtful'.

A number of workers have suggested that O may increase sensitivity by observing sensory input for a longer period of time. This increases the number of inspections n, upon which the decision is based (Thomson, 1920; Crossman, 1955; Hammerton, 1959). If this strategy is interpreted within the context of signal detection theory, then the distributions in Figure 3.4a become sampling distributions of means, their standard deviations decreasing as a function of n, as shown in Figure 3.4b. This position therefore predicts that d' will increase as a function of $\sqrt{n}$ (Green et al, 1957; Taylor et al, 1967), and has been specifically applied in an attempt to estimate noise in the human auditory system by Swets et al (1959) and Green (1964). They argue that, since variability between observations for the same alternative in a forced choice procedure is held to be caused by noise in O's sensory system, any increase in d', following multiple observations where external noise is held constant, may be regarded as the result of averaging over internal noise only.

Although both experiments result in consistent estimations of noise, which agree with the findings of a number of similar investigations cited by Swets (1961), the

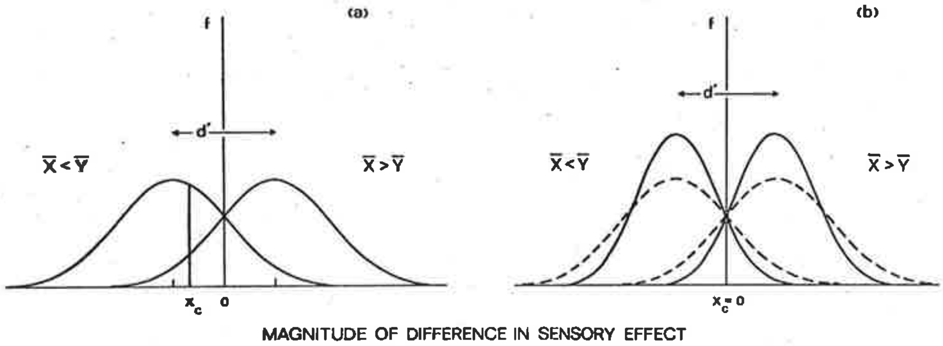


Figure 3.4:

Hypothetical frequency distributions of (X-Y) differences in the magnitude of sensory effect between the signals X and Y, consistent with signal detection theory.

(a) the distributions for single observations;

(b) the distributions of mean observations (continuous lines) have decreased variance compared with the originals (dotted lines), and discriminability (d') of the alternatives is therefore increased.

hypothesis of a linear relation between d' and $\sqrt{n}$ has been criticized by Vickers (1970), who points out that data by Green et al (1957), Swets et al (1959), and Schouten and Bekker (1967) is as well described by a sigmoidal, as by a linear relation. More seriously, when stimulus difference is randomly varied from trial to trial, thereby preventing O from determining in advance the number of observations required, there is abundant evidence that Os not only make more errors at the smaller differences, but take longer to reach a decision (Vickers, 1970; Vickers et al, 1972; Swensson, 1972).

Within the context of signal detection theory, changes in discriminatory judgement as a function of time are indistinguishable from variations in sensitivity, arising from increases or decreases in internal noise. It has been suggested, however, that these changes might result from the degree of *caution* exercised by O, as reflected in a compromise or *trade-off* between speed and accuracy in responding (Hick, 1952; Crossman, 1955; Fitts, 1966; Pachella and Pew, 1968; Laming, 1968; Swanson and Briggs, 1969; Vickers et al, 1971; Vickers et al, 1972; Swensson, 1972). Whereas differences of bias should cause *shifts* in the differential threshold, variations in the speed-accuracy trade-off should change the *precision* of the psychometric curve, as a function of judgement time.

These different considerations find an integrated account in recent *optional-stopping* decision models of judgement, in which O is assumed to accumulate the outcome of a series of observations of the sensory input, made one at a time and at a steady rate until some pre-determined level of caution is satisfied (Audley, 1970; Vickers, 1970, 1972a). The nature of the decision criterion varies from model to model, Audley (1960) assuming that it is equivalent to an unbroken *run* of *k* positive or negative signal differences. A *random walk* hypothesis, based on a proposal by Stone (1960), and developed by Laming (1962, 1968) and Edwards (1965), postulates that the criterion is a difference of *k* events between the positive and negative elements inspected, while La Berge (1962) has proposed a *recruitment* model in which accumulation of *k* events of either class is the critical factor. Audley and Pike (1965) have considered a random walk process in which *k diminishes* within the course of a single trial, while Pike (1968, 1971) has suggested a *variable recruitment* model in which *k* varies randomly from trial to trial.

Vickers (1970) has attempted to account for apparent inconsistencies in the available experimental data by developing a model which incorporates an *accumulation* process in which both magnitude and probability of occurrence for a sampled event may vary. The observer is assumed to accumulate in 'uni-directional counters' two running totals of the *amount* of positive and negative differences until one of the totals exceeds a criterion. Vickers (1972a, 1972b) presents convincing evidence that the properties of an accumulator model agree closely with the empirical features of discrimination and perceptual organisation.

Despite differences between detailed properties of the various models, all predict that the probability of a correct response is a sigmoidal function of signal difference, $\sigma_{(X-Y)}$ decreasing with increasing k. Thus, increased precision is held to be due to the accumulation, over time, of information concerning the discriminanda, and represents an improvement upon performance restricted to a single observation. It follows that if O adopts, or is forced to adopt, a sufficiently low value of k so that his judgement is based upon the inspection of a single (X - Y) difference, then the probability p of sampling a positive difference will be given by the proportion of correct responses of the form 'X > Y', and *in these circumstances*, the standard deviation s_D of the psychometric curve for responses of the form 'X > Y' should correspond to the value of the standard deviation $\sigma_{(X-Y)}$ of the underlying distribution of signal differences. It is proposed, therefore, that the measure s_D, obtained under these conditions, provides an index of the noise limiting discriminative capacity.

A CONSTANT INSPECTION TIME

Considerable evidence exists that Os are able to make faster judgements if instructed to do so (Garrett, 1922; Festinger, 1943), rewarded for responding quickly, or punished for being slow (Johanson, 1922), even though they tend to make more errors when responding quickly (Pew, 1969). It has also been found that Os are able to respond before a specified deadline has elapsed (Fitts, 1966; Ollman, 1966; Schouten and Bekker, 1967; Yellott, 1967, 1971; Pachella and Pew, 1968; Link and Tindall, 1971), using criterion times as low as 100 msec. with response latencies as short as 170 msec. (Schouten and Bekker, 1967). It seems probable, therefore, that O might be influenced to base his decision on a single *inspection*, "implicit" or "covert response" (Audley, 1960, 1964), or "processing period" (Efron, 1967) if this could be specified. Although it may at some later stage, prove necessary to regard *inspection time* (λ) as a single cognitive operation incorporating many smaller units, it would seem that, for the present, λ is most conveniently treated as a unitary process, the most likely estimate being provided by experiments investigating the duration of a "perceptual moment" (Stroud, 1956; White, 1963; Efron, 1967; Sanford, 1971). These, together with a number of experiments concerned with the durations of stimuli over which meta-contrast effects are observed (Kahneman, 1968) suggest a hypothetical perceptual mechanism controlling temporal patterning processes in the central nervous system, and which functions in accordance with a constant time interval of approximately 100 msec. This estimate is supported by evidence concerning the periodicities of the brain's alpha rhythm and saccadic eyemovement, multimodalities in distributions of reaction time, and the integration time implied by the perception of phenomenal simultaneity and temporal numerosity, although other estimates appear to exist (Sanford, 1971). It is not critical to the current proposals whether the integrating period is best described by a discrete sampling mechanism, or a continuous sampling model as outlined by Allport (1968) and Uttal (1970).

Arguing that the distribution of latencies for correct responses to an easy discrimination should conform to the Laplace distribution, Vickers (1970) deduced from McGill (1962) that an estimate of λ should be given by the difference between the minimum and modal latencies. He found that the average of the estimates based on data from five subjects was 100 msec. Welford (1971a) has obtained an independent estimate of 92 msec. for λ, using a rationale designed to isolate a number of processes contributing to choice-reaction time. A more recent estimate gives λ = 100 msec. (Welford, personal communication). While it may subsequently be found that there are substantial differences in inspection time, both between and within individuals (Stroud, 1956; Shallice, 1964), it is hypothesized here that O can in certain circumstances be restricted to a single inspection of the stimulus difference, and encouraged to adopt a low value of k, by presenting discriminanda tachistoscopically for 100 msec., followed by appropriate backward masking to prevent further accumulation of useful data from momentarily stored sensory information (Averbach and Sperling, 1961; Kahneman, 1968; Haber, 1970).

THE MEASUREMENT OF INSPECTION TIME λ

It seems highly plausible that there are large differences between discriminanda which are so easy for human observers that they could be resolved without error on the basis of a single sample, provided O had the opportunity to make one inspection of the sensory data. An estimate of λ should therefore be given by the stimulus duration empirically determined as necessary for performance of such a task to achieve some predetermined, high level of accuracy. A suitable discrimination task would appear to be one in which the stimulus difference subtends a visual angle of 0.8 deg. This figure is 2.67 times the maximum value of s_D = 0.3 deg., estimated by Vickers et al (1972) from experimental data obtained by Botwinick et al (1958) for older Os (median age = 71 years) (See Appendix 3.1). Using 0.3 deg. as a provisional upper estimate of noise, the expected probability of error following one inspection of sensory input with a stimulus difference corresponding to 0.8 deg. should be less than 0.005. Allowing for the possibility of other sources of error, such as anticipation, or momentary inattention, the more conservative 97.5% limit of confidence should provide a suitable criterion for virtually error free performance.

EXPERIMENT 3.1

Apparatus

Stimuli were plotted in non-storage mode on a Tektronix 611 storage display, controlled by a PDP 8/L digital computer. The refresh cycle was less than 3 msec., so that all parts of a figure seemed to appear and disappear simultaneously. Responses were made by pressing one of two morse keys. The timing, recording and preliminary analysis of responses was carried out by the computer.

Stimuli

Stimuli consisted of two vertical lines, 28.8 and 38.4 mm long, and 14 mm apart, with their upper ends terminated by a third, horizontal line, as shown in Figure 3.5a. The display was viewed from a distance of 66 cm, so that the stimulus difference of 9.6 mm corresponded to a visual angle of 0.8 deg. A 7 mm square, appearing 512 msec. before the display onset and remaining for 256 msec. in the position shown in Figure 3.5a, provided O with an attentional cue. Immediately *following* presentation, a backward mask overlaid the stimulus display, extending the shorter vertical line to the same length as the longer, as illustrated in Figure 3.5b. The pattern position was virtually constant in the middle of the screen, shifting only 0.3 mm in 16 successive trials before recycling, in order to avoid scorching the screen. Luminosity could not be accurately determined, but was previously established

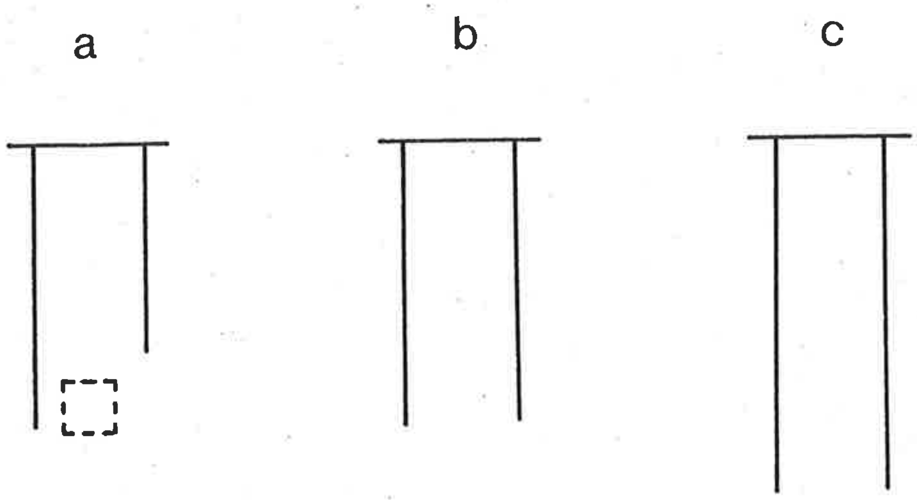


Figure 3.5:

a. Scale drawing of the type of stimulus display, with the position of the square attention cue in broken lines.

b. The backward mask used in Experiment 3.1.

c. The backward mask used in Experiment 3.2.

as being sufficient for the display to be clearly visible, while still being well below an intensity at which overwriting with the mask produced a discriminable change in brightness. The display was terminated by a response, and the following trial initiated after 2 sec.

Design

An experimental session consisted of 6 runs, each with 105 trials. The initial run, and the first 5 trials of each subsequent run, were for practice only, and were therefore excluded from analysis. Within each run, stimuli were presented for 10 different exposures, ranging from 8 to 80 msec. in steps of 8 msec., with an equal number at each duration randomly presented throughout each successive block of 20 trials. Within each block, the sequence was random except that the occurrence of the shorter line on the left or right was equiprobable.

Procedure

Prior to the experimental session, each O was screened for normal binocular visual acuity, using a Snellen eye chart.

For the session itself, O was seated before the display in a dimly illuminated experimental room and acquainted with the apparatus and the nature of the task. O was instructed to respond to the shorter line by pressing the appropriate key as quickly as possible. It was emphasized that, once overwritten by the backward mask, no further evidence would be available from the display.

The room was then darkened completely, and following a 5 minute period for initial adaptation, the experiment began. Between runs, O rested for about 2 min., was told that performance was satisfactory, and encouraged to keep it stable.

Observers

Six male and four female undergraduates, aged 18-25 years, enrolled in the first year Psychology course at the University of Adelaide, served as Os as part fulfilment of a course requirement. All were naive with respect to the aims of the experiment.

RESULTS AND DISCUSSION

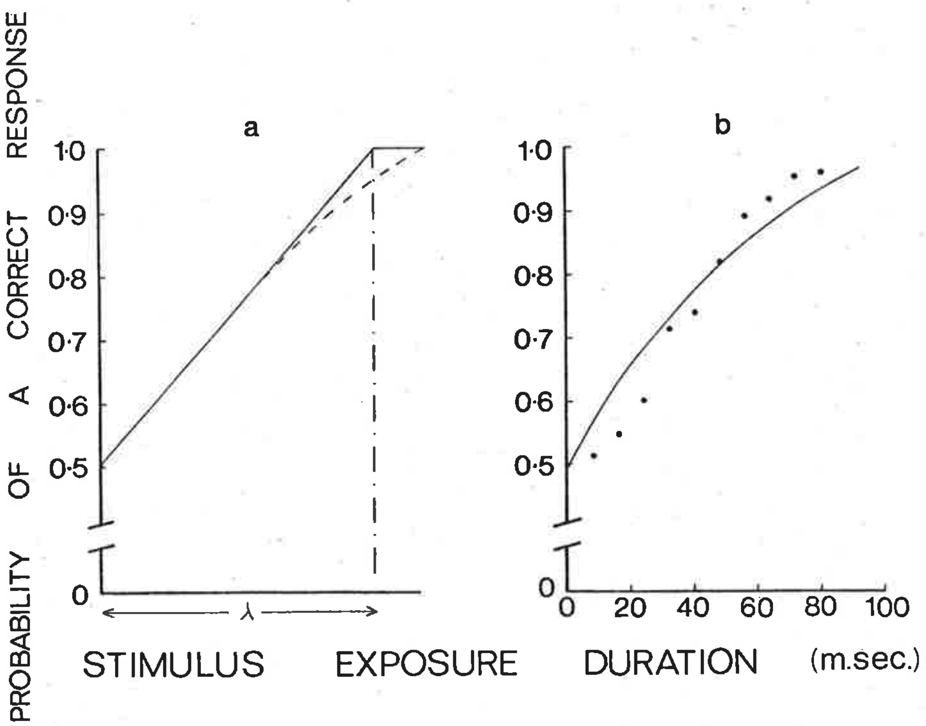
Response probability

The psychophysical procedure used constitutes an incomplete method of constant stimulus differences, in which the proportion of correct responses of the forms 'the left line is shorter' and 'the right line is shorter' may be combined to yield the upper half of the psychometric function. The mean for all 10 Os of the proportion of correct responses at each stimulus exposure duration is shown in Figure 3.6b, expressed as a probability. Data show no significant departure from a theoretical ogive with a mean of zero ($\chi^2 = 5.83$; d.f. = 17; $1-p < 0.01$; a discussion of the use of the Pearson goodness-of-fit χ^2 test is included in Appendix 3.2). For the group data, the point at which the empirical curve crosses the 97.5% level of confidence

Figure 3.6: The probability of a correct response in Experiment 3.1, as a function of stimulus exposure duration.

(a) The predicted pattern when the signal is completely registered in a proportion of inspection periods determined by exposure duration, or when each stimulus difference is registered, the magnitude of registration being determined by exposure duration. The dotted line characterises the smoother pattern produced if the processes were subject to random sources of variation.

(b) The empirically determined average probability of making a correct response, as a function of stimulus exposure duration.



PROBABILITY OF A CORRECT RESPONSE
a
b
1·0
0·9
0·8
0·7
0·6
0·5
0
λ
0
20
40
60
80
100
STIMULUS EXPOSURE DURATION (m.sec.)

yields an estimate of λ equal to 105 msec.

Measures of λ were similarly calculated for each individual O (Appendix 3.2) and range from 74 up to 144 msec., with a mean of 107 and a standard deviation of 23 msec. These data show considerable variability, 3 Os lying outside the 99% confidence interval 82-132 msec., suggesting that the measure λ may itself be an important indicant of individual differences in perceptual performance. Despite individual differences, however, the estimate for λ obtained from group data is, in every case, above the 75% discrimination threshold established for individual Os, suggesting that an exposure of 100 msec. should serve as a useful approximation to λ.

The pattern of response probabilities obtained here is equally consistent with two alternative perceptual sampling mechanisms. The first possibility is that any signal present at the start of an inspection period is either completely registered, or completely lost. The probability of coincidence between signal registration and the start of inspection is given by $f = E/\lambda$, where E = exposure duration, and the probability of a correct response $p = 0.5 + f$. It is not possible to distinguish between this possibility and the alternative, that the magnitude of signals registered is directly determined by the stimulus exposure duration, since both would result in a linear function closely resembling that illustrated in Figure 3.6a. A smoother curve, resembling that in Figure 3.6b rather than 3.6a would in either case be expected, since signals are subject to noise.

The most plausible description for the discrimination processes involved in this experiment would appear therefore to be a cumulative normal ogive with a mean of zero. An examination of individual data by applying the Pearson goodness-of-fit χ^2 test confirms this assumption. As may be seen from the Table in Appendix 3.2, H_0 is only rejected in one instance (observer 3), and reasonable fits are obtained for 9 Os.

Response latency

Three main hypotheses concerning the expected pattern of response latencies appear to deserve consideration:

(i) Since O cannot control the duration of the stimulus display, he may abandon an optional-stopping strategy of accumulating some criterion amount of signal difference k, and, instead, control the length of time for which sensory input is fed to the decision mechanism (Link and Tindall, 1971). In addition it might be supposed either that O has no fixed inspection time λ, or that λ is constant and at least as short as the briefest stimulus exposure duration of 8 msec. Expressing response latency as a relation of exposure duration should therefore result in an increasing linear function, as shown in Figure 3.7a.

(ii) If we suppose that λ = 100 msec. and that O can abandon an optional-stopping procedure, responding on the basis of a likelihood ratio, as in a fixed sample

Figure 3.7:

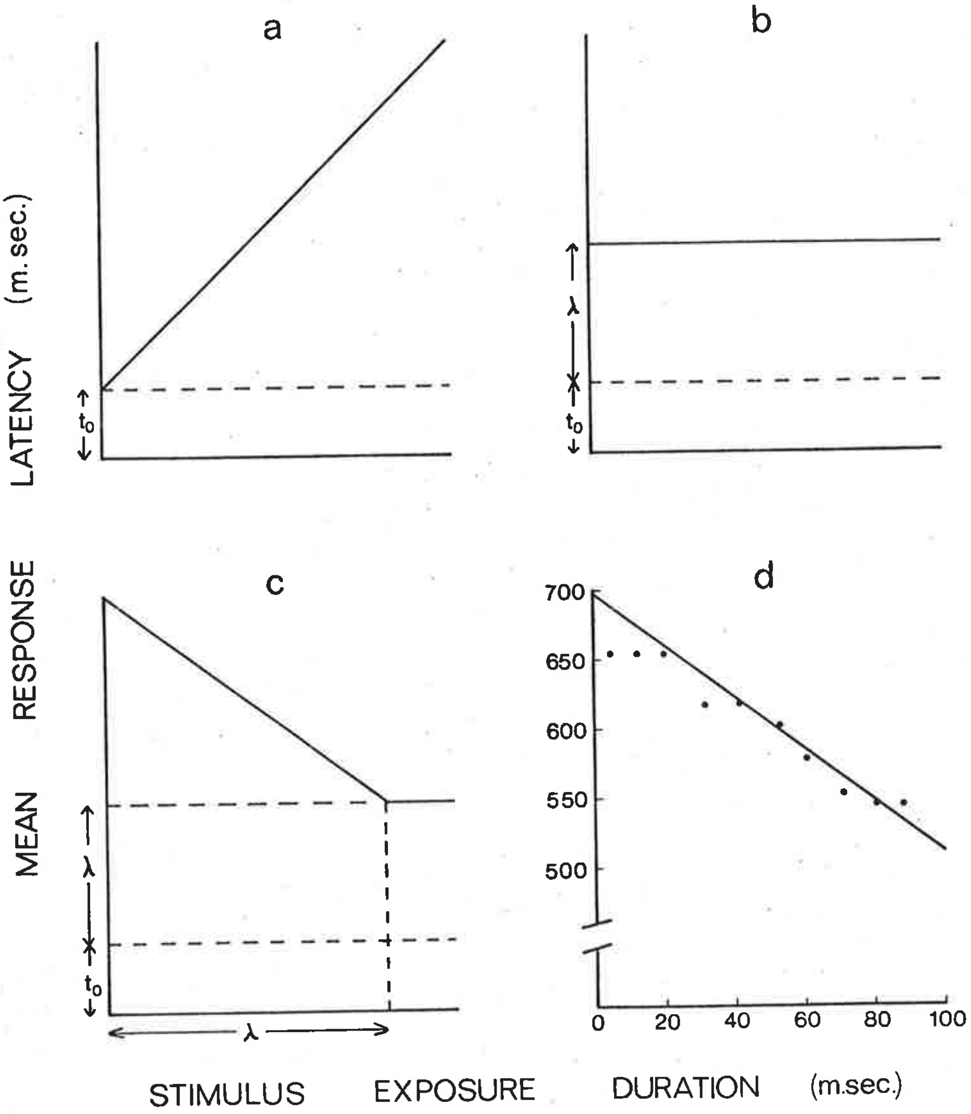
Patterns of predicted and obtained mean response latencies in Experiment 3.1 as a function of stimulus exposure duration.

a. The predicted pattern when λ is less than 8 msec., and O is capable of abandoning an optional-stopping decision procedure, responding instead on a deadline. The time t_o represents the sum of apparatus and response system delays.

b. The predicted pattern for deadline responding when λ is large.

c. The predicted pattern when λ is large, and O maintains an optional-stopping decision procedure, even if this means accumulating non-informative, noise-produced differences when stimulus exposure durations are less than λ.

d. The obtained pattern of mean response latencies, fitted by a linear function, shown as a continuous line.



a
b
c
d
MEAN RESPONSE LATENCY (m.sec.)
t_o
λ
700
650
600
550
500
0
20
40
60
80
100
STIMULUS EXPOSURE DURATION (m.sec.)

statistical decision model (Crossman, 1955), then the latency function should remain invariant with respect to stimulus exposure duration, as illustrated in Figure 3.7b.

(iii) O may require a minimum inspection time of 100 msec., and may not be able to abandon an optional-stopping strategy. To the extent that insufficient evidence is obtained from a momentary inspection of the sensory input, O will continue to sample non-informative, 'noise-produced', differences between the objectively equal lines which constitute the backward mask. Such differences might be expected to be smaller than stimulus-produced differences, and would favour either alternative equally often, so that the time to accumulate evidence to criterion should be lengthened. Thus, response latency should be inversely related to stimulus exposure duration, the function reaching an asymptote at λ, as shown in Figure 3.7c.

Pooled latency data from all 10 Os at each exposure duration are included in Appendix 3.4(ii), and are plotted in Figure 3.7d. There is a highly significant negative average correlation between response latency and stimulus exposure (mean $\tau = -0.60$, $p < 0.001$, two tails; Jonckheere, 1954). The data are well fitted by a straight line with the equation $y = -1.58x + 678$, though there appears to be a tendency for the function to level out towards the maximum exposure of 80 msec. When individual data are considered, negative correlations between latency and exposure are found for all Os, and these are significant

(Pearson $r \geqslant -0.71$; $p \leqslant 0.02$; two tails) in all but two cases (Appendix 3.3).

These results are inconsistent with the suggestion of Link and Tindall (1971) that Os are capable of controlling the time for which information is fed to the decision process. Their finding, that response latency remained constant for all degrees of discriminability when a 260 msec. deadline for responding was imposed, probably results from the fact that their stimuli were presented in sub-blocks of 60 successive trials *of equal discriminability*, thereby making it possible for O to vary caution between sub-blocks, in order to maintain a stable mean response latency. The finding here, that Os take longest to respond when stimuli are presented for the shortest time, clearly supports the hypothesis that Os cannot abandon an optional-stopping strategy, even though delay does not result in any further information becoming available.

Latencies for correct and incorrect responses

To the extent that O accumulates noise-produced differences, the range of uncertainty should increase and the probability of error increase. An additional prediction, arising from the hypothesis above, is therefore that latencies for incorrect responses should exceed those for correct responses. The prediction is supported, both across observers ($z = 2.60$; $p = 0.009$; two tails; Wilcoxon matched-pairs signed-ranks test; Siegel, 1956), and across exposures ($z = 2.80$, $p = 0.005$;

two tails). Tables are included in Appendix 3.4.

Independence and stability of measures

Taken together, the preceding results provide strong support for the hypothesis that O inspects signal differences until he has accumulated a criterion magnitude k of positive or negative difference (Vickers, 1970, 1972a), and that where signals are attenuated before k is reached, O 'tops up' both accumulators with noise-produced differences. Since the amount of necessary topping up will increase as a direct function of k for any particular stimulus exposure, it follows that the mean latency L for all responses made by O might provide an index of k, although care must be exercised when interpreting L in this way because of individual differences in λ. In this experiment, these two measures appear to be independent (Pearson $r = 0.25$; d.f. = 8; $p = 0.501$; two tails; Appendix 3.2). Further, L is not significantly correlated with the total number of errors made by each O (Pearson $r = 0.40$; d.f. = 8; $p = 0.246$; two tails), an exception to the speed-accuracy trade-off which is, however, to be expected here, since no additional information is accumulated following termination of the stimulus display by the backward mask.

Turning to consider differences between runs, there are not sufficient data to provide separate estimates of λ for each run. As regards L, Table 3.1 shows that mean response latencies decline over runs, and an analysis of variance, summarized in Appendix 3.5(i), reveals that the

Mean response latency (msec)	Runs of 100 trials 1	2	3	4	5
	641.6	614.5	612.5	590.1	585.4

Table 3.1: Mean response latencies (msec.) obtained for each of 5 separate runs within Experiment 3.1.

decline has been roughly constant for different stimulus exposures, since there is no significant interaction between stimulus exposure duration and the position of the run during the session. Application of the Newman-Keuls procedure (Winer, 1962) shows the principal sources of variance to be the differences between runs 1 and 4 and between runs 1 and 5 ($p < 0.01$), with no other comparisons reaching significance at the 5% level (Table 3.1). While latency may not directly measure k, a plausible explanation for the small drop in latency between the initial and the last two runs is that it reflects a slight reduction in criterion.

EXPERIMENT 3.2: A SECOND MEASURE OF λ

A possible criticism of the first experiment arises from the manner in which backward masking was achieved by extending the shorter stimulus line so as to equal the length of the other. Although the effect was not apparent for exposures up to 80 msec, it was subsequently noticed, using an exposure of 100 msec, that the shorter 'leg' of the display appeared to 'run out' when the mask replaced the stimulus. This observation is paralleled by previous findings discussed by Kahneman (1967, 1968) which suggest that the perception of apparent movement is optimal when the interval between the onset of two stimuli is about 100 msec. It could therefore be argued that Os in the first experiment were responding to apparent movement and that since this would render the backward mask ineffective, Os were gaining additional information from some residual effect of apparent movement, particularly at the longer stimulus exposures.

A second experiment was therefore undertaken in which the original mask was replaced with a similar figure having both legs equal to 48 mm and therefore considerably longer than those of the stimulus, as shown in Figure 3.5c. This greatly reduced the illusion of movement and, more importantly, removed the possibility that any appearance of movement could act as a cue to the position of the shorter line. The task could therefore be confidently regarded as a simultaneous discrimination of line lengths.

Two other minor modifications were incorporated. Viewing distance was more precisely controlled by means of a padded chin rest, fixed 66 cm from the screen, and the range of exposure durations was changed so that it encompassed the expected mean value for λ, extending from 12 to 120 msec. in steps of 12 msec. In all other respects, including the Os used, this experiment was a replication of the first.

RESULTS AND DISCUSSION

Response probability

The mean proportion of correct responses at each stimulus exposure is shown in Figure 3.8a. These group data closely resemble those obtained in the previous experiment, and shown in Figure 3.6. As in Experiment 3.1, there is no significant departure from a theoretical ogive with a mean of zero (χ^2 = 2.71; d.f. = 15; 1-p < 0.005). The 97.5% confidence limit yields an estimate of 99 msec. for λ, which is very close to the original estimate of 105 msec.

Measures of λ for individual Os are included in Appendix 3.2, and range from 85 to 169 msec., with a mean of 106, and a standard deviation of 30 msec. The suggestion from the earlier experiment, that λ might itself be an important, stable behavioural descriptor, is supported by a comparison of results for the same Os in both experiments. No significant difference has been found between the two sets of scores (related samples t = 0.243; d.f. = 9; p = 0.808; two tails), although there is a highly significant correlation between them (Pearson r = 0.80; d.f. = 8; p = 0.003; one tail). The capacity of the normal ogive to account for the data of individual Os has again been examined by applying the Pearson goodness-of-fit χ^2 test. Results, included in Appendix 3.2., suggest that a reasonable fit is obtained for 5 Os (1-p < 0.50), whilst

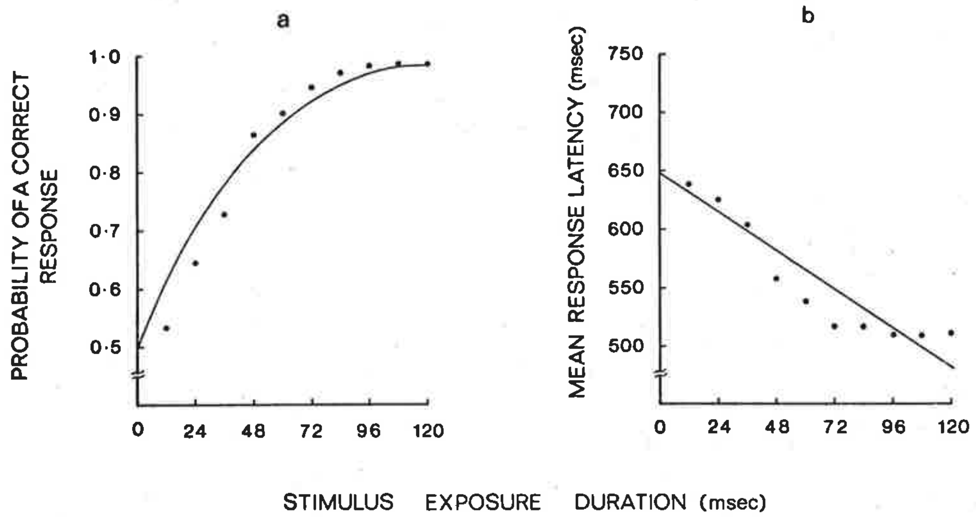


Figure 3.8:

Average patterns of response probability and latency obtained in Experiment 3.2 as a function of stimulus exposure duration. The continuous lines represent:

a) the best fitting cumulative ogive for a normal distribution with a mean of zero;

b) the best fitting linear function.

the hypothesis of no difference is not specifically rejected for any of the remaining 5 Os ($p \geq 0.10$).

The similarity of the proportions of correct responses obtained with group data in the two experiments indicates that Os in Experiment 3.1 had not used apparent movement as a cue, but based their decisions upon a comparison between the line lengths, and that their results are not vitiated by perception of apparent movement.

Response latency

Latencies for all responses at each stimulus exposure, pooled across Os are included in Appendix 3.4(iii), and again show a significant inverse relationship with stimulus exposure, as shown in Figure 3.8b (Mean $\tau = -0.622$; $p < 0.001$, two tails). The best fitting straight line is given by $y = -1.30x + 638$, though there is clear evidence of an asymptote in latency as exposure duration approaches 100 msec. Examination of individual data finds a negative correlation between latency and exposure for all 10 Os, and this is significant (Pearson $r \geq -0.70$; $p \leq 0.02$; two tails) in all but one case (Appendix 3.3).

When each O's mean overall latency *L* is compared with that for the previous experiment, there is a slight but insignificant drop, (related samples $t = 1.901$; d.f. = 9; $p = 0.087$; two tails). There is a just significant correlation between the *L* scores in the two experiments (Pearson $r = 0.56$; d.f. = 8; $p = 0.047$; one tail), suggesting that, although there may have been some tendency to adopt lower criterion values in the second experiment, *L* remains fairly characteristic of individual performance. Individual data are included in Appendix 3.2.

Once again, when the latencies for correct and incorrect responses are examined separately, it is found that latencies for errors exceed those for correct responses, both across observers ($z = 2.80$; $p = 0.005$; two tails; Wilcoxon matched-pairs signed-ranks test) and across exposures ($z = 1.89$; $p = 0.059$; two tails). Relevant tables are included in Appendix 3.4.

Independence and stability of measures

As in the former experiment, no significant relation was found between λ and *L* (Pearson $r = 0.12$; d.f. = 8; $p = 0.741$; two tails; Appendix 3.2), adding support to the view that λ is an independent index of performance, unaffected by changes in O's criterion. Again also there was no relation between *L* and the total number of errors made by O (Pearson $r = 0.09$; d.f. = 8; $p = 0.807$; two tails), a finding which reinforces the assumption that the additional evidence, accumulated by O in an attempt to satisfy a high criterion, is essentially non-informative.

The stability of mean response latency throughout the session was again examined by analysis of variance, results of which are summarized in Appendix 3.5(ii). As expected, stimulus exposure duration was again the major source of variance ($F = 7.69$; d.f. = 9,81; $p < 0.010$). In this experiment, however, there was no effect of position in the session, presumably because Os' criterion values had stabilized by the time they took part in the second experiment.

THE MEASUREMENT OF NOISE s_D

The measures of λ, obtained under the two sets of experimental conditions above, confirm that 100 msec is a good estimate of the mean time required to make a single inspection of sensory input. It is therefore suggested that a useful index of noise in the visual system should be provided by a measure s_D, defined as *the standard deviation of the best fitting normal ogive calculated for the psychometric function obtained in a forced-choice discrimination task using the method of constant stimuli, the discriminanda being presented for 100 msec., in random order, and followed by appropriate backward masking.* On the assumption that the distributions of sensory effect corresponding to X and Y have equal variances, and are uncorrelated, the noise s_N added to the original signals is given by $s_N = \sqrt{\frac{1}{2}s_D^2}$. The measure s_D is preferred here, however, since it is more directly related to traditional psychophysical measures of limit to discriminative capacity.

Estimates of s_D have been made by Vickers et al (1972), from the results of Henmon (1906), Garrett (1922), Festinger (1943), Botwinick et al (1958) and Vickers (1967), and are included in Appendix 3.1. While the mean of these estimates suggests 0.09 deg. of visual angle as a likely minimum for s_D, the considerable differences between estimates illustrate the difficulty of interpreting data that are obtained under conditions which are not strictly comparable. The generally low values obtained probably reflect the opportunity to accumulate data during the long exposures used. The shortest exposure of 0.15 sec, used by Botwinick et al (1958), yields higher values for s_D of 0.20 and 0.30 deg for the younger (median age 22.5 years) and older Os (median age 71 years) respectively, a finding consistent with the rationale proposed here that short exposures will force Os to adopt lower k values. The difference between the two groups is in line with the proposal that noise increases with age (Crossman and Szafran, 1956; Cane and Gregory, 1957; Welford, 1958; Gregory, 1956, 1959), but would also be expected if λ for the older Os was longer than 150 msec.

A further check on the validity of the rationale advanced here is provided by results from Vickers (1967) in which Os discriminated between two elongated, variable distributions of dark spots. Vickers' estimation of noise added to the signals, obtained directly from the known parameters of the distribution of the spots, closely agrees with the estimate of s_D, obtained by analyzing Os average responses (Vickers et al, 1972).

EXPERIMENT 3.3

The purpose of this experiment was to obtain an estimate of s_D, using the value of λ = 100 msec. as a standard stimulus exposure duration for each of 10 differences of line length, ranging from 0.3 mm to 8.4 mm in steps of 0.9 mm. The length of the longer line was constant at 38.4 mm, as in the previous experiments. Apart from the substitution of difference in line length for difference in stimulus exposure duration, the apparatus, design, procedure, and Os used in this experiment were exactly the same as those used in Experiment 3.2.

RESULTS AND DISCUSSION

Response probability

Group means of the proportion of correct responses at each stimulus difference are shown in Figure 3.9a. As in Experiment 3.1 and 3.2, no significant departure is found from the best fitting ogive or a normal distribution with a mean of zero (χ^2 = 1.64; d.f. = 15; 1-p < 0.005).

Individual estimates of s_D, included in Appendix 3.2, range from 0.27 deg. of visual angle up to 0.45 deg., with a mean of 0.32 and a standard deviation of 0.05 deg. This mean is much higher than the estimates made by Vickers et al (1972) on the basis of earlier experiments, with the exception of the figure of 0.30 deg., obtained for the older Os employed by Botwinick et al (1958), whose noise level has already been suggested as likely to be higher than that of the younger subjects used in the present experiment.

Since the reliability of s_D is clearly dependent upon the extent to which a normal cumulative ogive describes O's response probability function, individual data have been fitted by means of χ^2. As may be seen from Appendix 3.2, data for 9 Os are well accounted for (1-p $\leq$ 0.25) whilst for the remaining O, H_o cannot be rejected (p > 0.10).

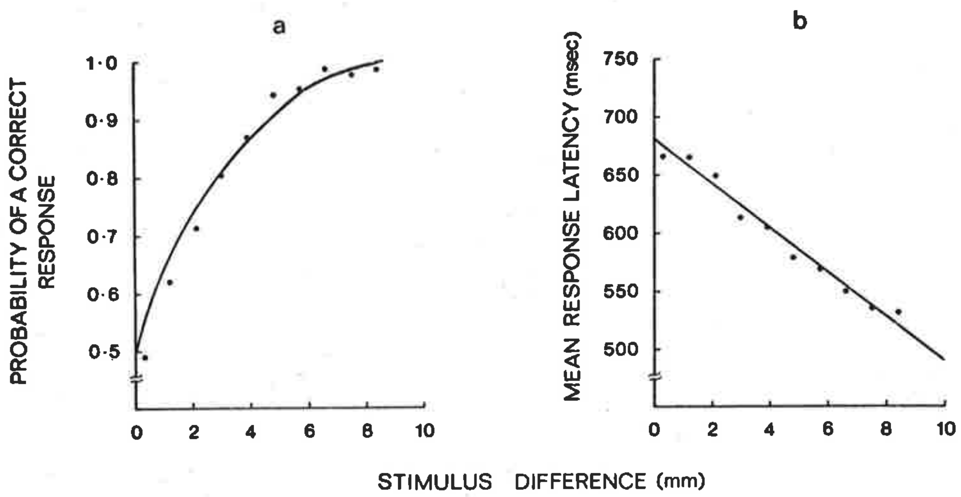


Figure 3.9:

Average patterns of response probability and latency obtained in Experiment 3.3 as a function of stimulus difference. The continuous lines represent;

a) the best fitting cumulative ogive for a normal distribution with a mean of zero;

b) the best fitting linear function.

Response latency

As predicted by an optional-stopping model of the discrimination process, response latency has been found to decrease as difference in line length increased, both across Os (mean $\tau = 0.81$; $p < 0.001$; one tail), and for each individual O (Pearson $r \geq 0.83$; $p < 0.002$; one tail). Relevant data are included in Appendices 3.3 and 3.4(iv). Figure 3.9b shows pooled estimates of latencies for all responses (correct and incorrect) for 10 Os, plotted against stimulus difference, and the data are well fitted by a straight line, given by $y = -18.8\,x + 677$. When individual data are similarly plotted, the slopes of the best-fitting straight lines become more steeply negative as mean overall latency *L* increases (Pearson $r = -0.76$; d.f. = 8; $p = 0.01$; two tails). If, as has been suggested above, *L* is interpreted as an approximate index of criterion value, then this finding is consistent with the idea that individual differences in the pattern of latencies are due to the adoption of different criterion values, which interact with stimulus difference to produce proportionately longer latencies at smaller differences.

When latencies for correct responses and errors are examined separately, it is found that latencies for errors again exceed those for correct responses, both across Os ($z = 2.80$, $p = 0.005$; two tails; Wilcoxon matched-pairs signed-ranks test; Appendix 3.4(i)) and across differences in line length ($z = 2.80$; $p = 0.005$; two tails; Appendix 3.4(iv).

Taken together, these results further confirm the suggestion above, that O cannot control the time for which information is fed into the decision process, as proposed by Link and Tindall (1971). Instead, the results are consistent with O employing an optional-stopping decision procedure, whereby a criterion amount of evidence favouring one alternative must be accumulated before a response can be initiated, even if this means including observations of stimulus difference produced entirely by noise.

Independence and stability of measures

The stability of mean response latency within this experimental session was examined by an analysis of variance, the summary of which is presented in Appendix 3.5(iii). Latencies remained stable throughout the session, with stimulus difference constituting the only significant source of variance ($F = 21.84$; d.f. = 9,81, $p < 0.001$). Mean overall latencies *L* in Experiment 3.3, included in Appendix 3.2, correlate highly with those in Experiment 3.2 (Pearson $r = 0.86$, d.f. = 8; $p < 0.001$; one tail), though they were also significantly longer (related samples $t = 2.56$; d.f. = 9; $p = 0.03$; two tails). When compared with *L* measures from Experiment 3.1, those obtained here are shorter, but not significantly so (related samples $t = 1.17$; d.f. = 9; $p = 0.274$; two tails), and there is again a significant positive correlation (Pearson $r = 0.68$; d.f. = 8; $p = 0.014$; one tail).

Some indication of the stability of s_D is provided by a split-half correlation between performances in runs 2 and 3 and in runs 4 and 5 of Experiment 3.3 (Pearson r = 0.87; d.f. = 8; $p < 0.001$; one tail). A comparison of mean values for the same pairs of runs shows no significant difference (related samples t = 0.82; d.f. = 9; p = 0.599; two tails). There is also a highly significant correlation (Pearson r = 0.66; d.f. = 8; p = 0.018; one tail) between runs 1 and 2, on the one hand, and runs 4 and 5, on the other. Again, there is no significant difference between means (related samples t = 0.03; d.f. = 9; p = 0.973; two tails). These data are included in Appendix 3.6.

CONCLUSIONS

The index s_D results in measures of noise that are considerably higher than those obtained from previous work and, at least within one experimental session, appears to provide a stable descriptor of individual differences in performance. Results from Experiments 3.1 and 3.2 provide strong evidence for λ as an independent index of performance and, if mean overall latency L is interpreted as a guide to O's criterion value, both λ and s_D appear to be unrelated, and to remain independent of variations in the value of the criterion adopted.

The proposed interpretation of L as an index of criterion receives support, since the measure appears to remain stable within a given situation, but to be sensitive to variation in the experimental conditions, whilst still serving as a consistent predictor of individual differences.

These results, together with patterns of response latency, including the relationship between those for correct responses and errors, appear to provide strong support for the rationale advanced in the preceding introductory sections of this chapter. A further interesting finding is that the mean value of s_D = 0.32 deg. is dramatically higher than the one minute of arc, or 0.017 deg., which is the commonly accepted standard of acuity for monocular vision (Duke-Elder, 1938). Since Os in these experiments had been screened before selection by means of a Snellen letter chart for visual acuity, it appears likely that 0.017 deg. does not represent the resolving power of the visual system at any given instant, but is rather an index of the extent to which the accumulation of information can offset the effects of noise. Thus, while standard tests of acuity may be adequate as screening procedures for situations in which O is self-paced, they may be unsatisfactory for others in which, because of time pressures, individual differences in the rate of data accumulation, noise, and caution become critical. Some support for this suggestion comes from a number of investigations reporting that acuity increases with exposure duration (Graham and Cook, 1937; Niven and Brown, 1944; Bárány, 1946; Low, 1947; Nachmias, 1967).

CHAPTER IV

THE EFFECTS OF ENVIRONMENTAL STRESS ON NOISE IN THE VISUAL SYSTEM

INTRODUCTION

It has been widely suggested that variations in non-specific central activity should accompany changes in arousal (Hebb, 1955, 1961; M. Treisman, 1964; Welford, 1962, 1968), and it seems likely, therefore, that the index s_D might be usefully applied to measure behavioural change caused by environmental stress resulting from monotony, lack of sleep, prolonged immobilisation, social isolation and sensory deprivation, or the differential effects of drugs, alcohol, exposure to extreme temperatures, noise, fatigue following extensive mental or neuromuscular exertion, or the outcome of increased anxiety.

Whilst abundant evidence supports the vital role of the reticular activating system in maintaining functional arousal level and integrating cortical activity (Moruzzi and Magoun, 1949; Magoun, 1954; Moruzzi, 1954), as well as producing related change in physiological concomitants (Berlyne and Lewis, 1963; Sokolov, 1963), changes in performance, as a consequence of arousal, are more difficult to interpret. Bills (1927) found that irrelevant muscular tension may improve efficiency in tasks involving verbal learning and perception, and Freeman (1931) early suggested that some degree of increased, non-specific arousal arising from muscular activity may increase sensitivity by facilitating the firing of cortical cells. Data from investigations of the effects of loud acoustic noise on behaviour, on the other hand, suggest that, whereas in some instances external noise appears to improve performance, in others it definitely impairs it. Hockey (1970) reports an earlier review of the literature (unpublished Ph.D. thesis, 1969) which establishes that the kind of noise is not a relevant factor in facilitatory or inhibitory effects, suggesting instead that aspects affecting the complexity of the task may be of significance. Berlyne (1966) has made similar proposals concerning the relationship between stimulus properties designated "by words like novelty, surprisingness, incongruity, complexity, variability and puzzlingness" (p.30), and arousal level. Hockey's suggestion would also appear to be in line with findings, beginning with the work of Yerkes and Dodson (1908), that optimal arousal level becomes lower as task difficulty increases.

Welford (1962, 1965b, 1968) discusses evidence for an optimal arousal level, above or below which efficiency is reduced (Hebb, 1955; Duffy, 1957; Malmo, 1959; Lindsley, 1961), proposing that both facilitatory and disruptive behavioural effects can be accounted for by a progressive increase in central nervous activity. Improvement in performance up to an optimum arousal level is explained, as by Hebb (1955), in terms of increased sensitivity as increasing activation renders cortical cells more readily fired by weaker signals. When the maximum limit for facilitating behaviour is exceeded, however, it is assumed that as "the stream of impulses impinging on the cortex becomes very intense, the cells there are not only rendered more sensitive but are actually fired .... the cortex becomes "noisy" so that signals coming from outside or passing from one part of the brain to another tend to be blurred .... cells which would otherwise be ready to carry signals are unavailable because they are refractory .... so that the channel capacity of the brain is reduced" (Welford, 1968, p.265). Indirect support for this model is found in Crawford's (1961) suggestion, that deterioration in driving performance may be due to over stimulation rather than lowered responsiveness, involving fatigue resulting from the stress and consequent emotional arousal encountered whilst driving, in addition to operational fatigue. Both Corcoran (1962) and Wilkinson (1963) have found that white noise, of an intensity sufficient to impair normal performance, actually reduces the deterioration of performance on a serial choice-reaction task, following sleep deprivation. Further, Wilkinson reports that the deleterious effect of loud, acoustic noise is greater when subjects are given feedback of their results, a treatment which normally results in improved performance. These results are conceivably explicable if one considers the possibility that arousal effects may be added algebraically and behaviour determined by the resultant level of activity.

A wide variety of behavioural descriptors have been used to detect the effects of environmental stress upon sensory discrimination, including the absolute threshold (Zubek, 1969), error rate and reaction time (Buck, 1966), reversal rate of ambiguous figures (Zubek and MacNeill, 1966), the estimation of the duration of time (Goldstone and Kirkham, 1968), recognition threshold (Friel and Derogatis, 1965), critical flicker frequency (for a review, see Welford, 1968, Chapter VIII), and visual acuity (Pollard et al, 1963). However, interpretation of results can be complicated by the instability of some measures (Siegel, 1969), and because the relationships between various effects are often unclear (Broadbent, 1971). Wilkinson (1969) and Sanders and Bunt (1972) have stressed the need for a more complete theoretical appreciation of underlying psychophysical mechanisms. The results obtained in the preceding experiments provide some grounds for optimism that the measures s_D, λ, and L may be useful in this regard.

A PILOT STUDY

A placebo, described as a drug designed to produce either tranquillizing or stimulating central effects, appeared to offer the possibility of manipulating Os' level of arousal in an experimental situation, without the difficulties attendant upon the use of actual drugs or other sources of emotional disturbance. It is well known that a neutral substance, presented with the assurance that it will result in a specific effect, will frequently produce the desired effect. Placebo treatment has been widely applied in clinical practice to produce a variety of effects, including relief from pain (Lasagna et al, 1954), sleep (Beecher, 1955), and the alleviation of psychosomatic symptoms (Joyce, 1966). In conjunction with appropriate behaviour provided by a stooge, a completely ineffective injection of saline has resulted in different emotional states (Schachter and Singer, 1962).

More recently, Clark (1969) has studied the effect of a placebo, described as a potent analgesic, on responses to painful radiant heat stimulation. Where analysis of the proportion of pain responses suggests that threshold has been raised, the application of signal detection procedures reveals that the placebo effect has raised response criterion, without affecting thermal sensitivity. However, before using placebo treatment as an independent variable in a full scale investigation of the sensitivity of s_D to changes in arousal, it was decided to examine the suitability of the treatment in a pilot investigation.

Forty male and female students enrolled in the first year Psychology course at the University of Adelaide, with a modal age of 18 years were randomly assigned to 1 of 4 groups. Os in the 3 experimental groups were asked to swallow a colour-coded gelatin capsule filled with placebo spansules resembling commercially manufactured drugs. In accordance with instructions included in Appendix 4.1, the placebo was presented as either an amphetamine, a barbiturate, or without specific information. Control Os did not receive a capsule.

Each group was tested together as a whole. All groups performed a detection task in which the signal was a 1000 c.p.s. tone embedded in white noise. Data were derived from 300 trials, on each of which Os rated their certainty concerning the presence or absence of the signal, using a 4 point scale. Immediately preceding and following the experimental session, each O measured his or her own pulse rate during a 60 sec period.

The analysis of variance summary tables for this study are included in Appendix 4.1. Measures of sensitivity and bias obtained from the group not given specific information about the expected effects of the placebo have been excluded from analysis, because of the possibility that an error on the part of the experimenter resulted in an increased signal to noise ratio in the task presented to this group. Data for the other 3 groups are summarized in Table 4.1. The effect of the placebo is to produce higher measures of response bias among experimental groups when compared with the control groups ($F = 5.51$; d.f. = 2,27; $p = 0.010$). On the other hand, treatment has not resulted in any differences in sensitivity ($F < 1.0$).

Analysis of pulse rate measures reveals a significant difference between groups ($F = 13.69$; d.f. = 3,36; $p < 0.001$). As may be seen from Table 4.2, the means for all 3 placebo groups are significantly higher

		Placebo treatment		
		Green-White ("amphetamine")	Red-White ("barbiturate")	Control
sensitivity				
	P(A)	1.84	1.88	1.77
		(0.16)	(0.20)	(0.36)
bias				
	B	1.66	1.85	1.55
		(0.19)	(0.24)	(0.15)

Table 4.1: Means and standard deviations (in parentheses) for non-parametric measures (McNicol, 1972) of:

(a) *sensitivity* P(A), the area under the R.O.C. curve: an arcsine transformation has been applied;

(b) *bias* B, the point in a rating task at which the observer is equally disposed to signal and noise responses.

Measures are obtained from 30 Os, assigned to 3 groups of equal size, and given differential placebo treatment. The related analysis of variance summary tables are to be found in Appendix 4.1(ii). For *bias*, the difference between the "Red-White" and the Control groups is significant at the 1% level; the difference between the "Green-White" and Control groups does not reach significance at the 5% level (Newman-Keuls a posteriori comparison between means; Winer, 1962).

Measure	Placebo treatment				TOTALS
	Green-White ("amphetamine")	Red-White ("barbiturate")	Red-Green (unspecific)	Control	
1	92.23 (7.19)	92.91 (11.95)	85.00 (12.74)	71.20 (2.86)	85.97 (12.56)
2	88.85 (8.15)	82.55 (12.44)	76.20 (9.95)	67.80 (3.68)	79.61 (11.88)
TOTALS	90.54 (7.73)	87.73 (13.03)	80.60 (12.01)	69.50 (3.65)	

Table 4.2: Table of means and standard deviations (in parentheses) of pulse rate measures (beats per minute) obtained from 40 Os, assigned to 4 groups of equal size undergoing differential placebo treatment. The differences between all placebo groups and the control group are significant at the 1% level; the differences between "Green-White" and "Red-Green", and "Red-White" and "Red-Green", are significant at the 5% level (Newman-Keuls a posteriori comparison between means; Winer, 1962). The relevant analysis of variance summary table is included in Appendix 4.1 (ii).

than that for the control group ($\alpha = 0.01$; two tails). Furthermore, the measures obtained from the 2 groups given specific information about the expected drug effects are significantly higher ($\alpha = 0.05$; two tails) than those found in the group not provided with any information.

These findings confirmed the efficacy of placebo treatment as a means of increasing both psychological and physiological activity, and an experiment was therefore undertaken to investigate the sensitivity of s_D to this treatment.

EXPERIMENT 4.1

Stimuli, apparatus and procedure for the discrimination task were exactly the same as those used in Experiment 3.3. In addition, Heart-Rate (HR) was recorded, using 3 limb electrodes, on a Both Electro-cardiograph, Model BH. Electrodes were attached to both arms, above the elbow, and to the lower tibia above the right ankle, skin resistance having first been reduced to less than 8K ohms by cleaning with alcohol, use of skin abrasion and electrode jelly. Recordings from these connections were found to indicate strong impulses, free from any somatic tremor, despite the key-pressing response. Before commencing, O's normal monocular acuity was tested for each eye separately, by reading from a Snellen letter chart. Each O attended two sessions, separated by approximately 1 week and, during each session, three 60 sec HR traces were taken, following the 20th response in the first, third and sixth runs.

Following the initial session, Os were matched in pairs on the basis of sex and s_D, and the members of each pair randomly allocated to either the experimental or control group. Each group therefore consisted of 5 males and 5 females, closely matching members of the other group. Immediately prior to the second session, Os designated to the experimental group were told that the investigation was concerned with the effects of certain drugs upon perception, asked to swallow a colour-coded gelatin capsule containing flour, but given no specific information concerning the possible effects, other than that they would be harmless and of relatively short duration. For control Os, the two sessions were identical.

Observers

Ten male and ten female undergraduates, with a mean age of 20 years, and enrolled in the first year Psychology course at the University of Adelaide, served as Os in part fulfilment of a course requirement. All were naive with respect to the aims of the experiment.

RESULTS AND DISCUSSION

Response probability

Since the reliability of s_D is clearly dependent upon the extent to which a normal cumulative ogive describes O's response probability function, individual data have again been fitted by applying the Pearson goodness-of-fit χ^2 test for a normal distribution. As may be seen from Appendix 4.2, these data are well accounted for by a theoretical ogive with a mean of zero. The only questionable fit (Observer 18, Session 2) is still sufficiently close that a chance variation this large might be expected to occur more than 25% of the time if the sample distribution is normal.

Noise

Summary data from a nested factors, three way classification analysis of variance (Winer, 1962) are included in Appendix 4.3(i). These show clearly that placebo treatment has failed to produce a significant change in the level of noise. Although, as may be seen from Table 4.3, there is a significant decrease in noise between sessions ($F = 35.47$; d.f. = 1,16; $p < 0.001$), individual measures for the two sessions are positively correlated (Pearson $r = 0.67$; d.f. = 18; $p = 0.002$; two tails; Appendix 4.2). The significant sex x session interaction ($F = 9.18$; d.f. = 1,16; $p = 0.008$) is due to the higher indices of noise registered by males during the initial session, a difference which is not apparent in the subsequent session. The overall mean and standard deviation of 0.33 and 0.09 deg of visual angle are very close to the values of 0.32 and 0.05 reported for Experiment 3.3, the higher variance being largely determined by the greater variance among males in the initial session. The extent of the sex difference in Session 1 ($p < 0.10$) may be interpreted as fortuitous since, as indicated by the larger variance

Session	Male	Female	TOTALS
1	0.42 (0.10)	0.33 (0.07)	0.38 (0.10)
2	0.29 (0.06)	0.29 (0.04)	0.29 (0.05)
TOTALS	0.36 (0.10)	0.31 (0.06)	

Table 4.3: Means and standard deviations (in parentheses) of s_D (degrees of visual angle), obtained from 10 male and 10 female Os, each taking part in two sessions during Experiment 4.1.

among males, it is principally caused by 3 individual male measures of s_D which exceed the mean for this session by more than 1 standard deviation.

Heart-Rate (HR)

A nested factor, four way classification analysis of variance, summarized in Appendix 4.3(ii), reveals no effect as a consequence of placebo treatment, but clearly demonstrates that HR has steadily decelerated throughout the course of the experimental session ($F = 107.65$; d.f. = 2,32; $p < 0.001$). A table of means for the HR measures obtained in this experiment is included in Appendix 4.4. Because of the complexity of this table, only summary tables directly relevant to the argument are included in the text.

There is a significant sex difference, females having higher HR than males, particularly when first entering the experimental situation. Whilst not itself significant, this tendency for an interaction between factors of sex and session is the principal contributor to the significant group x sex x session interaction (Appendix 4.3(ii)). The effect may be seen in Table 4.4. What at first appears to be an interaction between sex and change of HR during the session ($F = 3.22$; d.f. = 2,32; $p = 0.052$; Appendix 4.3(ii)), is caused by a greater decrease between the first and second measure, and a slower decrease between the second and final measure, for female Os, when compared to the steady decrease shown by

Session	Experimental Group (placebo treatment)			Control Group			*Overall*		
	Male	Female	TOTALS	Male	Female	TOTALS	Male	Female	TOTALS
1	73.0	98.5	85.7 (14.8)	82.3	87.5	84.9 (17.9)	77.6 (12.1)	93.0 (16.6)	85.3 (16.4)
2	76.7	82.1	79.4 (9.3)	78.6	89.4	84.0 (14.7)	77.7 (8.6)	85.7 (14.3)	81.7 (12.5)
TOTALS			82.6 (12.7)			84.4 (16.4)	77.7 (10.5)	89.4 (15.9)	

Table 4.4: Means and Standard deviations (in parentheses) of HR (beats per minute), obtained from 10 male and 10 female Os, each taking part in two sessions, and allocated to either the experimental group (placebo treatment) or the control group (no treatment) during Experiment 4.1.

Sex	*HR measures* 1	2	3	TOTALS
Male	83.3 (9.8)	76.8 (10.3)	72.9 (8.6)	77.7 (10.5)
Female	97.5 (16.6)	86.8 (14.5)	83.8 (13.5)	89.4 (15.9)
TOTALS	90.4 (15.3)	81.8 (13.3)	78.4 (12.6)	

Table 4.5: Means and standard deviations (in parentheses) of HR (beats per minute) obtained from 10 male and 10 female Os on three occasions within each of two sessions during Experiment 4.1.

males (Table 4.5). However, the initial high female measures are caused by the five experimental females (mean = 108 b.p.m.), all of whom show much higher HR for the initial measure than any of the males in the experimental group (mean = 79 b.p.m.), and this difference is not nearly so discrepant among control subjects (mean female = 95 b.p.m., mean male = 88 b.p.m.). Since Os in neither group were aware at the beginning of the first session that "drugs" would be administered to experimental Os at the second session, there is no reason to expect a result of this kind. There seems, therefore, to be no obvious explanation for this finding.

The results provide no evidence that individual differences in noise are directly related to the level of cardiac activity either using the third HR measure from Session 1 (Pearson r = -0.16; d.f. = 18; p = 0.503; two tails), or a number of possible relationships involving change in HR or s_D.

Response latency

A nested factor, three way classification analysis of variance, summarized in Appendix 4.3(iii), finds no evidence of change in mean overall latency (*L*) for any of the factors manipulated. The grand overall mean for *L* during session 1 is 683 msec, which is significantly higher than the mean of 596 msec obtained in Experiment 3.3 (unrelated samples t = 2.19; d.f. = 28; p = 0.035; two tails), and considerably higher than the mean of 608 found in Experiment 3.1 (unrelated samples t = 1.90; d.f. = 28; p = 0.065; two tails).

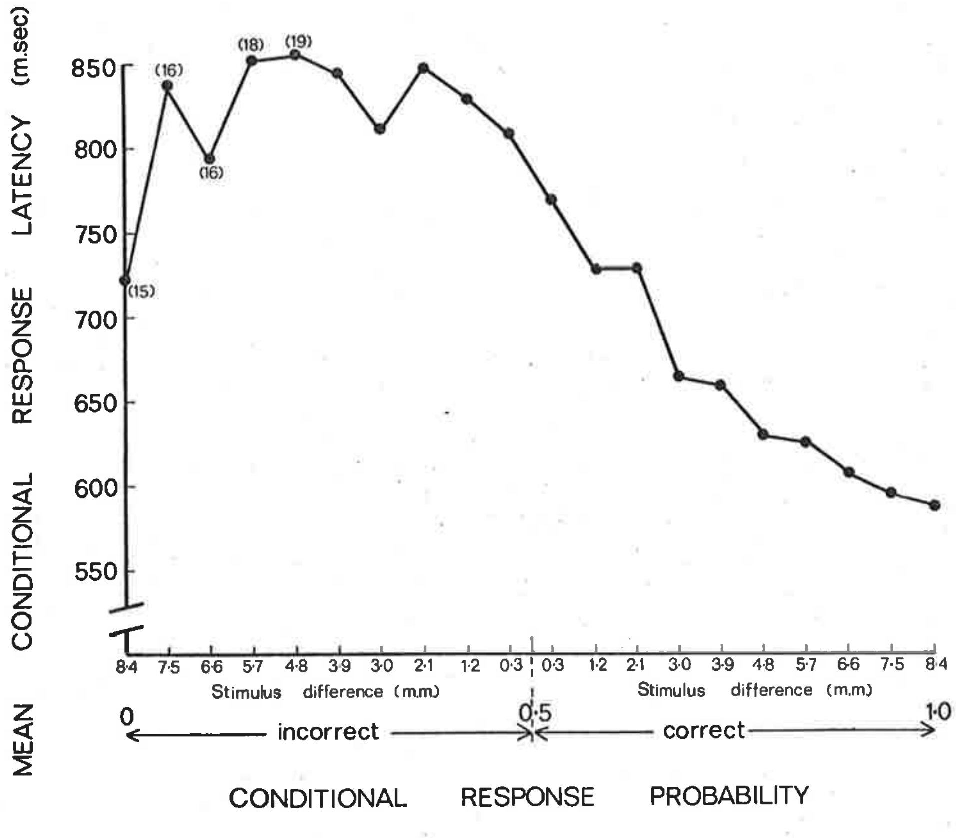
If L is interpreted as an index to O's caution, these results indicate that although caution has remained stable between sessions within this experiment, Os have adopted higher criteria for responding than their counterparts in the preceding experiments. The generality of this finding rules out the possibility that placebo treatment has produced this result. A reasonable alternative is, perhaps, that the procedure involved in locating electrodes, together with awareness that HR was being measured, has made Os more wary in the present situation, causing them to adopt higher levels of caution before responding.

This interpretation finds some support when the pattern of correct and error responses is examined. As shown in Figure 4.1, when group mean latencies during session 1 are plotted as a function of conditional response probability, the pattern obtained conforms closely to that predicted by the "accumulator" model for sensory discrimination when the response criterion is high (Vickers, 1970, 1972a), being asymmetrical with error latencies longer than those for correct responses, but with a tendency to tip down at low response probabilities. The general form of this function, and its implications are discussed further, when reporting the latencies obtained for correct and error responses in Experiment 4.2.

Using data from the first session, no evidence is obtained for a relationship between L and s_D (Pearson r = 0.12; d.f. = 18; p = 0.607; two tails) or HR (Pearson r =

Figure 4.1:

Mean latencies for correct and incorrect responses as a function of stimulus difference. Correct responses have a 'conditional probability' > 0.5, the probability increasing to 1.0 as the discrimination task varies from 'difficult' to 'easy'. Conversely, error responses have a 'conditional probability' varying from 0 to 0.5 as the discrimination task becomes increasingly 'difficult'. The n from which mean latencies are derived is 20 unless indicated in parentheses; n < 20 results when some Os make no errors in discriminations involving larger differences between the lines.


MEAN CONDITIONAL RESPONSE LATENCY (m.sec)
850
800
750
700
650
600
550
(16)
(18) (19)
(16)
(15)
8·4 7·5 6·6 5·7 4·8 3·9 3·0 2·1 1·2 0·3 0·3 1·2 2·1 3·0 3·9 4·8 5·7 6·6 7·5 8·4
Stimulus difference (m.m)
Stimulus difference (m.m)
0
incorrect
0·5
correct
1·0
CONDITIONAL RESPONSE PROBABILITY

-0.23; d.f. = 18; $p = 0.321$; two tails).

As in the previous experiments therefore, *L* appears to be independent of s_D. It appears as an index of performance which varies characteristically between individuals, and which at the same time is sensitive to general changes in experimental conditions, so that a change of conditions is reflected proportionally in all individuals.

Once again, as predicted by an optional-stopping model of the discrimination process, response latency during session 1 is found to decrease as difference in line length increases both across Os (mean $\tau = -0.72$; $p < 0.001$; one tail), and for each individual O, these being significant in 18 out of 20 cases (Pearson $r \gtrsim -0.68$; $p \lesssim 0.015$; one tail). The slopes of individual data become more steeply negative as *L* increases (Pearson $r = -0.63$; d.f. = 18; $p = 0.002$; one tail). Latency for errors is again significantly longer than for correct responses, both across Os ($z = 3.92$; $p < 0.001$; one tail; Wilcoxon matched pairs signed-ranks test), and across discriminanda differences ($z = 2.80$; $p = 0.003$; one tail).

The optional-stopping model discussed in Chapter III suggests that the point of asymptote for the decreasing monotonic latency function should coincide with a latency value equivalent to:

$\lambda + t_o$: where t_o = any delay occurring in the response system and apparatus.

Results to date suggest a value for $\lambda + t_o$ of approximately 510 msec, which, if $\lambda = 100$ msec implies that $t_o = 410$ msec. This value, however, far exceeds those usually found in straightforward disjunctive reaction time studies involving two alternatives. Kirby (1972) reports an overall mean of 270 msec for a task involving response to left or right hand position lights, where the intertrial interval is 2 seconds, as in this series of experiments. Welford (1971a) reports 280 msec in similar circumstances and derives an estimate of $t_o = 142$ msec, assuming the observer requires an average of 1.5 inspections, where $\lambda = 92$ msec, to make a correct decision. Estimates from more recent experiments are $\lambda = 100$ msec and $t_o = 128$ msec (Welford, personal communication).

The large discrepancy between the value found here and those obtained in these experiments is presumably due to the nature of the task. That of Kirby's and Welford's experiments required a disjunctive reaction to position, with the stimulus remaining visible until the response began. In the present experiments the task involves the comparison of discriminanda and brief exposures. In the discussion of response latency in Chapter III, it was suggested that, with these, decision time will be disproportionately lengthened as the criterion rises, since, to the extent that the initial inspection provides insufficient evidence, 0 will continue to sample from noise. Thus, even if the task can be performed correctly on the basis of information equivalent to $k = 1$, latency will be increased if 0 adopts a higher degree of caution. On this reasoning, the present results suggest that the average decision is based upon an initial inspection, followed by three further non-informative inspections.

CONCLUSIONS

Although no evidence has been found to support the prediction that placebo treatment increases arousal and induces a related change in noise, the measures s_D and L emerge creditably from the present experiment. Together with those from the three experiments reported in Chapter III, results are again inconsistent with the view of Link and Tindall (1971) outlined in Chapter III, that O can determine the duration of information sampling. Rather, they support the view that O employs an optional-stopping decision procedure, accumulating a criterion amount of evidence favouring one alternative before initiating a response. To the extent that available evidence falls short of k, he continues to sample from noise.

Contrary to the findings of the earlier pilot experiment, placebo treatment has failed to produce any apparent differences in heart rate among experimental Os. It seems possible, however, that the procedure for electrode placement used here, but not in the pilot study, is responsible for the increased cardiac activity in all Os, thereby masking the placebo effect. This suggestion is supported by an examination of the mean HR obtained in both circumstances. Thus, in the pilot study, the initial average pulse rate among subjects required to take placebo drugs was 90 b.p.m., and this fell to 83 b.p.m., during the 30 minute experimental session. These measures were significantly higher than those of 71 and 68 b.p.m. obtained from control subjects both before and after the session. The present situation, on the other hand, has resulted in means for session 1 of 86 and 85 b.p.m. among experimental and control Os respectively, extremely high measures being obtained from female Os, for whom the mean = 93 b.p.m. When one considers that subjects in the pilot experiment measured their own pulse-rate, whereas the placement of electrodes in the present experiment involved the observer in considerable handling by the experimenter, some females having to remove articles of clothing in order to bare arms and legs, the proposal here does not appear to be unreasonable.

Clearly, however, no conclusions can be drawn at this stage concerning a relationship between arousal and noise, or concerning the sensitivity of the index s_D to such a relationship. The significant decrease in mean and standard deviation of HR during the course of the experimental session emphasizes the extent to which habituation of physiological and psychological systems may occur if care is not taken to reactivate them periodically. An effort is made to overcome this problem in the next experiment, by inducing a state of anxiety.

EXPERIMENT 4.2

A second attempt was made to assess the sensitivity of s_D to changes in the individual under anxiety-provoking conditions. Following Lovibond (1968), it was argued that a series of painful, unpredictable electric shocks might produce non-specific, enduring arousal arising from the uncertainty of future stimulation, over and above specific aversion associated with the shock itself. Consistent with the model of the regulation of cognitive activity outlined in the Introduction to this chapter, it was expected that anxiety should increase random cortical activity or noise.

Stimuli, apparatus and procedure for both the discrimination task and the collection of cardio-vascular data were exactly the same as those employed in the previous experiment. Nine unpredictable shocks of 0.6 sec. duration were applied to experimental Os in the second session, during blocks of trials excluded from analysis. Shock was produced by a constant current AC stimulator, connected to an ammeter for measuring intensity, and delivered, by means of electrodes attached to the second and third toe of the right foot, at an intensity first adjusted to a level that O was prepared to tolerate "for about 10 such shocks throughout the session". The range of intensity used was 1.0 to 2.0 amp., and the unpredictable nature of the shocks was emphasized both initially and between experimental runs.

Data obtained from control Os in the previous experiment have been retained for control procedures. Six months after participation in the experiment, all Os rated the anxiety experienced on a scale from 0 to 10, when asked to recall the experimental situation and requested to take part in further research under the same conditions.

Observers

Because of the aversive nature of the experiment, undergraduate students were not used in the experimental group, and Os in this group were informed at the outset that some shock would be applied during session 2. Five male and five female volunteers, with a mean age of 25 years, drawn from among post-graduate students and members of the academic and ancillary staff of the Department of Psychology in the University of Adelaide, served as experimental Os. Although not aware of the immediate aims of the experiment, all were sophisticated with respect to psychological research.

RESULTS AND DISCUSSION

Noise

Mean values and standard deviations of s_D for the two groups are shown in Table 4.6. Following a nested factors, three-way classification analysis of variance (Appendix 4.5(i)), it is clear that the experimental treatment has produced a significant increase in noise ($F = 11.77$; d.f. = 1,16; $p = 0.004$), whereas noise in the control group has decreased slightly (treatment x session interaction $F = 18.12$; d.f. = 1,16; $p = 0.001$). Neither the sex factor, nor any other interaction approach

Session	Experimental Group (shock)	Control Group (non-shock)
1	0.50 (0.14)	0.37 (0.09)
2	0.66 (0.29)	0.28 (0.04)

Table 4.6: Mean values and standard deviations (in parentheses) of s_D in degrees of visual angle, for Shock and Non-shock groups.

significance at the 5% level. Nine out of the 10 Os in the experimental group show an increase in noise, whereas only 2 Os in the control group do so ($p < 0.01$; Fisher exact probability test; Siegel, 1956).

Whereas the means and standard deviations for the control group are very close to the values of 0.32 and 0.05 deg of visual angle reported for Experiment 3.3, the experimental Os show an average value of 0.66 deg for s_D in the second session, which is more than double the figure of 0.28 deg registered by their controls. Even during the first session the experimental group show a high value of s_D equal to 0.50 deg. This is just significantly higher than the mean of 0.38 deg in the control group (unrelated samples $t = 2.32$; d.f. = 18; $p < 0.05$; two tails), and is due mainly to four individual measures of s_D which are more than 1 standard deviation above the mean for the control group.

Whilst no measure of anxiety was made prior to the initial session, it seems plausible that s_D has proved sensitive to the effects of Os' apprehension, arising out of the prior knowledge that session 2 would involve shock.

Heart-Rate

A nested factors, four-way classification analysis of variance (Appendix 4.5(ii)) reveals no significant difference due to treatment, sex or session. However, there is a significant difference between HR samples, 1, 2 or 3 ($F = 18.28$; d.f. = 2,32; $p < 0.001$), due to a sharp drop in HR between the first and second samples (Newman-Keuls a posteriori comparison between means; Winer, 1962). The significant treatment x HR interaction ($F = 3.39$; d.f. = 2,32; $p = 0.04$) is caused by a slower rate of decrease in the group subjected to shock, but no other interaction yields a probability of less than 0.20.

A number of mathematical corrections and transformations were applied to the HR data in an attempt to obtain measures of responsivity independent of the basal level of somatic activity (Wilder, 1957), but without substantial clarification of these results. As may be seen from Table 4.7, average HR in the second session shows an increase over that in the first for experimental Os, whereas it tends to fall slightly among controls. However, the extremely large individual differences in cardiac activity have masked the effect within the analysis of variance.

Similarly, it has not been possible to establish a direct, significant relationship between HR and s_D, although there is weak evidence for a monotonic relationship between increased cardiac activity and increased noise when change in HR is derived from the initial samples only (Pearson $r = 0.31$; d.f. = 8; $p = 0.09$; one-tail). Taken together, these results suggest that whilst unpredictable shock may cause an initial increase in HR, it tends to adapt quickly, falling towards a baseline as the session advances, despite the threat of further aversive stimulation.

Sample	Experimental Group (shock)			Control Group (non-shock)		
	Session 1	Session 2	Change	Session 1	Session 2	Change
1	80.9 (13.3)	89.4 (19.1)	+8.5 (10.1)	91.6 (19.0)	88.7 (15.2)	-2.9 (18.2)
2	78.4 (9.3)	84.3 (14.3)	+5.9 (7.2)	81.8 (16.5)	82.9 (12.4)	+1.1 (13.7)
3	78.4 (7.3)	82.0 (12.0)	+3.6 (6.4)	79.6 (15.5)	77.2 (11.5)	-2.4 (11.0)

Table 4.7: Mean values and standard deviations (in parentheses) of absolute levels and the change in HR (beats per minute) between sessions 1 and 2. A positive mean score indicates an increase for session 2 and a negative mean score denotes a decrease.

This finding is not surprising in the light of the controversy that exists regarding the relationship between the cardiovascular system and general activation within the organism. Attempts to test the hypothesis, that the relationship between performance and level of activation is best represented by an inverted U-shaped function, have led to conflicting HR results. Investigating the effects of water deprivation upon bar pressing behaviour and HR of rats, Belanger and Feldman (1962) report that whereas the number of bar presses increases to a maximum and thereafter decreases as severity of deprivation rises, HR continues to increase monotonically. However, although Hahn et al (1962) report similar behavioural effects following deprivation, they found that HR did not continue to increase with longer periods of deprivation. The position is further complicated by a third study of rats by Winer (1970) in which thirst was controlled by means of salt injections. Whereas behavioural data from this investigation support the approach in terms of arousal outlined earlier in this chapter, HR measures are in the opposite direction to that predicted by activation theory, decreasing as thirst increases.

A number of studies have reported deceleration in HR when attentional demands are made on O (Lacey et al, 1963; Lacey, 1967; Obrist et al, 1970a, 1970b; Jennings et al, 1970). However, Eason and Dudley (1970) report increases in HR when Os are forced to maintain attention in order to avoid shock. Kahneman et al (1969) suggest that HR accelerates during the initial attentional stage, but that deceleration accompanies later information processing. Dahl and Spence (1970) have attempted to resolve the issue by proposing that the cardiovascular system is sensitive to both changes in attention and to general activation level. Their results suggest that HR may "reflect the biological system's assessment of how much information must be processed by the CNS" (p.375).

As regards the present experiment, despite the failure to establish HR as a reliable index of anxiety, there is no doubt that Os given shocks were made extremely anxious. Subsequent ratings of anxiety in the experimental situation, on a scale from 0 to 10, gave a mean of 7.00 for experimental Os, which was significantly higher than the mean of 1.85 for their controls ($p < 0.01$; two-tails, Mann-Whitney U test; Siegel, 1956).

Response latency

This experiment again provides support for the suggestion that mean overall latency L provides an index of caution or criterion for responding which is independent from s_D. The relationship between s_D and L measures obtained for experimental Os is low during both session 1 (Pearson $r = 0.45$; d.f. = 8; $p = 0.185$) and in session 2 (Pearson $r = 0.21$; d.f. = 8; $p = 0.569$). The independence of s_D and L was further examined, with a substantial increase in the degrees of freedom gained by combining data from this experiment with those obtained earlier. This appears justified, since the experimental procedure and conditions were very similar and an identical discrimination task was used. Data from Experiment 3.3 (10 Os) and Experiment 4.1, Session 1 (20 Os), combined with those obtained from the 10 experimental Os during the first session of this experiment, strongly confirm that no significant relationship exists between s_D and L (Pearson r = 0.17; d.f. = 38; p = 0.298; two tails).

If L is taken as an index of caution adopted by O, the present results suggest that there is no significant relationship between anxiety and change in caution. For both groups there is a significant decrease in latency between sessions (F = 10.82; d.f. = 1,16; p = 0.005; Appendix 4.5(iii)), as may be seen in Table 4.8. The significant interaction between sex and sessions (F = 7.19; d.f. = 1,16; p = 0.016) occurs because this tendency is most marked among male Os, due to the higher group means registered by male Os during session 1 (Table 4.9). This result, however, is largely caused by two extreme measures, one being 1.3 and the other 1.9 standard deviations above the group mean, and the sex difference during session 1 is not significant (unrelated samples t = 1.22, d.f. = 18; p > 0.20; two tails). Whilst the decrease in L between sessions is less marked in the presence of unpredictable shock, it is not significantly so (F = 2.56; d.f. = 1,16; p = 0.26). There is in any case no obvious rationale for supposing that caution should reflect change in the level of anxiety: on the other hand, changes in caution are to

Session	Experimental Group (shock)	Control Group (non-shock)	TOTALS
1	623.0 (129.4)	651.5 (97.6)	632.3 (115.6)
2	584.9 (118.2)	570.2 (103.0)	577.6 (111.1)
TOTALS	604.0 (125.4)	610.9 (108.3)	

Table 4.8: Means and standard deviations (in parentheses) for measures of mean overall latency L (msec) obtained from 10 experimental and 10 control Os during both sessions of Experiment 4.2.

Session	Male	Female	TOTALS
1	661.8 (133.5)	602.7 (84.5)	632.3 (115.6)
2	562.5 (86.3)	592.6 (129.6)	577.6 (111.1)
TOTALS	612.2 (119.6)	597.7 (106.6)	

Table 4.9: Means and standard deviations (in parentheses) for measures of mean overall latency L (msec), obtained from 10 male and 10 female Os during both sessions of Experiment 4.2. The mean for males, excluding the 2 extreme readings discussed on p.108 is 609 msec.

be expected from the first to the second session as O becomes more familiar with the task.

As predicted by an optional-stopping model of the discrimination process, mean response latencies obtained from the 10 experimental Os are found to decrease as differences between stimuli increase, both during session 1 (mean $\tau = -0.51$; $p < 0.001$; one tail), and during session 2 (mean $\tau = -0.40$; $p = 0.001$; one tail). When individual data are considered, negative correlations between latency and stimulus difference are found in both sessions for 9 Os, these being significant (Pearson $r \geq -0.65$; $p \leq 0.019$; one tail) for 8 Os in session 1 and 5 Os in session 2. Although there is some tendency during session 1 for the slopes of individual data to become increasingly negative as *L* increases (Pearson $r = -0.42$; d.f. = 8; $p = 0.111$; one tail), this result is clearly not as convincing as those obtained in earlier experiments. Furthermore, the prediction is clearly not upheld for session 2 (Pearson $r = -0.24$; d.f. = 8; $p = 0.259$; one tail).

When this prediction is re-examined using latencies for correct responses only, it is upheld for session 1 (Pearson $r = -0.62$; d.f. = 8; $p = 0.027$; one tail) but again fails for session 2 (Pearson $r = -0.20$; d.f. = 8; $p = 0.288$; one tail). Examination of individual data, however, reveals that the failure is principally caused by the atypical results obtained from two Os, these being different persons than those, discussed above, who had deviant *L* measures.

When group data are reanalyzed excluding these two, the relationship between the slope of the latency functions and *L* is found to be much improved for session 1 (Pearson $r = -0.54$; d.f. = 6; $p = 0.08$; one tail), and to reach significance for session 2 (Pearson $r = -0.85$; d.f = 6; $p = 0.004$), despite the smallness of the sample.

An examination of the performance of the two atypical Os suggests that both have tended towards dead-line responding, latencies being markedly regular, regardless of stimulus difference and whether responses are correct or incorrect. As may be seen from Appendix 4.6 where their individual data are presented, the tendency is found in both sessions, suggesting that anxiety aroused by shock is not a relevant factor. Nor does it appear to be directly linked with caution, since one O ranks fifth, whilst the other ranks tenth for mean overall latency. Both Os, however, have registered high measures for s_D, ranking eighth and tenth in the experimental group during both sessions, which suggests the interesting possibility that a very 'noisy' individual, faced with a series of discriminations which are too 'difficult', may abandon an optional stopping procedure, adopting instead a strategy which is based on a fixed sample statistical decision process.

Correct and Incorrect response latency

An optional stopping account of the discrimination process is once again supported by an examination of correct and error response latencies among experimental Os. As predicted, mean latencies for errors are significantly longer than those for correct responses, both across Os (session 1; $z = 2.80$; $p = 0.003$; one tail; Wilcoxon matched pairs signed-ranks test: session 2; $z = 2.50$; $p = 0.006$; one tail) and across stimulus differences (session 1; $z = 2.40$; $p = 0.008$; one tail: session 2; $z = 2.80$; $p = 0.003$; one tail).

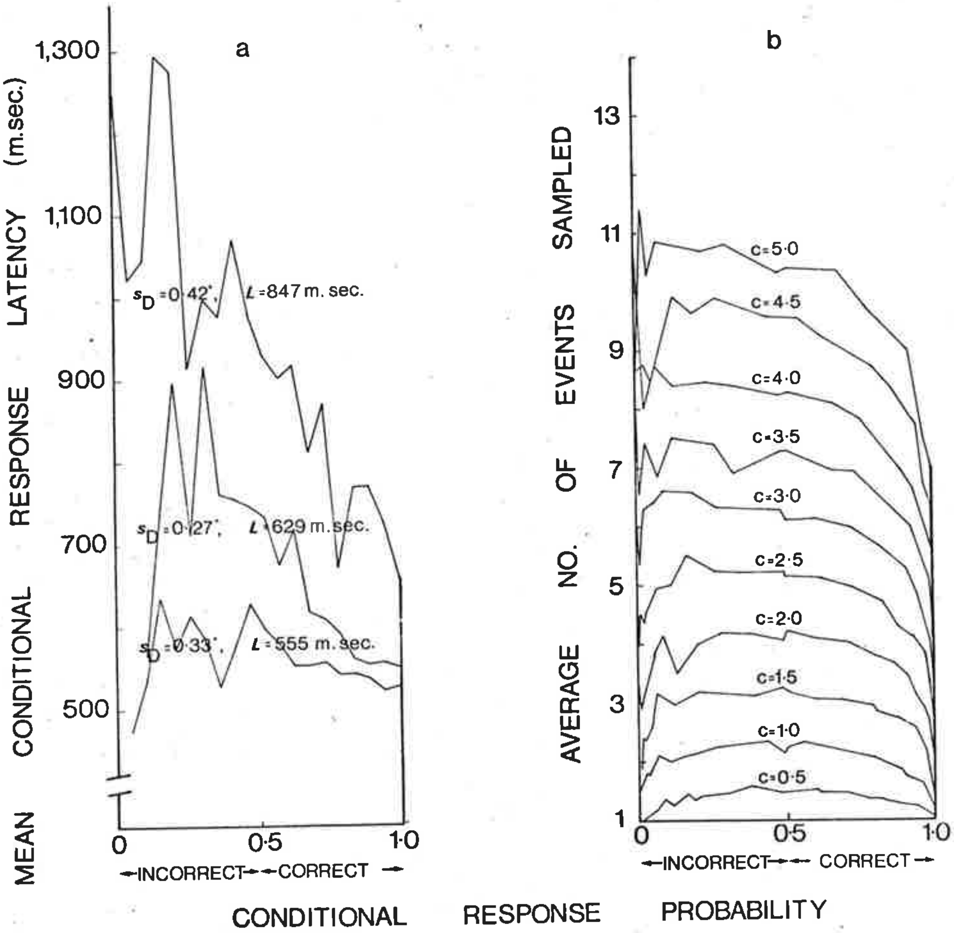
A possible means of obtaining direct comparisons between the alternative optional-stopping models of discriminatory judgement, discussed in Chapter III, has been proposed by Audley and Pike (1965), who suggest comparing the time taken to choose one of two equiprobable alternatives with the probability of making that response. The "latency-probability function" so obtained provides a comparison of latencies for correct responses and corresponding errors and each of the models predicts a characteristic pattern. Because the greatest divergence between the predicted functions occurs with errors having a low probability of occurrence, a direct comparison between the various predictions has proved difficult. Vickers (1970, 1972a), however, has presented evidence to suggest that, in accordance with an "accumulator" model, the pattern of the function changes, latencies for errors increasing relative to those for correct responses as the criterion adopted by O increases. This model therefore appears largely to reconcile differences between the various models, since, for observers with a high criterion k, Vickers' model predicts a latency-probability function resembling that predicted by the 'recruitment' model (La Berge, 1962). As k decreases, however, the function approximates that predicted by Audley's (1960) 'runs' model. Finally, for low k values, the function increasingly tends towards the inverted U-shaped function predicted by the 'random walk' model (Stone, 1960).

Although the 'accumulator' model has been developed in a discrimination situation which differs from that used in the experiments reported here in that no constraints were imposed upon O's inspection time, Vickers' prediction is examined here, using data from 40 Os in 3 experiments, as described above, by examining the relationship between the regression coefficient for a symmetrical conditional probability function of correct and incorrect latencies, derived from individual data, and caution, as indicated by the measure L. Results strongly support an 'accumulator' account of the perceptual decision process (Pearson $r = -0.59$; d.f. = 38; $p < 0.001$; two tails), indicating that the function becomes less symmetrical and more steep, due to relative increase in the latencies for incorrect responses, as caution increases. Data obtained from 3 Os, representing a low, intermediate and high criterion for responding, are plotted in the form of latency probability curves in Figure 4.2a. These would appear to provide a reasonable match with the general form of corresponding theoretical functions derived by Vickers (1970; Figure 3, p.45), as shown in Figure 4.2b.

Figure 4.2:

(a) Latency probability functions for 3 Observers, derived from the latencies to correct and incorrect responses during Session 1, Experiment 4.2.

(b) Latency probability functions for a computer simulation of the accumulator model for 10 different criteria. Based on Vickers (1970, Figure 3, p.45).



a
b
MEAN CONDITIONAL RESPONSE LATENCY (m.sec.)
1,300
1,100
900
700
500
s_D = 0·42°, L = 847 m. sec.
s_D = 0·27°, L = 629 m. sec.
s_D = 0·33°, L = 555 m. sec.
0
0·5
1·0
←INCORRECT→ ←CORRECT →
AVERAGE NO. OF EVENTS SAMPLED
13
11
9
7
5
3
1
c=5·0
c=4·5
c=4·0
c=3·5
c=3·0
c=2·5
c=2·0
c=1·5
c=1·0
c=0·5
0
0·5
1·0
←INCORRECT→ ← CORRECT →
CONDITIONAL RESPONSE PROBABILITY

CONCLUSIONS

Taken together, these results suggest that anxiety produced by unpredictable electric shocks has little predictable effect on HR, but does substantially increase the noise of which the measure s_D is a sensitive index. This finding provides support for the suggestion by Vickers et al (1972) that the measure s_D used in conjunction with other indices of discriminative performance, which can be clearly interrelated within a comprehensive theory of perceptual discrimination, should have considerable usefulness in studies of the effects of varying arousal. In addition to its potential for investigating effects of various environmental stresses, s_D might be used to study changes in performance accompanying ageing, or induced by conditions requiring sustained vigilance. It seems likely, furthermore, that s_D might be applied to the assessment of individual differences in personality or cognitive functioning.

CHAPTER V.

INDIVIDUAL DIFFERENCES IN 'INSPECTION TIME', 'NOISE', AND ASSOCIATED PERCEPTUAL INDICES OF PERFORMANCE

INTRODUCTION

The demonstration by F.W. Bessel in 1820 (cited by Welford, 1968), that characteristic individual differences in reaction time existed among colleagues required to make routine astronomical observations, was soon followed by other attempts to develop measures of fundamental capacity in the human information processing system, using such descriptors as reaction time, speed of movement, absolute and differential thresholds, and muscular strength (Galton, 1869; Cattell, 1890). The importance of the speed of mental processes as a major source of difference in ability has since been widely recognized (Thorndike, 1926; Eysenck, 1953; Furneaux, 1960), together with conative traits revealing determination, persistence and caution (Wechsler, 1958; Furneaux, 1960). Similarly, from studies concerned with 40 different tests of perceptual performance, Thurstone (1944) has isolated a factor termed "speed of judgment", similar to the factor of "decision speed" extracted by Kunnapas (1969) in an investigation of individual differences in the rate of figure reversal.

Both mental efficiency and subjective factors influencing the speed of decision are incorporated in the theoretical approach outlined in the two preceding chapters.

The indices inspection time λ, governing the rate at which sensory input is passed to subsequent decision processes; noise s_D added to the signals; and the value of data accumulated k, adopted by O as a criterion for responding, which is indirectly measured by mean overall latency L, go a long way towards providing a conceptual framework for the understanding of individual differences in perceptual performance, and might also be directly applied to the investigation of differences in what are commonly termed traits of personality or temperament.

The frequently advanced model of arousal (Hebb, 1955; Duffy, 1957; Samuels, 1959; Malmo, 1959; Berlyne, 1960; Lindsley, 1961) implies that emotional reactions to an external situation may be followed by internal activation that provides a secondary source of stimulation which increases activity already existing in the nervous system. Where a task is relatively simple or the arousal the consequence of a small increase in stimulation, the sensitivity of perceptual mechanisms in the brain may be improved, thereby facilitating learning and performance. At higher levels of activation or in more complex tasks, however, the effect of increasing arousal will tend to be disruptive as internal noise is raised and the channel capacity of the brain reduced, so that performance is impaired (Welford, 1962, 1973). Welford (1968) cites work by Davis using the Cambridge Cockpit, a simulated aircraft in which subjects were tested for 2 hour periods on complicated manoeuvres designed to result in mental fatigue. Commenting on these he says: "Onset of fatigue may lead to marked overactivity, often coupled with signs of anxiety. These in turn may direct attention from the task to worrying about whether it is being performed adequately and thus lead to still further slowing and disruption" (Welford, 1968, p.255).

Deese (1955) suggested, on the basis of a similar model, that personality measures reflecting tension might correlate with performance on vigilance tasks. One instrument widely applied to the measurement of tension or anxiety is the Manifest Anxiety Scale (M.A.S.), developed by Taylor (1953) in accordance with Spence's extension of the Hullian concept of excitatory potential (Spence, 1958). The M.A.S. score is assumed to reflect "emotional responsiveness", which is in turn related to "drive". In accordance with drive theory the model proposed by Taylor and Spence supposes that total effective drive is determined by summation principles. Performance will tend to improve as drive level rises, although higher drive levels need not always result in improved performance, since performance may be disrupted if drive level reaches a point at which several competing response tendencies are elicited.

A somewhat different approach is provided by Eysenck's (1965, 1970) theory of personality which is based upon the distinction between the two empirically derived dimensions of extraversion - introversion, and neuroticism - stability. These are linked to hypothetical physiological constructs.

Initially derived from Pavlovian and Hullian concepts of excitation and inhibition (Eysenck, 1957), the theory has more recently attempted to link the psychological dimensions directly with physiological arousal (Welford, 1965, 1966; Eysenck, 1967). It is postulated that chronic level of cortical activity is related to extraversion-introversion, while increase in arousal level when stress is applied is linked to the concept of neuroticism or instability.
Gray (1967) has emphasized that there are considerable similarities between this approach and that of Soviet psychologists, principally under the direction of the late B.M. Teplov. This work represents the extension and development of Pavlov's (1927) theories concerning the physiological basis of personality, isolating dimensions of "strength" of the nervous system. The Russian concept of "equilibrium in dynamism" bears a close resemblance to Eysenck's proposals concerning excitation - inhibition, which he has postulated to underly the dimension of introversion - extraversion, and there exists a considerable body of experimental data concerning various precisely defined parameters for conditioned reflexes, the orienting response, and E.E.G. measures that support the existence of differences between individuals in the extent to which excitatory or inhibitory processes predominate (Sokolov, 1963; Lynn, 1966; Gray, 1967). Lynn (1966), however, has emphasized that where Eysenck has remained close to Pavlov's (1927) original single stage model of habituation, suggesting

that response threshold is raised as a result of the continual generation of internal inhibition, the Russians themselves have modified this in favour of a two stage model, in which the analysis of input in terms of certain critical criteria precedes either excitation or inhibition (Moruzzi, 1960; Jouvet, 1961; Sokolov, 1963). Similarly, Broadbent (1971) has also summarized difficulties for a unitary state model of arousal, speculating about the existence of both upper and lower level decision systems, the higher level mechanism monitoring and modifying the operation of the lower, which is responsible for the execution of the response.

Within Eysenck's model, the two dimensions of introversion-extraversion and stability-instability are held to represent the principal sources of variance in what we commonly term 'personality', and have been repeatedly shown to be independent as measured by the Eysenck Personality Inventory (Farley, 1967). Eysenck therefore avoids the approach to the description of personality favoured by Cattell (1965), whereby intercorrelated primary or "first-order" factors are isolated. Instead, he prefers to deal with the more comprehensive, independent "second order" factors. Controversy regarding the relative merits of these two approaches continues to generate discussion (Eysenck, 1972).

Although the concepts of extraversion and introversion have perhaps been most widely applied within clinical and psychiatric practice, there is additionally a vast experimental literature linking them to other measures of traits, to developmental aspects of behaviour and to hereditary mechanisms underlying behaviour (Eysenck, 1967, 1970). Evidence exists to suggest differences between the sexes (Eysenck and Eysenck, 1969), females tending to be more introverted and less stable than males. Broadbent (1958, 1963) has suggested that the perseveration and caution widely attributed to introverts might be due to their using longer sampling times when inspecting sensory input. He has argued that because of higher chronic arousal, introverts may show less decrement in vigilance under conditions in which overall stimulation is low and the risk of monotony or boredom or high, a suggestion supported by data from Bakan et al (1963) and from Halcomb and Kirk (1965). Similarly, introverts have been found to be less susceptible to fatigue caused by loss of sleep (Corcoran, 1965), while extraverts have been found to incur significantly more traffic accidents and violations than introverts, a finding ascribed to the assumption that extraverts are less socialized than introverts because of slower conditionability and therefore less bound by traffic regulations (Fine, 1963). A great deal of research has been concerned with the application of these dimensions to the investigation of a variety of educational problems, to ability and achievement factors in vocational guidance and industrial fields, and to uncovering individual differences in the influence of social psychological variables (Eysenck, 1971a, 1971b).

As was discussed in Chapter IV, Welford (1962, 1965b, 1968) has proposed a unidimensional model of stress and performance as a function of personality, which postulates that both improved and impaired performance is accounted for by the increase of activity within the nervous system. Welford (1973) has further extended this model to suggest possible explanations for differences that might exist in the norms and characteristics of different social and national groups.

If these various arguments and suggestions hold good, we might expect that measures susceptible to individual differences in noise and inspection time might also apply in the area. However, it is perhaps unlikely that the individual differences of interest can be reduced to variations in a single measure, such as s_D or λ, and rather that useful distinctions may involve an interaction between these or even additional measures. It is possible for example, that some individuals may adopt relatively more stringent criteria in response to increased levels of noise, or that the effects of noise might be reduced by differing degrees in accordance with the use made of stored data. At least within the context of the simple line discriminations used in the experiments reported here, interesting variations in the use of temporarily stored information might be uncovered by determining the difference δ between values of s_D and $\sigma_{(X-Y)}$ obtained under equivalent conditions both with and without backward masking (Vickers et al 1972).

The aims of the following experiments were to investigate individual differences in the indices λ, s_D, L and δ, and to examine their relationships with differences in personality dimensions measured by the M.A.S. and the E.P.I.

EXPERIMENT 5.1

Apparatus and Stimuli:

Apparatus and stimuli used in the tasks concerned with measures of λ and s_D were very similar to those described for earlier experiments. Some modifications, however, were made. The number of examples used to familiarize O with the task before the initial session, concerned with measuring λ, was increased from 4 to 12, 2 being of 2 sec exposure and 10 being of 150 msec exposure. The range of exposure durations for this task was also expanded so as to extend from 15 to 150 msec in steps of 15 msec. In an additional session, concerned with obtaining a second measure of λ, the shorter of the two vertical lines in the stimulus display was further reduced to 24 mm, so that viewed from a distance of 66 cm, the stimulus difference of 14.4 mm corresponded to a visual angle of 1.2 deg.

For the session associated with measuring δ, a minor program change removed the backward mask following the exposure of the display for 100 msec.

Design

Each O completed four sessions in the same order, one week apart, each at the same time of day and lasting approximately 1 hour. Os were randomly assigned to sessions before or after 12 noon, with the constraint that there were equal numbers of low and high anxiety Os in morning and afternoon sessions. This precaution was taken because of evidence that personality characteristics are associated with variations in performance at different times of the day (Colquhoun and Corcoran, 1964, Blake, 1967).

A measure of the individual's inspection time λ was taken at the first session. In the second an estimate of noise s_D was obtained, using 100 msec exposure for all Os. At the third session a measure of noise was obtained under conditions without backward masking, the difference between this estimate and the former providing the index of the effects of *immediate memory* δ.

The fourth session was undertaken in order to obtain a second measure of λ. This proved necessary since during the course of the initial session it was discovered that while testing 16 Os a modification to the intensity of illumination on the oscilloscope by another user had not been corrected.

The design of each of these experimental sessions was as described for earlier experiments.

Procedure

The procedure for sessions involving line discrimination, remained the same as described in relation to earlier experiments with the exception of two minor modifications. Following initial instruction concerning the task, all communication with O was carried out by means of a two-way inter-communication system.

Observers

Observers were selected from the first year psychology course at the University of Adelaide on the basis of their M.A.S. scores (Taylor, 1953) this test having previously been administered to 405 undergraduates enrolled in this course. Scores for this population ranged from 0 to 40, with mean = 16.7 and S.D. = 8.0. The distribution tended to rectangularity with modes at 10 and 22 and median = 17, but showed little skewness (0.34) or kurtosis (2.8; conventional mean = 3.0). Males tend to score lower than females, the means of 15.7 and 17.5 respectively being significantly different (unrelated samples t = 2.20; d.f. = 403; p = 0.027; two tails). In view of the widely reported correlations between the M.A.S. and the N scale of the M.P.I. and E.P.I., this result would appear to support the finding that women tend to score more highly on the neuroticism scale than men. Selected male and female Os were therefore matched for M.A.S. score, as a control for the possible effects of this difference.

All Os had previously completed the A.C.E.R. Advanced Intelligence Tests AL-AQ (Catalogue of the Australian Council of Educational Research), the IPAT 16 PF, form C (Cattell, Eber and Tatsuoka, 1970) and either form A or B of the E.P.I. (Eysenck and Eysenck, 1964). Before selection each O was required to identify correctly all letters in the 6 m line of a Snellen eye chart, viewed from a distance of 6 m under conditions of normal room illumination. O wore correcting lenses if this was normal practice, but was tested monocularly, a different chart being used for each eye.

Five males and five females, closely matched for M.A.S. score and age, were assigned to each of four groups defined by M.A.S. scores 1-8, 9-16, 17-24, and 25-39, the four groups providing intermediate and extreme categories of both low and high anxiety.

The 40 Os were aged 17-28 years (mode = 18 years). All were naive with respect to the aims of the experiment. Participation in the sessions fulfilled part of a course requirement.

RESULTS AND DISCUSSION

Inspection time

Estimates of λ calculated for the fourth session range from 74 up to 156 msec, with a mean of 101 and a standard deviation of 22 msec. These results closely resemble those obtained in Experiments 3.1 and 3.2, and confirm the earlier suggestion that λ provides a stable behavioural descriptor of individual differences in inspection time. Further confirmation of the stability of λ was obtained by comparing the results of the 24 Os completing session 1, with results for the same Os during the fourth session. Although the means decrease from 115 to 105 msec (related samples $t = 2.00$, d.f. = 23; $p = 0.055$; two tails), there is a highly significant correlation between the two sets of inspection times (Pearson $r = 0.78$; d.f. = 22; $p < 0.001$; two tails).

Whereas it may be seen from Table 5.1 that λ bears no significant linear relationship to the personality or I.Q. measures, an analysis of variance, summarized in Appendix 5.2(i), finds a highly significant difference between measures of λ obtained for the four levels of chronic anxiety, as indicated by the Taylor M.A.S. ($F = 6.81$; d.f. = 3,36; $p = 0.001$). Application of the Newman-Keuls procedure (Winer, 1962) shows the principal sources of variance to be the differences between the extreme groups, when compared with the groups immediately above and below the mean (Table 5.2). Neither the comparison between the two extreme groups, nor that between the two intermediate groups is significant ($\alpha = 0.05$).

Planned comparisons for trend (Hays, 1963) confirm that the form of the relationship existing between M.A.S. scores and λ is best represented by a quadratic function in which λ is longest at both very high and very low levels of anxiety ($F = 19.50$; d.f. = 1,36; $p < 0.001$; Appendix 5.2(i)). The U-shaped trend is also present when inspection time data are ranked against scores for extraversion on the E.P.I., a quadratic function accounting for literally all between-cells variance ($F = 5.28$; d.f. = 1,36; $p = 0.020$; Appendix 5.2(ii)). The same trend is again found when data are ranked against neuroticism scores on the E.P.I. ($F = 7.88$; d.f. = 1,36; $p = 0.008$; Appendix 5.2(iii)). The extent of these trends may be clearly seen from Table 5.2. The measure λ is essentially derived from the number of errors made, and the

	Taylor	Cattell (16 P.F.)					Eysenck (E.P.I.)			A.C.E.R
	M.A.S.	Q4	Anxiety	Extraversion	Neuroticism	M.D.	Extraversion	Neuroticism	Lie	I.Q.
λ	-0.01	-0.16	-0.06	+0.04	-0.16	+0.15	+0.06	-0.20	-0.20	-0.16
s_D	+0.02	-0.01	+0.10	-0.18	+0.10	+0.02	+0.01	-0.07	-0.03	-0.33**
δ	-0.02	-0.04	+0.11	-0.26	+0.22	+0.04	-0.29*	+0.03	+0.08	+0.00
$L_{(\lambda)}$	-0.08	-0.10	+0.05	+0.02	+0.08	+0.06	-0.21	-0.03	-0.34**	-0.09
$L_{(s_D)}$	-0.15	-0.05	+0.07	+0.11	-0.01	-0.20	-0.03	-0.09	-0.41***	-0.21
$L_{(\delta)}$	-0.19	-0.04	+0.01	-0.02	+0.03	-0.00	-0.10	-0.22	-0.34**	-0.19

Table 5.1: Correlations found between λ, s_D, δ, L and various personality measures, obtained from 40 Os during Experiment 5.1. In this and subsequent tables the measure λ refers to that obtained in the fourth session.

***$p < 0.01$ (two tails)
**$p < 0.05$ (two tails)
*$p < 0.10$ (two tails)

The Pearson correlation coefficient r has been used for all comparisons except those involving I.Q. where the Spearman rank correlation coefficient r_s has been applied, since the I.Q. test has a maximum of 135+, scored here as 136, and this has resulted in bunching at the upper limit.

Personality dimension	Low scores		High scores	
	extreme	intermediate	intermediate	extreme
anxiety (M.A.S.)	115.1 (26.6)	89.9 (13.7)	84.9 (13.7)	112.3 (12.8)
extraversion (E.P.I.)	108.9 (27.5)	92.2 (15.9)	92.4 (17.7)	108.7 (19.0)
neuroticism (E.P.I.)	115.2 (26.6)	89.0 (14.3)	93.7 (16.3)	104.3 (19.3)

Table 5.2: Means and standard deviations (in parentheses) of inspection time λ (msec) obtained from 40 Os assigned to 4 groups of equal size in accordance with scores on 3 personality dimensions. Relevant analyses of variance are included in Appendix 5.2.

present results may therefore be interpreted as analogous to an inverted U-shaped function describing the relationship between performance and personality dimensions widely linked with arousal (Welford, 1973).

Although the M.A.S. has been frequently interpreted as an index of chronic anxiety, Taylor (1956) has emphasized that the scale was developed to provide an objective measure of general 'drive' level, as defined in the introductory section of this chapter. She points out that while test scores have successfully reflected differences in a chronic emotional state, regardless of the situation, they have also reflected individual differences in the degree of reaction to factors causing anxiety and are therefore also sensitive to differences in the extent to which anxiety leads to arousal.

This implies that the M.A.S. is not only sensitive to the kind of activation commonly linked with introversion, but also to that associated with neuroticism. An examination of the relationships found between M.A.S. scores and these dimensions in this experiment, provides some evidence for such a conclusion, although the correlations are most marked with the Cattell 16 P.F. measures, which, clearly, are not themselves independent of each other. A table showing the relationships found between the various psychometric tests is included in Appendix 5.1. For the E.P.I. dimensions, M.A.S. scores are significantly related to neuroticism (Pearson $r = 0.83$; d.f. = 38; $p < 0.001$; two tails), but not to extraversion (Pearson $r = -0.22$; d.f. = 38; $p = 0.191$; two tails).

The present results may therefore be best interpreted as suggesting that both the individual's level of chronic arousal as indicated by extraversion, and the propensity or resistance to positive stress, as indexed by neuroticism or the M.A.S. score, affect inspection time. Persons at both extremes in these dimensions tend to employ longer inspection times than do those in the intermediate categories, although presumably for different psychological reasons.

One may speculate, for example, that a highly stable individual with a low level of chronic activity in the brain, may adopt longer periods for the inspection and sampling of sensory data in order to acquire additional stimulation and enhance the operational efficiency of the perceptual system. On the other hand, a person who is highly unstable, having a high chronic level of arousal, may benefit by sampling more slowly from the environment, thereby partially offsetting the effects of random internal noise.

Noise

These speculations receive some support from the fact that s_D is not related to any of the personality variables, either linearly, as may be seen from Table 5.1, or non-linearly as is indicated by Table 5.3 ($F < 1.0$ for both M.A.S. and extraversion; Appendix 5.3).

Individual estimates of s_D range from 0.26 deg of visual angle up to 0.48 deg with a mean of 0.30 and a standard deviation of 0.06 deg. These results bear a close resemblance to the estimates obtained in Experiments 3.3., 4.1, and 4.2 for Os in a comparable situation.

Personality dimension	Low scores		High scores	
	extreme	intermediate	intermediate	extreme
anxiety (M.A.S.)	0.31 (0.05)	0.29 (0.07)	0.30 (0.07)	0.31 (0.05)
extraversion (E.P.I.)	0.31 (0.06)	0.30 (0.06)	0.30 (0.07)	0.30 (0.04)

Table 5.3: Means and standard deviations (in parentheses) of noise s_D (in degrees of visual angle) obtained from 40 Os assigned to 4 groups of equal size in accordance with scores on 2 personality dimensions. Relevant analyses of variance are included in Appendix 5.3.

Table 5.1 shows a significant negative correlation between s_D and intelligence (Spearman r_s = -0.33; d.f. = 38; p = 0.034; two tails). This degree of relationship is surprising, since the range of I.Q. sampled is very narrow, extending from 112 to the maximum of 136. Clearly, the question of a relationship between these two variables can only be adequately examined where the sample encompasses a much wider range of intelligence.

Although earlier experiments found no evidence of interdependence between s_D and λ, the two appear to be significantly related in this experiment (Pearson r = 0.45; d.f. = 38; p = 0.004; two tails). It seems possible that this result may be caused by employing a common exposure of 100 msec, based on the average λ of the same duration obtained in Experiments 3.1 and 3.2, when deriving estimates of s_D. Thus Os having longer inspection times will be disadvantaged and therefore make more errors, while those with inspection times of less than 100 msec will profit from the additional opportunity for sampling, thereby reducing the noise. This suggestion is examined in Experiment 5.2 by obtaining estimates of s_D using individual measures of λ instead of the common average value of 100 msec and, to anticipate the results there, in those circumstances the significant relationship between λ and s_D was not found.

Taken together then, these results suggest that the measures λ and s_D may not be as independent as previous evidence has suggested when a common measure of mean inspection time is utilized. This contamination might, however, be eradicated if care is taken to derive s_D under conditions which take account of individual differences in λ. There is no evidence at this stage to suggest that s_D is related to the widely used psychometric tests which purport to measure arousal, a finding which emphasizes the independence of the noise and inspection time indices.

Immediate memory, δ

Individual estimates of δ suggest wide differences in the effects of temporarily stored information, producing reductions of noise ranging from 0.00 up to 0.30 deg of visual angle, with a mean of 0.12 and a standard deviation of 0.08 deg. As may be seen from Table 5.1, only extraversion shows any evidence of a significant linear correlation with δ (Pearson r = -0.29; d.f. = 38; p = 0.067; two tails), a relationship which is improved by the application of a square root transformation to basic observations to correct positive skewness caused by bunching of δ scores towards zero (Pearson r = -0.31; d.f. = 38; p = 0.050; two tails). The trend is shown in Table 5.4, where means for groups with different levels of M.A.S. scores are also included.

Since differences in s_D have not been found to be related to extraversion, the differences in δ suggest a tendency for introverts to make more effective use of temporarily stored data. There is, however, no evidence to suggest that the improved performance is related to a change in the degree of caution exercised by O, since the

Personality dimension	Low scores		High scores	
	extreme	intermediate	intermediate	extreme
anxiety (M.A.S.)	0.12 (0.05)	0.11 (0.10)	0.14 (0.08)	0.10 (0.08)
extraversion (E.P.I.)	0.14 (0.08)	0.13 (0.07)	0.12 (0.09)	0.08 (0.09)

Table 5.4: Means and standard deviations (in parentheses) of immediate memory δ (in degrees of visual angle) obtained from 40 Os assigned to 4 groups of equal size in accordance with scores on 2 personality dimensions. Relevant analyses of variance are to be found in Appendix 5.4.

correlation found between extraversion, and mean overall latency in the unmasked situation, $L_{(\delta)}$, is low (Pearson r = -0.10; d.f. = 38; p = 0.451; two tails), as is that between δ and $L_{(\delta)}$ (Pearson r = 0.23; d.f. = 38; p = 0.159; two tails).

More efficient use by extreme introverts of sensory traces temporarily stored in immediate memory is in accordance with the suggestion that they employ long inspection times (λ), since both a longer inspection period and an unmasked memory trace should provide additional opportunity for the integration and co-ordination of incoming sensory data. Extreme extraverts, however, also show relatively long inspection times, and it might therefore be argued that their performance should also benefit when the short-term trace is not obliterated by the backward mask. As may be clearly seen from Table 5.4, this is not the case. A feasible explanation for this apparent contradiction is that stimulus-induced excitation might raise a general level of activity in extraverts that would otherwise be too low for maximally efficient functioning, while the stimulation arising from previously registered stored information would be much weaker and probably leave the general level of activation virtually unaffected.

Mean overall latency L

It may be seen from Table 5.1, where the three L indices are identified by subscripts appropriate to the experimental session, that none shows a significant linear relationship with any of the personality measures, except the E.P.I. Lie scale which is a measure of inconsistency in responding to the items in the E.P.I.: the Pearson r = -0.34 in two instances (d.f. = 38; p = 0.030; two tails), and -0.41 in the other (p = 0.008; two tails). This finding is difficult to interpret since little research has been specifically concerned with the Lie scale. Eysenck and Eysenck (1969) report that it is not unusual for Lie scale scores to correlate negatively with neuroticism scores, the implication being that liars pretend to lower neuroticism. This, however, has not been found to be the case here, the correlation between neuroticism and the Lie scale being very low (Pearson r = 0.09). In the light of the present results a reasonable conclusion would seem to be that inconsistency in responding to the E.P.I. questionnaire may be the consequence of lowered caution in formulating answers, rather than the outcome of a deliberate attempt to select responses seen as socially desirable.

Mean latency L for the sessions concerned with s_D, δ, and the second determination of λ are shown in Table 5.5. It will be seen that L steadily declines over sessions (F = 19.54; d.f. = 2,72; p < 0.001; Appendix 5.5). Application of the Newman-Keuls procedure (Winer, 1962) finds that all differences between sessions are significant at the 1% level. M.A.S. scores are not related to differences in L (F < 1.0).

The high correlations shown in Table 5.6 between the various measures of L indicate that it is a stable index of individual differences in performance from one experimental

Session	Anxiety (M.A.S.) low	intermediate	intermediate	high	TOTALS
s_D	597.5 (153.4)	592.5 (118.4)	596.0 (148.2)	556.3 (113.8)	585.6 (135.6)
δ	553.6 (93.5)	552.8 (70.0)	578.1 (122.2)	511.1 (59.1)	548.9 (92.7)
λ	492.3 (88.2)	503.5 (101.6)	456.9 (39.3)	487.2 (119.3)	485.0 (93.6)
TOTALS	547.8 (123.3)	549.6 (105.2)	543.7 (128.9)	518.2 (105.1)	

Table 5.5: Means and standard deviations (in parentheses) of mean overall latency L (in msec), obtained from 40 Os assigned to 4 groups of equal size in accordance with Taylor M.A.S. scores, during 3 sessions concerned with obtaining indices of λ, s_D and δ.

	s_D	δ	$L_{(\lambda)}$	$L_{(s_D)}$	$L_{(\delta)}$	$b_{y.x}L_{c(\lambda)}$	$b_{y.x}L_{c(s_D)}$
λ	+0.45***	-0.01	+0.29*	+0.15	+0.14	-0.00	+0.10
s_D		+0.53***	+0.05	+0.30*	+0.53***	+0.09	+0.13
δ			+0.13	+0.11	+0.23	-0.02	+0.10
$L_{(\lambda)}$				+0.55***	+0.47***	-0.77***	-0.21
$L_{(s_D)}$					+0.74***	-0.54***	-0.70***
$L_{(\delta)}$						-0.36**	-0.24
$b_{y.x}, L_{c(\lambda)}$							+0.44***

Table 5.6: Relationship between the perceptual indices λ, s_D, δ and the various measures of mean overall latency L obtained during 3 sessions in Experiment 5.1, together with the slope of the line best fitting latencies for correct responses L_c in the sessions concerned with λ and s_D. This slope is provided by the regression coefficient $b_{y.x}$ obtained between latency and differences of exposure when measuring λ, and between latency and differences in line length when measuring s_D.

*** $p < 0.01$ (two tails)
** $p < 0.05$ (two tails)
* $p < 0.10$ (two tails)

situation to another, despite the decline over sessions. These findings are consistent with the earlier proposal in Chapter III that L may be interpreted as a guide to the degree of caution adopted by O, and confirm that the level of caution may vary in accordance with the situation, falling when circumstances become relatively more familiar.

This interpretation of L receives further support when relationships between the various L indices, and the slope of the line best fitting latencies for correct responses, are examined. It has earlier been found that, in accordance with an optional stopping account of the perceptual decision process, response latencies will increase with difficulty of discrimination, the slopes of the best fitting straight lines becoming more steeply negative as L increases. The slope of latencies for correct responses L_C is preferable to the slope for all responses as an index of caution because of evidence discussed in Chapter IV that the shape of the latency probability function is related to degree of caution in a complex manner. As may be seen from Table 5.6, these slopes provided by the regression coefficients $b_{y.x}$, obtained between latency and differences of exposure when measuring λ, and between latency and differences in line length when measuring s_D, do become more steeply negative as L increases. This supports the interpretation of L as a measure of caution. There is, furthermore, a substantial degree of consistency between the slopes obtained when measuring s_D and λ (Pearson r = 0.44; d.f. = 38; p = 0.005; two tails), even though, as is to be expected in line with the drop in L between these sessions, the mean slope decreases from -8.23 in the session measuring s_D, to -0.99 in the session concerned with λ.

Indeed, $b_{y.x}$ for latencies of correct responses may provide an even more satisfactory index of caution than L itself, since the measures of slope remain independent of the indices λ, s_D and δ, whereas, as may be seen in Table 5.6, there is some evidence of a relationship between L and s_D. Some interdependence between noise and caution might be expected, however, since Os having high values of s_D may possibly attempt to compensate for this by adopting higher levels of caution.

EXPERIMENT 5.2

This investigation represents an extension of Experiment 5.1, the aim being to derive measures of s_D, having replaced the common exposure of 100 msec used hitherto with individual estimates of inspection time. In addition, an attempt was made to obtain indices of caution in an experimental situation where O could examine the discriminanda for as long as he wished. The relationships between these measures, and the personality variables previously discussed, are investigated.

Except for minor modifications, apparatus, stimuli, design and procedure were the same as for Experiment 5.1.

There were two sessions. In the first the new measurement of s_D was obtained. During the second session, no backward mask followed the discriminanda, and the display remained visible until terminated by a key-press. Viewing distance was increased to 185 cm, established during pilot sessions as appropriate to conditions in which exposure was unlimited.

Observers

Fourteen males and eight females, drawn from among Os in Experiment 5.1 and with M.A.S. scores ranging from 1 to 39 served as Os. All were naive with respect to the aims of the experiment.

RESULTS AND DISCUSSION

Noise

Overall results appear similar to those obtained in Experiment 5.1, individual estimates of s_D ranging from 0.26 deg of visual angle up to 0.41 deg with a mean of 0.30 and a standard deviation of 0.05 deg. However, these estimates are not significantly related to those obtained from the same Os in the previous experimental situation (Pearson $r = -0.31$; d.f. = 20; $p = 0.154$; two tails). This finding therefore tends to confirm the earlier suggestion that estimates of s_D might be artificially increased or reduced by assuming a common $\lambda = 100$ msec.

As anticipated when discussing the estimates of noise obtained in Experiment 5.1, the relationship between λ and s_D shown in Table 5.6 disappears under the conditions of the present experiment (Pearson $r = -0.17$; d.f. = 20; $p = 0.545$; two tails). Once again, no evidence is found to suggest a linear relationship between noise and M.A.S. scores (Pearson r = 0.09), extraversion (Pearson r = 0.10), or neuroticism (Pearson r = 0.05). There is, furthermore, no support for the earlier finding shown in Table 5.1 of an inverse relationship between intelligence and noise (Spearman r_s = 0.06).

These low correlations strongly suggest that the index s_D provides a behavioural descriptor that is independent of λ, providing care is taken to ensure that O's performance is based upon only one inspection of the discriminanda. They further confirm that s_D provides information about the individual's capacities, which is not readily obtained from conventional psychometric tests for personality traits.

Caution

As was the case in Experiment 5.1, the appropriate subscript is applied to measures of mean overall latency L, derived under different experimental circumstances. The symbol $L_{(opt)}$ is used here to designate the measure of mean overall latency obtained in session 2 where exposure was unlimited.

Once again L emerges as a relatively stable behavioural descriptor. The measures of $L_{(\lambda)}$ obtained from the same Os in Experiment 5.1 (mean = 573 msec; standard deviation = 154 msec) closely resemble those of $L_{(s_D)}$ obtained here (mean = 570 msec; standard deviation = 131 msec) and there is a high positive correlation between the two measures (Pearson r = 0.86; d.f. = 20; $p < 0.001$; two tails). Moreover, as reported in Experiment 5.1, $L_{(s_D)}$ appears to be independent of both λ (Pearson r = 0.005) and s_D (Pearson r = -0.08).

The suitability of L as an index of caution receives considerable support when the speed and accuracy of responding during the second session are compared with measures of $L_{(s_D)}$ obtained in the first, and with values of $L_{(\lambda)}$ obtained in Experiment 5.1. As may be seen from Table 5.7, both these measures correlate significantly with $L_{(opt)}$ despite the considerably longer latencies recorded in this situation (mean = 1,193 msec; standard deviation = 348 msec). A similar result is obtained when measures of $L_{(\lambda)}$ and $L_{(s_D)}$ are compared with $L_{(opt)} \div \lambda$, an index of the number of inspections of sensory data preceding a decision, and which should therefore be directly related to the criterion determining data accumulation under these circumstances.

Relationships between various measures of L and the total errors made in the second session, as well as with the traditional psychophysical measure of the *precision* h of the psychometric function (Corso, 1967), are not as marked as might be expected. Although correlations are in the direction predicted by a speed-accuracy trade-off (Vickers et al, 1972; Swensson, 1972), only that between $L_{(s_D)}$ and h reaches significance at the 5% level. These

	$L_{(s_D)}$	$L_{(opt)}$	$L_{(opt)}+\lambda$	Total errors	h	$b_{y.x}L_{c(\lambda)}$	$b_{y.x}L_{c(s_D)}$
$L_{(\lambda)}$	+0.86***	+0.48**	+0.41*	-0.26	+0.31	-0.78***	-0.65***
$L_{(s_D)}$		+0.61***	+0.57***	-0.41*	+0.43**	-0.53**	-0.73***
$L_{(opt)}$			+0.89***	-0.31	+0.31	-0.32	-0.65***
$L_{(opt)}+\lambda$				-0.37*	+0.37*	-0.34	-0.63***
Total errors					-0.99***	+0.27	+0.37*
h						-0.38*	-0.36*
$b_{y.x},L_{c(\lambda)}$							+0.52**

Table 5.7: Experiment 5.2. Matrix of correlation coefficients (Pearson r) found to exist between 8 behavioural descriptors for the level of caution adopted by O before responding. Estimates are obtained from 22 Os during Experiments 5.1 and 5.2.

*** $p < 0.01$ (two tails)
** $p < 0.05$ (two tails)
* $p < 0.10$ (two tails)

correlations are, however, reduced by the fact that there has been no strong tendency for Os to compromise between speed and accuracy (Pearson r = -0.31; d.f. = 20; p = 0.157; two tails). Most Os have, in fact, adopted a strategy biased towards a low error rate, two thirds having error rates as low as from 8 to 23% in a task designed to produce high rates. In line with this is the high mean overall latency of 1,193 msec and the high mean value of 10 for the index $L_{(opt)} \div \lambda$, implying that, on an average, judgements have been based upon data accumulated within 10 inspection periods.

The slopes $b_{y.x}$ of the lines best fitting individual correct response latency data remain characteristic of individual performance. Those obtained for the same Os while calculating λ during Experiment 5.1 show a substantial correlation with those found in session 1 of this experiment (Pearson r = 0.52; d.f. = 20; p = 0.013; two tails). Once again, the slope becomes more steeply negative as caution, indicated by $L_{(s_D)}$, increases (Pearson r = -0.73; d.f. = 20; p < 0.001; two tails).

CONCLUSIONS

The results obtained in Experiments 5.1 and 5.2 provide considerable encouragement for regarding the measures that have been developed as providing a basis for the understanding of the decision mechanisms underlying discrimination processes. Results again appear to provide evidence for an optional stopping process such as the accumulator model proposed by Vickers (1970, 1972a).

The measures λ and s_D appear independent when care is taken to derive s_D under conditions taking account of individual differences in λ. At the same time individual differences of λ have been found to correlate consistently with certain facets of personality widely regarded as being associated with extreme levels of activity in the brain.

The interest of the measure δ as an index of the use made of temporarily stored information has been enhanced by its relationship with the personality dimension of extraversion-introversion, despite the finding that at this stage there is no evidence of a similar relationship between personality and s_D. This implies that noise is independent of the use made of immediate memory, as well as of inspection time.

CHAPTER VI.

EMERGENCE AND ALTERNATION OF THE PERCEPT

INTRODUCTION

Vickers (1972b) has argued that the *emergence* of a perceptual organization, figure or pattern may be mediated by the same types of optional stopping decision processes, discussed at length in the three preceding chapters. It has already been suggested in these chapters that this kind of model, particularly the accumulator model proposed by Vickers, provides a good account of the features of simple psychophysical decisions like those made by Os in the experimental situations described there.

A problem related to the question of perceptual organization concerns the *alternation* between different organizations which occurs with a number of ambiguous phenomena long known to give rise to the sensation of spontaneous change in appearance. Examples of figures which involve depth reversal include the Necker cube, the Schroder staircase and the Mach book, while others, like the Maltese cross, Rubin's reversible goblet, or the graphic art work of Escher, result in spontaneous figure-ground alternations. Boring's well known "my wife, my mother-in-law" involves the alternation of the perceived object, while other figures appear to change with respect to grouping and orientation (Attneave, 1971). In addition to these phenomena, the simultaneous presentation of conflicting cues, one to each eye, may result in monocular predominance, one field only dominating perception, or in 'binocular rivalry', where the two fields alternate so that O is first aware of one field and then the other (Vernon, 1952; Woodworth and Schlosberg, 1958; Engel, 1956; Bagby, 1957; Shelley and Toch, 1962; Reynolds and Toch, 1965). Mefferd (1968) has emphasized the similar nature of perceptual fluctuations occurring with a wide variety of stimuli and Vickers (1972b) has suggested that these phenomena might all be regarded as *perceptual alternations*, arguing that certain general features common to all such situations (Sadler and Mefferd, 1970; Vickers, 1972b) are the consequence of a single underlying perceptual decision process which is cyclic. Thus the optional stopping accumulator process is hypothesised to mediate the initial organization, beginning anew as each decision is reached. However, because of the essentially stochastic quality of the data sampling mechanism, the current perceptual organisation remains unchanged unless the decision cycle is reversed. Where this occurs, the new result in the accumulator process corresponds with a change in perceptual organization.

Vickers (1972c) had discussed the main properties and characteristics of the cyclic decision model in detail, proposing that a wide variety of direct and indirect stimulus and environmental factors shown to influence the rate of perceptual alternation might be reconciled if it is assumed that these affect the value of k adopted by O. Thus 'preference' or 'set' amounts to a lowered value of k, gained by 'priming' the accumulator relevant to the favoured percept before inspecting the stimulus input. Increases in alternation rate under conditions involving increased heat or external noise (Heath et al, 1963), or strenuous exercise (Ash, 1914; Hollingworth, 1939; Tussing, 1941) may be interpreted as the consequences of heightened psychological arousal which results in the partial filling of the decision accumulators and an apparent decrease in k.

Whilst it seems likely that characteristic individual differences exist in a number of different measures of perceptual performance associated with perceptual alternation such as the "active period of orientation" (Sadler and Mefferd, 1970), termed elsewhere the "initial latency" (Lindauer and Lindauer, 1970), or the duration of the initial percept (Howard, 1961; Price, 1967a, 1967b, 1969a, 1969b), or the relative dominance of each percept (Kunnapas, 1957; Price, 1969a), the vast majority of investigations concerned with variance between individuals have concentrated upon differences in the rate of perceptual alternation (Guilford and Hunt, 1931; Frederikson and Guilford, 1934; George, 1936; Porter, 1938; Philip and Fisichelli, 1945; Brown, 1955; Jackson, 1956; Wieland and Mefferd, 1967; Lindauer and Lindauer, 1970; Lindauer and Reukauf, 1971).

No clear conclusion can at this stage be drawn regarding possible relationships between individual differences in alternation rate and individual differences as measured by tests of extraversion - introversion. The variety of questionnaires used to ascertain levels on the personality dimension contributes considerably to the difficulty of interpretation. Whereas some workers have reported that introverts register more rapid alternation rates than extraverts (Mc Dougal, 1926; George, 1936; Porter, 1938), others find no evidence for such a difference (Washburn et al, 1929; Guilford and Braly, 1930; Guilford and Hunt, 1931; Frederikson and Guilford, 1934). In a situation involving the alternation of the Necker cube, Franks and Lindahl (1963) report significant differences between extraverts and introverts as measured by the Maudsley Personality Inventory (M.P.I.) introverts showing a more rapid rate of alternation when instructions emphasize holding any one percept as long as possible, which might be assumed to induce slow alternation. Under neutral instructions, however, the trend is only weakly apparent. On the other hand, Lindauer and Reukauf (1971), using a number of ambiguous figure-ground stimuli, report that extraverts, as measured by the E.P.I., register higher rates of reversal.

Data obtained from persons categorized as mentally ill, whose scores on the extraversion-introversion dimension fall into extreme categories, are no less discrepant than those already discussed above. Thus, whereas Hunt and Guilford (1933) report more rapid alternation for extreme introverts, the opposite is found by Costello (1957). In both experiments, the rate of alternation is in any case slower in the extreme groups than is found among normal controls. Results obtained in experiments investigating the effects of stimulant and depressant drugs are as equivocal. McDougal (1929), Guilford and Braly (1930) and George (1936) report positive increases in alternation rate following the application of a stimulant drug, but Eysenck et al (1957) fail to find such an outcome. Again, McDougal (1929) and George (1936) find that depressant drugs cause a decrease in rate of alternation. Guilford and Braly (1930), however, find the opposite, while Eysenck et al (1957) report that there is no evidence to support a significant relationship in either direction. Finally, Wertheimer et al (1955) report that although stimulant drugs increasing metabolic efficiency do not affect the rate of perceptual alternation, depressant drugs, which reduce metabolic efficiency, do result in a slow rate of alternation.

Eysenck (1967) has suggested that the trait of "field dependence" (Witkin, 1959) can be directly related to extraversion. Investigations relating the degree of field dependence and rate of alternation are slightly less ambiguous than those dealing with extraversion directly. However, while several reports indicate that slow alternation is a function of increasing field dependence (Jones, 1955, using instructions emphasizing fast alternation; Kidd and Cherymisin, 1965; Immergluck, 1966), others fail to replicate this finding (Frenkel-Brunswik, 1949; Jones, 1955, using instructions emphasizing slow alternation; Haronian and Sugarman, 1966).

Finally, it has frequently been reported that high introversion is related to high M.A.S. scores and Kidd and Cherymisin (1965) find that the rate of figure reversal falls as anxiety increases.

Thus, although the evidence appears to favour the hypothesis that introversion will result in more rapid perceptual alternation, the results are by no means unambiguous. The rate of perceptual alternation has also been applied as an index to differences between sexes (George, 1936; Kidd and Cherymisin, 1965), males being more rapid than females, and to the effects of ageing (Heath et al, 1963), where results support the widely held conclusion that age slows down all psychomotor activity (Williams, 1970). Stable individual differences in the initial emergence of perceptual organization have been found to exist independent of the extraversion-introversion dimension (Lindauer and Reukauf, 1971), the index discriminating between older and younger Os (Botwinick et al, 1959) and between mental retardates and normal controls (Spitz and Blackman, 1959).

To date then, although the perceptual measures associated with the emergence and alternation of perceptual organization have been found to provide fairly characteristic indices of individual difference, attempts to equate these with other dimensions of difference have been relatively unsuccessful.

The aims of the following experiment were threefold: first, to investigate the possible relevance of the indices

λ, s_D, L and δ to phenomena of perceptual emergence and alternation; second, to examine possible relationships between individual differences in these variables and differences in personality dimensions hypothetically linked with physiological arousal levels; and third, to consider Vickers (1972b, 1972c) extension of the optional stopping accumulator process to a more complex perceptual phenomenon.

EXPERIMENT 6.1

Apparatus and stimuli

The stimulus used to obtain measures of various parameters of the emergence and alternation of percepts was the Necker cube shown in Figure 6.1a. It was back projected onto a ground-glass screen by means of a Carousel 35 mm slide projector and viewed at a distance of 185 cm. The projected sizes of the front and back faces were 5 cm square. The lines defining the sides were 45 deg from the vertical, and the orientation remained invariable for all Os. Luminance could not be accurately determined but was of an intensity previously judged to be sufficiently clear without resulting in after images. Responses were made by pressing one of two morse keys when one percept appeared, and the other alternative key when the other percept appeared. The timing and preliminary analysis of responses were carried out by the computer.

Procedure

The observer was seated before the illuminated Necker cube and the nature of the task explained using a box, open

Figure 6.1:

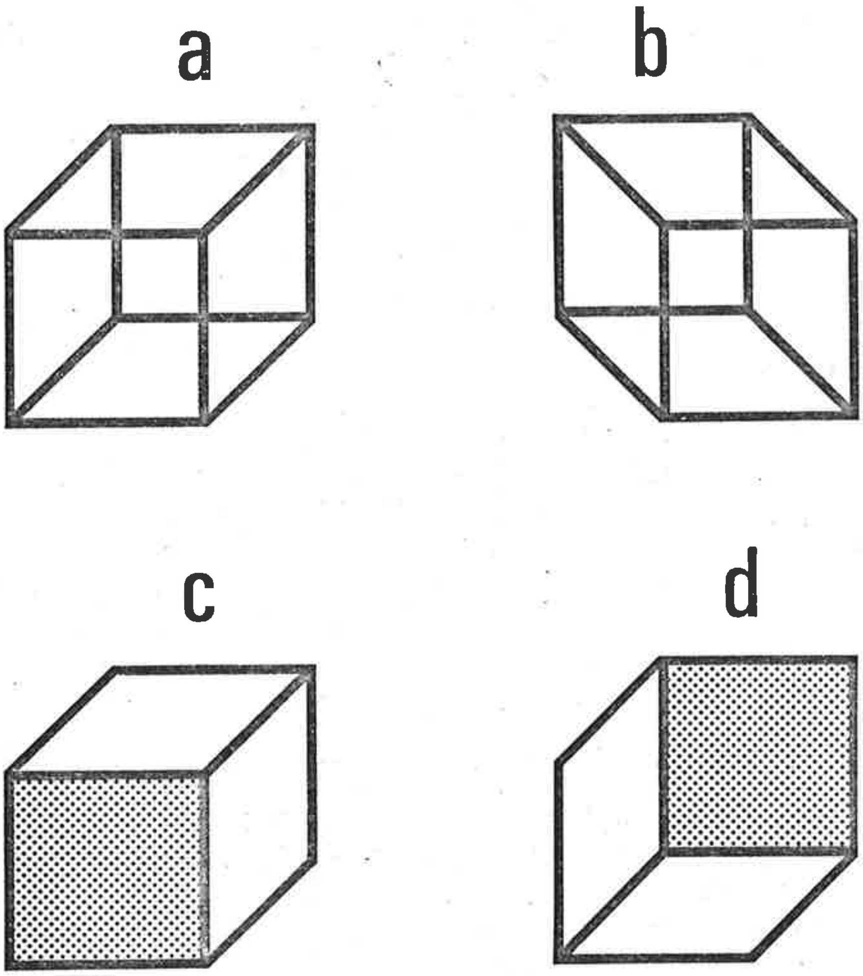
The Necker cube used in Experiment 6.1

a. orientation presented to all Os

b. orientation used by White (1972)

c. "left" perceptual organisation

d. "right" perceptual organisation


a
b
c
d

on one side, to model the alternative percepts. O practised responding to alternative percepts, verbalizing the response whilst pressing the appropriate key, for 5 minutes. It was emphasized that figure reversal should not be actively encouraged, but rather allowed to occur involuntarily.

Following practice, O sat facing the screen, with hands resting lightly on the keys, and was instructed to press the key corresponding to the initial percept as quickly as possible. It was emphasized that undivided attention must be maintained, although blinking was permitted, and that all subsequent alternations should be indicated by an appropriate key-press, made as soon as possible after the organization had occurred. O was not informed of the number of alternations to be recorded but was asked to continue responding until further notice. Timing commenced with the exposure of the Necker cube, so that the latency for the first response gave a measure of the initial emergence of 3 dimensional organization. The latency of the next response provided a measure of the time required for the alternative organization to be perceived. The stimulus remained exposed continuously while 50 alternations, additional to the initial percept, were recorded.

Observers

The 40 Os were those taking part in Experiment 5.1. All were naive with respect to the aims of the experiment.

RESULTS AND DISCUSSION

The Emergence of the Initial Percept

It is apparent that the initial percept has in most cases been the "left" perceptual organisation illustrated in Figure 6.1c, being so with 38 out of the 40 Os. Results from White (1972), on the other hand, suggest precisely the opposite result. In an experiment in which 5 separate estimates of the latency for the initial percept were made for each O, 49 out of 50 Os more frequently indicated the right hand organisation in preference to the left for the initial organisation. As may be seen from Figure 6.1, this outcome is the consequence of the orientation of the stimulus figure, White's figure being the mirror-image of the stimulus used here. In both experiments it is the organisation dominated by a *lower* front face which has resulted in the emergence of the initial percept.

Two alternative explanations, between which it would be difficult to distinguish, suggest themselves. It is possible that the perceptual mechanism is 'set' or 'tuned' by past expectations to register the organisations illustrated in Figure 6.1c and Figure 6.2a(iii), since boxes are most frequently seen from above, rather than from

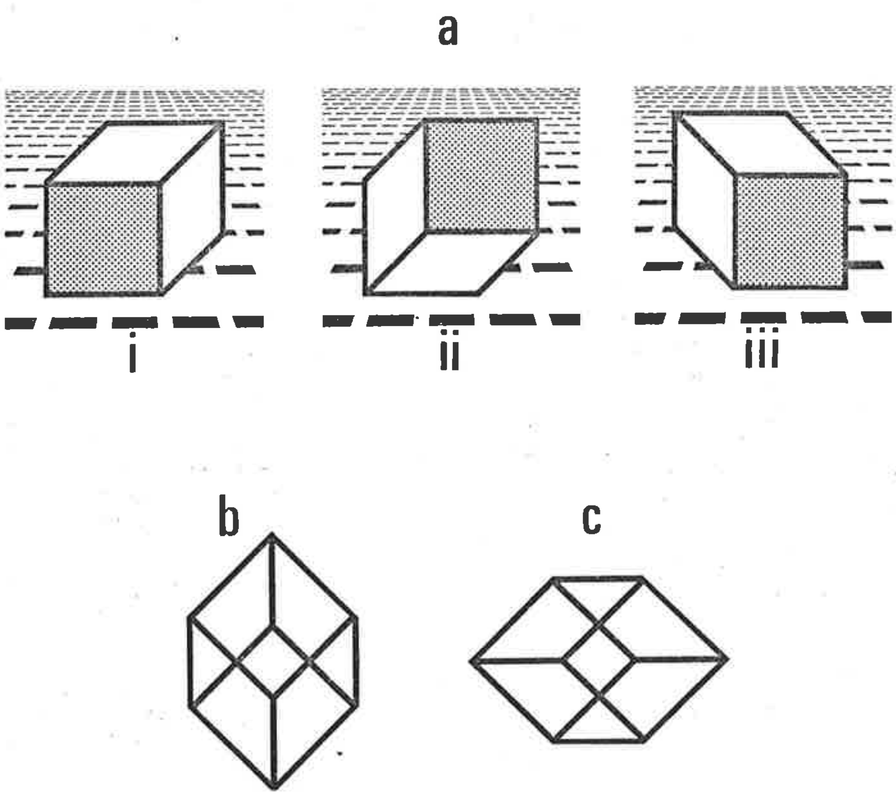
Figure 6.2:

The Necker cube in different organisations and orientations

a. "left" and "right" percepts from Experiment 6.1, together with the "right" percept from White (1972) set against a textural gradient similar to that employed by Vickers (1971).

b. an "up" or "down" orientation

c. an alternative "left" or "right" orientation


a
i
ii
iii
b
c

below, as in Figure 6.1d. Alternatively, as may be seen from Figure 6.2a orientations (i) and (iii) are more consonant with a receding textural gradient than is (ii), although not entirely so, since the uniform lengths and angles in the cube do not conform to the rules of perspective drawing. Proposals by Vickers (1971) that perception may involve more than a simple principle of economy or parsimony within a figure (Hochberg and McAlister, 1953; Attneave, 1954; Garner, 1962, 1966, 1970) would appear relevant to the second alternative. Vickers suggests that the perceptual system may tend to reduce redundancy in the encoding of sensory data to a minimum, whilst at the same time seeking a compromise between the advantages of this strategy and the possible cost of error, caused by ignoring inconsistencies in the stimulus array. Thus, the total context in which the figure is found must be considered. Either an experiential or a modified economy hypothesis would predict that the upper face in Figure 6.2b would be seen to be closer, and therefore initially preferred, but both organisations in Figure 6.2c should be equiprobable since neither is more consonant than the other with respect to expectation arising out of past experience or a textural gradient implying depth perspective.

Latencies for the emergence of the initial percept range from 323 up to 2726 msec, with a mean of 1011 and a standard deviation of 605 msec. These data suggest wide differences between individuals with respect to this measure of perceptual performance. As may be seen from Table 6.1, this measure does not appear to relate to any of the personality measures associated with an arousal hypothesis, a result which supports Lindauer and Reukauf's (1971) finding that the latency for the emergence of the initial percept is not related to the degree of extraversion.

The relationships between these data and anxiety, as indicated by the M.A.S., and extraversion, as measured by the E.P.I., have been examined by analysis of variance (Appendix 6.1a), and, as may be seen from Table 6.2, no evidence suggestive of either a linear or a non-linear relationship between the variables is found ($F < 1.0$).

On the other hand, Table 6.1 shows significant correlations between initial percept duration and four of the five measures of latency, suggested in Chapter V as providing an indirect index of k. This suggestion is further strengthened by the high correlations with $L_{(\lambda)}$ (Pearson $r = 0.45$; d.f. = 38; $p = 0.004$; two tails) and the regression coefficient $b_{y.x}$ for latencies to correct responses in the session measuring λ in Experiment 5.1. (Pearson $r = -0.52$; d.f. = 38; $p < 0.001$; two tails). Further support for this suggestion is found when making comparisons with data obtained in Experiment 5.2. Once again, significant correlations between the index of slope for correct latencies and alternation measures suggest that caution appears to be the important determinant of both the

		Perceptual Alternation Measures			
		Initial percept duration	Mean percept duration	S.D.	Change during session
	Taylor M.A.S.	-0.06	-0.07	-0.08	-0.03
16 P.F.	Q4	+0.02	-0.06	-0.08	-0.08
16 P.F.	Anxiety	+0.03	-0.01	-0.06	-0.00
16 P.F.	Extraversion	+0.13	+0.06	+0.07	+0.14
16 P.F.	Neuroticism	+0.12	+0.03	+0.01	-0.15
16 P.F.	M.D.	+0.03	-0.01	+0.02	-0.14
E.P.I.	Extraversion	-0.05	+0.01	-0.05	+0.24
E.P.I.	Neuroticism	+0.04	+0.02	+0.00	+0.14
E.P.I.	Lie	-0.22	+0.06	+0.05	-0.01
	I.Q.	-0.24	-0.27*	-0.28*	-0.13
	λ	+0.15	+0.04	+0.02	-0.20
	s_D	+0.15	+0.09	+0.14	-0.08
	δ	-0.15	-0.22	-0.11	+0.08
	$L_{(\lambda)}$	+0.45***	+0.21	+0.29*	-0.01
	$L_{(s_D)}$	+0.28*	+0.23	+0.25	+0.19
	$L_{(\delta)}$	+0.27*	+0.17	+0.22	-0.08
$b_{y.x}$,	$Lc_{(\lambda)}$	-0.52***	-0.39**	-0.52***	-0.24
$b_{y.x}$,	$Lc_{(s_D)}$	-0.15	-0.17	-0.13	-0.21
Initial percept		-	-0.50***	+0.50***	-0.10
Mean percept			-	+0.93***	+0.03
S.D.				-	+0.10

Table 6.1: Correlations found between measures of percept emergence and alternation, and various personality and psychophysical indices, obtained from 40 Os during Experiments 5.1 and 6.1.

***p 0.01 (two tails)
**p 0.05 (two tails)
*p 0.10 (two tails)

The Pearson correlation coefficient r has been used for all comparisons except those involving I.Q. where the Spearman rank correlation coefficient r_s has been applied, since the I.Q. test has a maximum of 135+, scored here as 136, and this has resulted in bunching at the upper limit.

Personality dimension	Low Scores		High Scores	
	extreme	intermediate	intermediate	extreme
anxiety (M.A.S.)	956.1 (622.7)	1231.8 (736.4)	827.9 (280.0)	1029.6 (608.7)
extraversion (E.P.I.)	1032.2 (780.2)	1097.9 (713.8)	951.2 (359.3)	964.1 (451.1)

Table 6.2: Means and standard deviations (in parentheses) of the latency for the emergence of the initial percept (in msec), obtained from 40 Os assigned to 4 groups of equal size in accordance with scores on 2 personality dimensions. Relevant analyses of variance are included in Appendix 6.1.

emergence and subsequent alternation of the perceptual organization. (A table of correlation coefficients relevant to Experiments 5.2 and 6.1 is to be found in Appendix 6.2).

These results provide direct support for Vickers' (1972b) prediction that individual differences in perceptual organization should reflect characteristic differences in the degree of caution adopted in making perceptual decisions.

The rate of perceptual alternation

The reciprocal of alternation rate, namely the mean percept duration, derived from all responses, has been used as an index of perceptual alternation. Results range from 1155 up to 9287 msec, with a mean of 3852 and a standard deviation of 1642 msec. As with initial latency, no evidence is found to support a linear relationship between alternation rate and any of the personality variables (Table 6.1). Again, as may be seen from Table 6.3, no evidence is found to suggest a linear or non-linear relationship with either level of anxiety or extraversion (Appendix 6.1b).

Although correlations between mean percept duration and the various latency measures from Experiment 5.1 are less convincing than was the case with the measure of initial percept duration (Table 6.1), there is nevertheless a significant relationship with the regression coefficient for correct response latencies in the session concerned with λ (Pearson $r = -0.39$; d.f. = 38; $p = 0.012$; two tails).

Personality dimension	Low scores		High scores	
	extreme	intermediate	intermediate	extreme
anxiety (M.A.S.)	3795.9 (1508.5)	4229.5 (2235.0)	3154.8 (824.3)	4227.5 (1435.7)
extraversion (E.P.I.)	3813.6 (1776.7)	4084.7 (1876.6)	3593.9 (1196.8)	3915.5 (1596.0)

Table 6.3: Means and standard deviations (in parentheses) of the mean percept duration (msec) obtained from 40 Os assigned to 4 groups of equal size in accordance with scores on 2 personality dimensions. Relevant analyses of variance are included in Appendix 6.1.

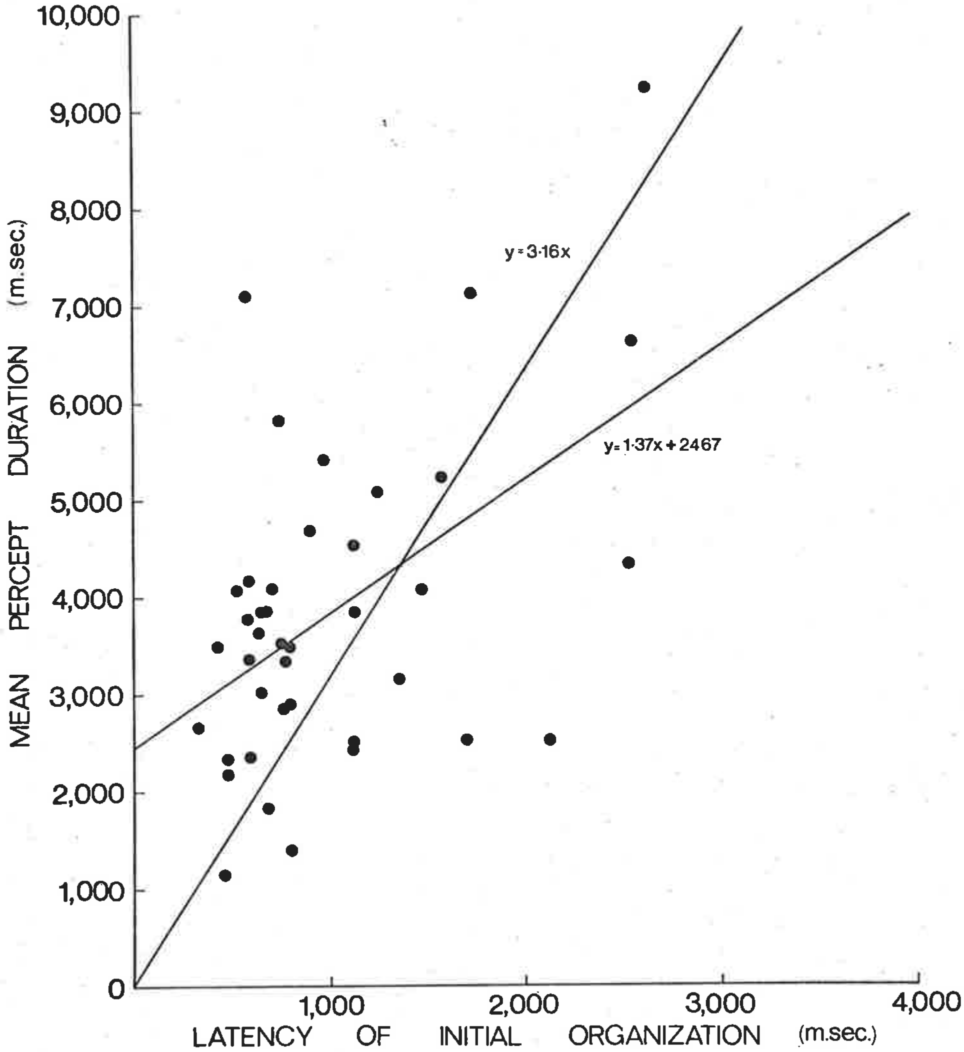
It has been suggested in earlier chapters than this slope may be more sensitive than *L* to the degree of caution adopted by O, and this result therefore provides some evidence for the prediction of Vickers (1972c) that individuals displaying slower rates of alternations might be expected to maintain higher levels of criterion for decision.

As predicted by a cyclic accumulator process (Vickers, 1972c), mean percept duration appears to be a linear function of the latency for emergence of the initial percept (Pearson $r = 0.50$; d.f. = 38; $p = 0.001$; two tails), the data being fitted by a straight line with the equation $y = 1.37x + 2467$ as shown in Figure 6.3. Vickers (1972c, p.37) makes the specific prediction that the coefficient of slope should be 2, on the assumption that the two alternative percepts are equiprobable, the mean number N of successive events being given by 1/0.5, and it may therefore be seen that the obtained coefficient is lower than the predicted value. To some extent this may be due to the degree of scatter encountered in the data, but, more importantly, it is clear that the two percepts were not equiprobable.

Since 95% of Os registered an initial left hand organization it might be argued that the probability associated with this response is 0.95 and the relevant coefficient of slope should therefore be 1.05. In fact, when the relationship between initial latency and the mean duration of the *corresponding percept* is examined, the data are well fitted (Pearson $r = 0.52$; d.f. = 38; $p < 0.001$;

Figure 6.3:

Mean percept duration as a function of the latency for the emergence of the initial organisation. The data are best fitted by the straight line with the equation $y = 1.37x + 2467$. The line with the equation $y = 3.16x$ is the best fitting straight line passing through the origin.


10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
MEAN PERCEPT DURATION (m.sec.)
y = 3·16x
y = 1·37x + 2467
1,000
2,000
3,000
4,000
LATENCY OF INITIAL ORGANIZATION (m.sec.)

two tails) by a straight line with the equation y = 1.21x + 2124, a result which appears to equate reasonably well with the prediction of 1.05.

The intercept of 2467 msec is unexpected since the cyclic model would predict that the line of best fit should pass through zero. The straight line best fitting the data in Figure 6.3 while passing through the origin is given by the equation y = 3.16x, a value which is too high. The most likely explanation is that lapses in attention on the part of observers are responsible for the high intercept. The difference between the overall mean percept duration of 3852 msec and the intercept of 2467 is 1385 msec, a value which agrees well with the times of 1340 and 1520 msec reported by Kunnapas (1957) for the durations of the equiprobable alternative percepts of a Maltese cross, and the 1500 msec estimated by Vickers (1972c) as representative of a difficult discrimination.

Mean percept durations for left and right organisations

A higher probability for the emergence of a particular percept is hypothesized by Vickers to be the consequence of a lower *k* value associated with it. As reported above, the "left" organisation has predominated as the initial percept in this experiment. Mean duration for that percept should therefore be longer during the alternation phase, since the lower criterion should result in longer runs of decisions favouring the more probable percept. 30 out of the 40 Os are found to have a mean duration for the organisation seen initially which is *longer* than that for the other percept ($p < 0.001$; two tails; Binomial test): the mean duration for the left percept of 4449 msec obtained from pooled data is significantly longer than that of 3255 msec for the right (related samples $t = 4.68$; d.f. = 39; $p < 0.001$; two tails), although, as expected, there is a high correlation between the two measures (Pearson $r = 0.77$; d.f. = 38; $p < 0.001$; two tails).

Interestingly enough, the right percept predominated during alternation in White's (1972) experiment and, because the orientation of the stimulus was the reverse of that used here, the right percept predominated initially. His results, together with those reported here, support a cyclic model, there being no discrepancy between the two measures of perceptual dominance.

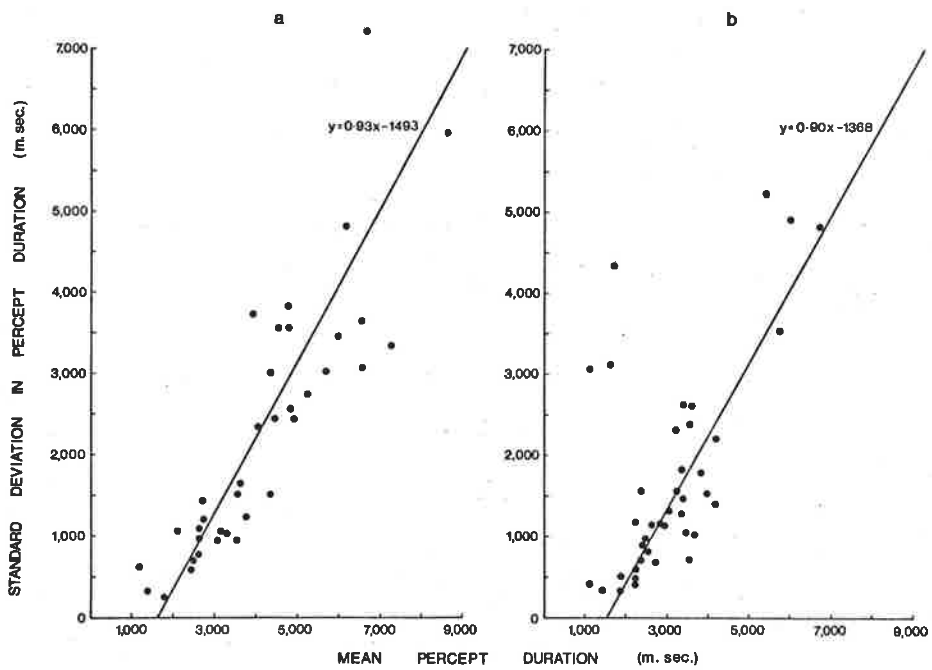
The standard deviation of percept duration

As may be seen from Table 6.1, the relationships found to exist between the standard deviation of percept duration and other variables are very similar to those applying to mean percept duration. This is only to be expected in view of the high degree of relationship between the means and the standard deviations (Pearson $r = 0.93$; d.f. = 38; $p < 0.001$; two tails). The principal relevance of the standard deviation measure here is that Vickers' (1972c) cyclic decision model predicts a linear relationship between the mean and standard deviation. Since the mean number N of successive events is given by $N = 1/q$, where $q = 1-p$, and the variance of this run by p/q^2, then the coefficient of slope for the relationship between the standard deviation and the mean should be 0.71. The value obtained from the data produced by the computer simulation referred to by Vickers (1972c) was 0.83 (Vickers, personal communication), a reasonable agreement, especially since the estimate of 0.71 was acknowledged to be a minimum estimate, being based upon the variability in one percept only.

As may be seen from Figure 6.4, the standard deviation of the duration of each percept does follow the mean for that percept closely, and the coefficients of slope are close to the predicted value. The left organisation is well-fitted by a straight line having the equation $y = 0.93x - 1493$ (Pearson $r = 0.91$; d.f. = 38; $p < 0.001$; two tails), while the right is described by $y = 0.90x - 1368$ (Pearson $r = 0.88$; d.f. = 38; $p < 0.001$; two tails). The negative intercepts in excess of 1 sec are unexpected, however, being much longer than might be anticipated as a result of movement time or delays in the decision mechanism. If, as suggested in Chapter III, we accept 150 msec as an estimate for t_o, then the present result implies that, on an average, at least 10 inspections of the figure, each lasting for an average of about 100 msec, are made before an alternation occurs. This is consistent with the result obtained in Experiment 5.2 for the task where exposure was not limited.

Figure 6.4:

The standard deviation in percept duration as a function of mean percept duration for (a) "left" organisation and (b) "right" organisation.


a
b
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
1,000
3,000
5,000
7,000
9,000
y=0·93x-1493
y=0·90x-1368
STANDARD DEVIATION IN PERCEPT DURATION (m. sec.)
MEAN PERCEPT DURATION (m. sec.)

It is equally possible, however, that the longer values are caused by tentative responding, or lapses in attention, and it must be acknowledged that uncontrolled and undetectable observer inconsistencies in the maintenance and direction of attention present problems which are almost certainly intrinsic to the particular task used in this experiment.

The change in alternation rate during the session

Since Vickers (1972c) has made speculations concerning the possible relevance of increases and decreases in arousal to changes in the rate of alternation as a function of viewing time, an attempt was made here to obtain a measure of change and examine its relationships with other experimental variables. However, because a significant trend ($\alpha = 0.05$) between perceptual alternation rate and viewing time could be established for only 6 Os by correlational procedures, it was decided to use the difference between the means for the first 10 and last 10 alternations as an index of change. As may be seen from Table 6.1, this measure shows no relationship with any of the other experimental variables. Since the measure is negative, indicating an increase in alternation rate, for 18 Os, and positive for 22, it may be concluded that no specific trend has emerged, and that the measure is not of consequence within the context of this experiment.

Final examination results

The possibility of a relationship between O's success in coping with an introductory course in Psychology and any of the personality or behavioural indices was examined, using the total of all marks accumulated in terminal and final exams, and from practical and tutorial assignments throughout the year, as an indicant of success. These could be obtained for 38 Os, 2 failing to complete the course.

As might be expected, success is found to correlate significantly with I.Q. (Spearman r_s = 0.50; d.f. = 36; p = 0.005; two tails) but relationships with personality measures are low. For the M.A.S., Pearson r = -0.10 (p = 0.557), while for Cattell's Q4 and M.D., r = -0.18 (p = 0.279) and 0.16 (p = 0.339) respectively. There is little evidence of a relationship with extraversion (r = -0.07), but for neuroticism Pearson r = -0.24 (p = 0.143).

With regard to the behavioural indices obtained in the experiments described in this and the preceding chapter, correlations are all low, most relationships being found with the latency for the emergence of the initial percept (Pearson r = -0.24; p = 0.143) and s_D (Pearson r = -0.19; p = 0.252). It has been proposed that the latency of the initial percept may be largely dependent upon O's caution in making a decision. The result is therefore consonant with the widely held opinion that individual differences in criterion play a significant part in the attainment of success. It is hardly surprising, however, that these measures of simple psychophysical decisions have not proved sensitive to performance in a situation as complex as that of coping with a university subject over an extended period of time.

CHAPTER VII

GENERAL CONCLUSIONS

Further applications of the perceptual indices of performance

The experiments reported in the preceding chapters have emphasized the importance in a judgement task, of applying accurate measuring procedures to the analysis of the individual's perceptual decision processes, and of providing conditions which enable the precise specification and control of stimulus variables. The results also indicate a number of fundamental measures of performance, namely *inspection time* (λ), *noise* (s_D), *caution* (as evidenced by latency or measures derived from it), and *use made of immediate memory* (δ). These measures appear to go a long way towards providing an understanding of the decision mechanisms underlying perceptual processes. In particular, the experimental data provide strong evidence that at least some simple psychophysical judgements are mediated by an *optional stopping decision process* such as the *accumulator model* proposed by Vickers (1970, 1972a). Support is also found for Vickers' (1972b, 1972c) suggestion that the model may be extended to account for the emergence and alternation of perceptual organisation in ambiguous figures by supposing that the discrimination process is cyclic.

Measures of inspection time λ, obtained under a variety of experimental conditions, have confirmed the initial hypothesis that 100 msec is a reasonable estimate of the average time required to make a single momentary inspection of the sensory input. The measure has, moreover, proved to be a stable, consistent predictor of individual differences that is sensitive to certain facets of personality widely hypothesised to be associated with more extreme levels of activity in the brain. There are some grounds for optimism that the measure of λ, derived here from the analysis of the pattern of O's correct responses, will prove to be analogous to the index of inspection time, calculated directly from response latencies by Welford (1971a). If these two measures should prove to be interchangeable, stable indices of individual differences, it would imply that periodicities of about the order suggested by the experiments reported here characterize large parts of the transmission and integration of sensory data in the human information processing system.

The comprehensive measure of noise in the visual system s_D has also emerged as an important independent index, providing consistent characterization of individual differences in performance. While evidence at this stage suggests no direct relationship with personality variables characterized by chronic anxiety or arousal, s_D has proved to be extremely sensitive to the direct application of environmental stress. As suggested by Vickers et al (1972), the potential that s_D appears to have as an index of environmental stress might lead to some reassessment of current theoretical interpretations of sensory deprivation. Whereas the lower sensory threshold and diminished physiological arousal encountered in deprivation research has been interpreted as a corrective sensitization of the organism in response to reduced cortical activity (Schultz, 1965; Zubek, 1969), the viewpoint presented here predicts that s_D should diminish as a function of time spent under conditions of sensory deprivation and that any improvement in performance under these conditions would be a direct result of lowered random cortical activity. A particularly interesting finding that has emerged from these experiments is that the measures of s_D obtained are much higher than might have been expected from earlier work where exposure time was less restricted. This result has important implications for the significance and validity of standard untimed tests of visual acuity, and reinforces the work of Weston (1949) in suggesting that these tests may be unsatisfactory, or indeed quite inappropriate, for the screening of individuals required to work under conditions making severe demands, either continuously or intermittently, for speed of performance. These conditions might be presumed to apply, for example, to persons operating complex industrial machinery, driving motor vehicles, particularly when entering or leaving heavy traffic, flying aircraft during take off and landing, or responsible for the co-ordination and control of air traffic.

The measure of mean overall response latency L has emerged most creditably from the present results as a consistent index of characteristic levels of caution in a wide variety of experimental situations. Although the measure appears to be largely independent of inspection time and noise, there is some evidence in the results of Experiment 5.1 of a relationship with both λ and s_D. While both correlations are low, it is clearly desirable that an index of the caution adopted by O be developed, which is not dependent upon the analysis of response latencies. An example of such a measure would be the direct estimation of the value of O's criterion for a decision, involving the discrimination between the frequency of occurrence of two easily distinguishable alternative events, as used by Sanders and Ter Linden (1967) and by Vickers et al (1971). In this situation, O responds as soon as a decision is reached as to which of two lights is flashing more frequently. The probabilistic structure of the stimulus events is exactly specified, and stimuli are presented at a predetermined rate, leaving the adopted level of caution as the major source of variance between individual observers. Vickers and Willson (Vickers et al, 1972) are currently exploring the possibility of deriving such a measure from a logistic function of the general form discussed by Ogilvie and Creelman (1968), within an experimental situation where no constraints are imposed upon inspection, as described in Chapter V. The index $L_{(opt)} \div \lambda$, representing the average number of inspections of sensory data preceding a decision, might also be expected to be directly related to the criterion determining data accumulation under these circumstances.

The relevance of the measure δ, as a standard index of the benefit of temporarily stored information to performance, has been greatly enhanced by the finding that introverts make more effective use of this data than extraverts. This finding has underscored the importance of developing a battery of behavioural descriptors which can be used in conjunction with one another because they are derived within the same conceptual framework. As emphasized by Vickers et al (1972), some support for the general approach advocated in this thesis is provided by evidence that similar psychophysical decision mechanisms appear to underly a number of perceptual phenomena that have not previously been treated as theoretically interdependent. For example, a number of workers have demonstrated that critical cycle time for the perception of flicker decreases as stimulus exposure duration increases, at least up to exposures of approximately 1 sec (Anderson et al, 1966). This finding suggests that, with longer exposures, O is able to accumulate additional information which facilitates the detection of the presence of flicker. Again, in reviewing recent research of individual differences in figural after-effects, Over (1970) has emphasized the influence of decision processes, summarizing evidence that "the magnitude... is dependent upon the speed with which post-inspection judgements are made, the extent to which a response set is formed, and the criterion adopted by the subject when judgements are made" (p.409). These suggestions clearly reflect a viewpoint very similar to that advocated in this thesis.

Over further suggests that persons categorized in accordance with clinical diagnoses, or differences in intellectual ability or age might be shown to differ systematically in "judgement time, set and judgemental criterion", as these response variables underly the group differences in figural after-effects found by some investigators. It seems highly likely therefore that the measures λ, s_D, δ, and L, together with those associated directly with perceptual alternation, might be usefully applied to the investigation of developmental and ageing processes. Indeed, a number of recent reviews have emphasized the advantages of measures of perceptual-motor speed in this area (Welford and Birren, 1965, 1969; Hicks and Birren, 1970).

It is hoped that the measures might also find valuable application in the study of mental retardation and even psychopathological conditions (Welford, 1971b). The experimental task from which these measures are derived is relatively simple, and one in which it may be possible to overcome the difficulties associated with obtaining data from the intellectually retarded. An experimental situation is being developed at present, employing a 2 field tachistoscope, modified to provide backward masking. This apparatus, together with a portable, programmed recorder system can be readily transported into the field, and therefore affords the opportunity to collect data from these persons under environmental circumstances with which they are familiar. It has the additional advantage that the demands made upon the observer's comprehension of instructions, and attention during the course of the experimental session, are considerably reduced. Although the collection of data in this manner is very much slower than in the setting described in this thesis, evidence has already been obtained that the less formal situation enables the experimenter to maintain closer contact, and to provide more intensive training in the task required. As a consequence, data have been collected from intellectual retardates who were unable to cope with the more constrained and demanding conditions which they encountered in the fully computerized laboratory.

Although many current diagnostic tests and procedures for assessing intellectual abilities and basic aptitudes enjoy reasonable face validity, they are nevertheless all too often inappropriate to the situation in which, for want of suitable alternatives, they are applied (Savage, 1970). Measures of fundamental perceptual processes, such as those described, would seem well suited to the assessment and appraisal of basic human capacity and performance, particularly in the area of vocational rehabilitation where, although sensory handicaps and intellectual retardation are frequently encountered, careful training procedures can lead to encouraging results (Neff, 1971). The techniques described here, for example, might be better suited to the assessment of some fundamental capacities of a deaf-mute, than the more readily available diagnostic tests and procedures for the appraisal of abilities or aptitudes, which are rendered inappropriate because of their heavy dependence upon verbal skills. Again, the measures might be developed to distinguish the educationally under-priviledged from the intellectually retarded. Finally, since these indices would appear to be directly relevant to fundamental capacities of the kind hypothesized to underly a potential for various manual skills, the measures λ, s_D, δ and L might usefully be considered in relation to the kind of direct industrial training procedures advocated by Seymour (1954) and Belbin (1969): for example, are the functions underlying these measures open to training, or do they have to be accepted as 'given' in any training situation, and therefore important criteria governing acceptance for certain jobs?

A re-evaluation of the concept of subliminal perception

Following the attempt in Chapter VI to extend the optional stopping accumulator model to account for more complex perceptual phenomena, it is tempting, in conclusion, to try to re-evaluate the concept of subliminal perception in terms of the discrimination process outlined in the previous chapters. The sigmoidal form of the psychometric function, which has provided the central principle for the explanatory model developed in Chapters III, IV and V, has been assumed to occur because discriminatory sensitivity is not only dependent upon the intensity or magnitude of stimulation, but also upon random factors which are manifest in accordance with the laws of probability. No evidence has been found to suggest that a statistical account of the discriminative decision process is inappropriate.

The model presupposes that, even in the idealized situation, the presence of noise in the decision processes will, by its very nature, prevent the possibility of precise behavioural prediction. The correlation found to exist between phenomenal representation and the energy state registered by the appropriate sensory system therefore becomes a question of degree, since discrimination will depend upon the strength of the signal relative to that of noise in the system. The term 'subliminal' is therefore only appropriately applied to the perceptual process under conditions in which the inspection of the sensory input is limited by an exposure of less than λ, and where the signal is thoroughly erased from short-term memory without the opportunity for any data processing at even the primary level of the analysing system.

In these circumstances responding would be made either on a chance basis, or in terms of environmental and subjective factors influencing the criterion adopted beforehand for each alternative. Vickers (1970, 1972c) has suggested that a decrease in the value of k applying to a particular decision would result from the partial 'priming' of the accumulator mechanism by factors such as changes in attention, sensitivity to non-equiprobabilities in the sequence of stimulus presentation, or the effects of instructions and incentives. Another set of biasing factors would be provided by the expectations brought into the situation by the observer. Thus, where a preference for a particular percept existed, the accumulator process would favour it, and this tendency would be more pronounced under circumstances where no informative data were obtained and the accumulators were entirely 'topped up' with noise. This explanation would seem to account for the demonstration of a response bias against infrequent stimuli in the absence of any stimulus, but where observers have been led to expect rapidly presented stimulus material (Goldiamond and Hawkins, 1958; Zajonc and Nieuwenhuyse, 1964).

Turning now to the more usual situation, in which a decision is made on the basis of at least one inspection of the discriminanda, or where short-term memory is used to take advantage of additional processing time after the signal has ceased, it is suggested that the emergence of a percept is, in every case, the consequence of an interaction between the incoming data, the criteria governing the response mechanisms, and the level of noise in the system. One of the most interesting findings reported in this thesis is that observers generally appear unable to abandon an optional stopping procedure, even under conditions where every attempt is made to impose a minimum, uniform criterial level. On the contrary, Os adopt characteristic criteria that can sometimes only be met by 'topping up' the decision mechanisms with non-informative data derived from the noise in the system.

This proposal appears to go a long way towards resolving the controversy outlined in Chapters I and II, as to whether "subliminal" effects can be wholly explained in terms of response organization. To the extent that partial or fragmentary information is obtained from the discriminanda, it will enter into the analyzer system. The end decision, however, will depend also upon the extent to which various biases already exist in the response system, and on the level of noise, an influence that will increase as the signal to noise ratio decreases. Thus, the presentation of a stimulus of insufficient intensity in itself, will nevertheless interact with the pre-existing organisation, and therefore influence the outcome. In the same way, a stimulus erased by backward masking might be expected to produce at least some limited effect upon behaviour. Although Experiment 2.1 failed to find evidence for this, it is now widely accepted that briefly exposed stimuli can be processed, even when directly followed by a masking stimulus (Averbach and Coriell, 1961; Sperling, 1967).

Variations in the recognition threshold to emotionally connotative material may be understood in terms of the model of arousal discussed in Chapters III and IV. Thus, a mild increase in the activity of a system operating below its optimum should raise the effective strength of incoming signals. A more intense degree of general activation, however, would increase the level of noise, rendering the discrimination more difficult. Whether the outcome was perceptual 'vigilance' or 'defense' would depend upon:

(i) the signal to noise ratio defining the difficulty of the discrimination;

(ii) the degree of increased activity produced by the emotional stimulus;

(iii) the level of chronic arousal already existing in the system.

This account of 'perceptual defense' leads to two predictions. The first is that, to the extent that emotional stress increases the level of noise and reduces the discriminability in the situation, the latency of responding should be lengthened. This follows because, if the decision criterion remains unchanged, more non-informative noise will have to be accumulated. Very little research on this question is available at the present time. There is, however, some evidence which supports the prediction: Dixon (1956) and Brown (1965) report that response times are longer to emotional material.

The second prediction is concerned with individual differences in the dimensions of extraversion-introversion, and stability-instability. As discussed in Chapter V, these are commonly associated with the chronic level of arousal, in the first case, and the reactivity of the individual to changes in arousal, in the second. The model outlined above predicts that severely threatening stimulation should markedly increase the level of activity in the nervous system and therefore produce a higher threshold for recognition among introverts and neurotics, already in a high state of arousal, than among persons at the other ends of these dimensions. There is some evidence to suggest that individuals scoring high on the psychasthenia scale (Pt) of the M.M.P.I., or on the M.A.S., have lower recognition thresholds for emotionally toned stimulation than do individuals having high hysteria (Hy) scores, or low M.A.S. scores (for a review, see Inglis, 1960). Brown (1961) has extended these findings, and suggests that low thresholds for emotional stimuli should characterize introverts, while high thresholds should characterize extraverts.

In accordance with the hypothesis put forward here, however, this outcome would only follow if the stimuli were of relatively slight emotive connotation. As the emotive content of the stimuli was increased this trend would be reversed, so that when stimulation was highly stressful, its effect would be most disruptive for individuals already in a high state of arousal. Recognition thresholds would be raised accordingly.

Dixon (1958b) reports that females showed a significantly higher relative brightness threshold for the left eye, during subliminal stimulation of the right eye with the word 'whore', than did males. This result is to be expected, particularly if this word is regarded as more anxiety-provoking by females, since, as was emphasized in Chapter V, females have been found to be more introverted and more neurotic than males. However, the amount of evidence available in this area is as yet small, and the personality measures somewhat crude, so that more precise studies may need to await future developments in technique. Before turning from the relevance of response bias to the concept of subliminal perception, we should consider an explanation for those investigations, discussed in Chapter II, which have reported a change in sensitivity (d'), as measured by signal detection methodology, following the presentation of taboo or emotional material. It will be recalled that the effect was not uniform, two experiments finding that taboo words were significantly more discriminable than neutral words (Dorfman et al, 1965; Dorfman, 1967), and two others reporting that sensitivity was lower during emotional stimulation (Broadbent and Gregory, 1967; Hardy and Legge, 1968).

A possible explanation for the increase in sensitivity is to be found in the finding by Dorfman et al that the difference in discriminability between taboo and neutral words increased with duration. This is precisely what one would expect from an optional stopping account of the perceptual process, since lengthening exposure time would allow O more opportunity to increase the number of inspections made of the stimulus. However, whereas in accordance with signal detection theory d' increases as a function of $\sqrt{n}$, the higher discriminability is regarded here as an example of the speed-accuracy compromise emphasized by the optional stopping model.

The lower d' measures obtained in the other two investigations find a possible explanation in the evidence of greater variance in the judgements of "bad words" in the Broadbent and Gregory study. As the authors themselves point out, if the distributions underlying ratings of emotional and neutral words had equal means, but did not have equal variance, as their analysis assumes, d' would appear to be different for the two classes of words. The same result, however, would presumably be obtained, if the level of noise was increased by the presentation of emotional stimuli, in accordance with the model of arousal outlined above.

Dixon (1962) has suggested that perceptual defense may result from a reduction in the level of cortical activity, caused by decreased reticular activity following cortical discrimination of stimulation. He argues that such a mechanism should result in a decrease in d', since general activity associated with the "noise plus signal" distribution would fall. However, as pointed out by Welford (1968, p.277 f.f.) while a fall in activation level should result in a rise in β, little if any change is to be expected in d'. The proposal put forward here, that the signal to noise ratio might be varied by increasing or decreasing intrinsic noise in the perceptual system, would appear to offer a more parsimonious explanation.

The proposed account of subliminal perception in terms of an optional stopping accumulator model of the decision process clearly assumes that sensory data may be registered by the appropriate sensory system, and subjected to some degree of analysis, without awareness on the part of the observer. It is therefore open to the objection, put forward by some opponents of the perceptual defense concept, that one cannot logically perceive, in order *not* to perceive (e.g. Howie, 1952; Gibson, 1968). As emphasized by Dixon (1971), however, this apparent contradiction only arises if one insists that terms like 'perception' and 'discrimination' can only apply to conscious acts. There is no logical inconsistency if we assume that these words apply to operations, performed within a complex system conceived in cybernetic terms (Welford, 1972). Common sense would certainly advise against adopting the extreme position that, because one is not aware of a particular event, it cannot possibly influence behaviour. We daily carry out a large number of habitual actions rapidly and accurately without being aware of them. As Welford (1972) points out, it is only when environmental factors such as fatigue and stress interfere with the complex patterns of biases permanently established in the behavioural repertoire, that we become aware of details in the operations involved. Indeed, when an error occurs, it is not uncommon to be "alerted to the fact... although... unaware of what error has been made" (p.309).

At the present time it is only possible to speculate about the actual mechanisms by which stimulation ultimately affects behaviour. The 'accumulator' posited here is conceived as analogous to an analyzer, within which evidence is compared with an internalized representation of a particular outcome. As already mentioned, this representation will be shaped by several different internal and external sources of bias, operating in both the short and long term. A decision is precipitated when correspondence is obtained between the accumulated evidence and the critical state of the analyzer.

These suggestions are in line with the commonly held view that the perceptual process involves a complex, hierarchical system of feature analyzers, operating both simultaneously and sequentially. Data are processed through a number of stages of organisational development, beginning with the registration of the sensory correlates of even the weakest portions of the stimulus array, and concluding ultimately in the highest centres of the brain. The system is widely acknowledged to include a number of preconscious stages (Dixon, 1971; Welford, 1972). A system of the kind outlined would have sufficient flexibility for some stimulation to result in awareness. However, other signals, although operating indirectly upon overt behaviour, would do so without affecting perceptual experience to an extent which would enable their contributions to be recognized.

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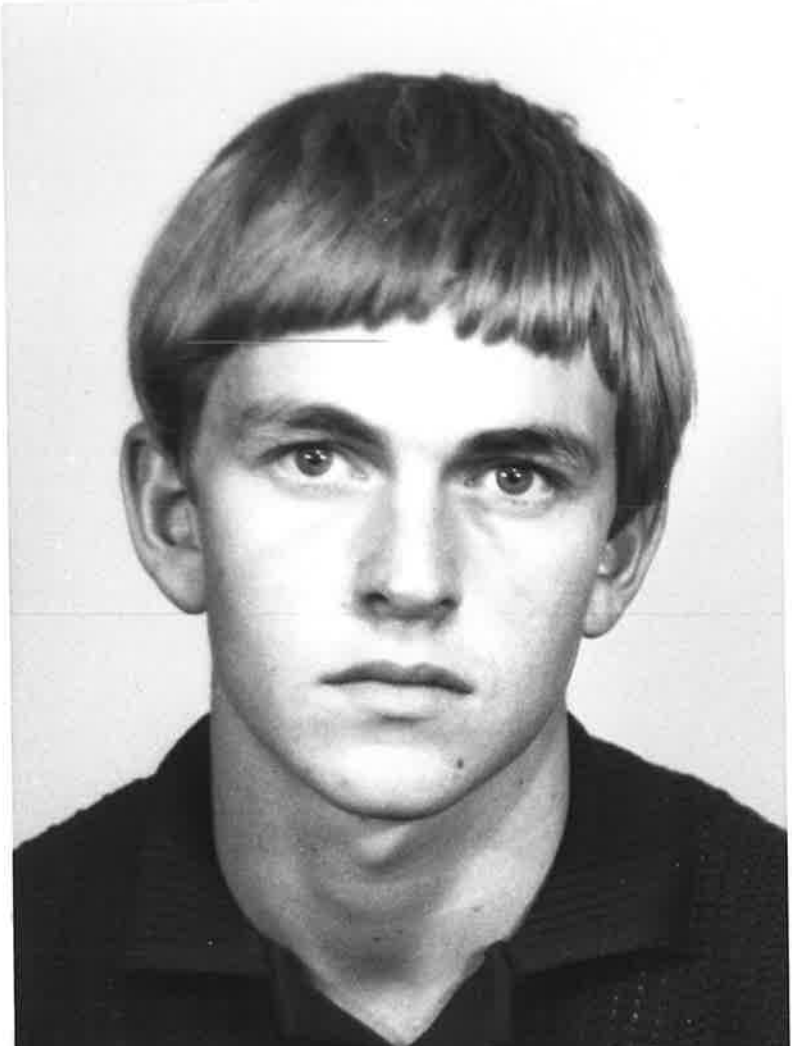
APPENDIX 2.1

Examples of the verbal stimulus material, formed from both angular and contoured lettering, used in Experiment 2.1.

HAPPY	*happy*
DELIGHTED	*delighted*
LAUGHING	*laughing*
JOYFUL	*joyful*
REJOICING	*rejoicing*
ANGRY	*angry*
SEETHING	*seething*
FUMING	*fuming*
FURIOUS	*furious*
ENRAGED	*enraged*
YAGPH	*yagph*
FAR	*far*
FOOT	*foot*
STOP	*stop*
RUN	*run*

APPENDIX 2.2

The male face, neutral with respect to expressions of happiness or anger, used in Experiment 2.1. Permission of the person concerned was obtained before proceeding.



APPENDIX 2.3

Mean ratings and standard deviations on the *Angry-Not angry* dimension, obtained using 35 faces categorized according to their ratings on the *Happy-Unhappy* dimension.

Angry-Not angry dimension	*Happy-Unhappy* dimension 1	2	3	4	5	6	7
Mean	6.47	5.49	5.18	4.66	4.31	3.79	3.78
Standard deviation	0.79	0.80	0.93	0.91	1.08	0.83	1.45
n	20	21	23	19	22	22	16

APPENDIX 2.4

The number of Os who correctly recorded 6 different stimulus words, exposed for the duration of one frame (approximately 40 msec), when no backward mask was present. One or more incorrect letters constituted an error.

	No. of Os making correct identification (N=23)		
	First exposure	Second exposure	Third exposure
Happy (angular)	23	-	-
Happy (contoured)	23	-	-
Angry (angular)	23	-	-
Angry (contoured)	23	-	-
Yagph (angular)	12	10	1
Yagph (contoured)	11	11	1

APPENDIX 2.5

Instructions and Response sheets for Experiment 2.1, including the rating scales and Questionnaires A, B, and C.

Initial instructions, Stage 1:

"This experiment is concerned with facial expression and with our ability to judge what facial expression reveals about a person. Before beginning, however, it is necessary to assess whether or not you have a dominant eye. If you are accustomed to wearing spectacles, please place them on.

A number of letters and words will be exposed on the screen and you are required to record them on the attached sheet in the spaces provided. *Do not leave any blanks.* If the letter or word is exposed too fast for you to read, you should guess what it was. You will be given 20 seconds in which to answer. Throughout the last 5 seconds of this answer period, a buzzer will sound, indicating that time is running out. When the buzzer sounds, look back at the screen and 5 seconds later the next letter or word will be shown.

First you will be shown eight single letters. Cover your left eye whilst viewing the first four exposures. Cover your right eye whilst viewing the next four exposures.

Eight words will then follow. *These must be viewed with both eyes open.*

Before you begin, please ensure that you have filled in all particulars on the top of your attached Response Sheet. During the course of the experiment, you will be required to provide these particulars several times. This is simply to assist the experimenter in the collation of data. Your identity is of no other consequence to the experimenter and your performance is in no way an indication of any specific ability.

Please do not talk in the experimental room. Occasionally instruction slides will appear on the screen. These will always be distinguished by two asterisks (**) in the top right hand corner of the slide. When the experiment is about to start, an instruction slide will appear on the screen, and a buzzer will sound for 5 seconds prior to the first exposure."

Response Sheet, Stage 1:

Letters (Left eye covered):

Exposure No. 1

Exposure No. 2

Exposure No. 3

Exposure No. 4

Letters (Right eye covered):

Exposure No. 5

Exposure No. 6

Exposure No. 7

Exposure No. 8

Words (Both eyes open)

Exposure No. 1

Exposure No. 2

Exposure No. 3

Exposure No. 4

Exposure No. 5

Exposure No. 6

Exposure No. 7

Exposure No. 8

Instructions, Stage 2:

Please provide the following information. During the course of the experiment you will be required to provide these particulars several times. This is simply to assist the experimenter in the collation of data. Your identity is of no other consequence to the experimenter and your performance is in no way an indication of any specific ability.

NAME (BLOCK LETTERS) ....

SEX .... AGE ....

I do/do not normally wear spectacles (cross out where inapplicable).

This experiment is concerned with facial expression and with our ability to judge what facial expression reveals about a person.

The attached sheet contains several pairs of antonyms i.e. words of opposite meaning to one another (e.g. good-bad). Since all the words are adjectives, each pair might be used to describe a particular aspect of an individual's personality.

Beside each of these dimensions is a 7-point scale. The figures 1 and 7 represent the two extreme meanings, whilst the figure 4 stands for the point of complete neutrality i.e. neither word used to define the dimension applies more than the other. The list below indicates the meanings attached to each of the scale values.

Strongly suggests (word on left)	1
Moderately suggests (word on left)	2
Weakly suggests (word on left)	3
Neither word applies more than the other	4
Weakly suggests (word on right)	5
Moderately suggests (word on right)	6
Strongly suggests (word on right)	7

If you understand so far, please read on. If you have any questions at this stage, please raise your hand.

You are about to be shown a photographed face. We wish you to study the expression of the face and to afterwards indicate *what you think it reveals* by using the dimensions listed on the attached sheet. Study the face carefully for the full exposure period. Do *not* attempt to write anything until the lights come on.

Indicate your opinion by placing a ring around the appropriate point on the scale. *The face must be rated on all dimensions.*

When you have done this, indicate whether the person photographed is known to you by *ticking the answer that applies*; (either Yes or No).

If, at this stage, there are any sections of these instructions which are not clear to you, please raise your hand.

The lights will now be dimmed and a buzzer will sound for 5 seconds prior to exposure of the face. Remember that you should pay close attention throughout the full exposure period.

Response sheet, Stage 2:

irreligious - religious	1	2	3	4	5	6	7
superstitious - realistic	1	2	3	4	5	6	7
not studious - studious	1	2	3	4	5	6	7
not angry - angry	1	2	3	4	5	6	7
sophisticated - naive	1	2	3	4	5	6	7
uneducated - educated	1	2	3	4	5	6	7
untidy - tidy	1	2	3	4	5	6	7
cowardly - courageous	1	2	3	4	5	6	7
unpretentious - ostentatious	1	2	3	4	5	6	7
unhappy - happy	1	2	3	4	5	6	7
verbose - concise	1	2	3	4	5	6	7
indiscreet - discreet	1	2	3	4	5	6	7

Is the person photographed known to you? YES NO

Questionnaires Stage 3:

A. Answer the following questions by ticking the appropriate response.

1. In your opinion, did the expression of the face change during the course of exposure? YES NO

2. Were you, at any time, aware of anything in the film, in addition to the person and his facial expression? YES NO

3. If you ticked "YES" in answer to question 2, please describe briefly what you thought you saw.

B. Sometimes, in addition to the face, you may have seen a word, or portion of a word. A word was definitely there. Please answer the following questions as carefully as possible.

1. Was the word identifiable? YES - NO

   The word was .... (If you have ticked 'NO', leave blank)

2. Could you clearly <u>see</u> the word YES - NO

3. If you were unable to see the entire word, could you *infer* what the word was? YES - NO

   I would infer that the word was ....

   (If you have ticked 'NO', leave blank).

4. If you could not *infer* what the word was, could you clearly *see* any of the letters? YES - NO

   The letters I saw were ....

   (If you have ticked 'NO', leave blank)

5. Although unaware of the presence of a word, did you *think* you saw letters? YES - NO

   The letters I thought I saw were ....

   (If you have ticked 'NO', leave blank)

C. The word that appeared in the film you have just seen is one of the following:

Place a figure 1 beside the word that you think was most probably the word in the film. Place a figure 2 beside the word that you consider was next most likely. Continue this process until you have ranked five of the words in the list.

concise
unpretentious
educated
not studious
realistic
sophisticated
religious
happy
cowardly
tidy
indiscreet
studious
verbose
angry
naive
superstitious
unhappy
discreet
untidy
not angry
ostentatious
irreligious
courageous
uneducated

APPENDIX 2.6

Chi-Square analyses referred to in Experiment 2.1. Frequencies in all Tables are derived from 279 Os, since one failed to complete questionnaire C correctly.

(i) The frequencies with which adjectives in questionnaire C (Stage 3) were selected, disregarding rank, as being most probably exposed during the film. The expected frequency under H_o is 58.33

	observed frequency	χ^2
uneducated	53	0.49
courageous	38	7.09
irreligious	44	3.52
ostentatious	14	33.69
not angry	62	0.23
untidy	78	6.63
discreet	45	3.05
unhappy	167	202.45
superstitious	27	16.83
naive	108	42.30
angry	108	42.30
verbose	14	33.69
studious	74	4.21
indiscreet	50	1.19
tidy	56	0.09
cowardly	40	5.76
happy	20	25.19
religious	36	8.55
sophisticated	9	41.72
realistic	84	11.30
not studious	43	4.03
uneducated	62	0.23
unpretentious	103	34.21
concise	61	0.12
TOTALS	1,396	528.87

(ii) Various distributions of Os selecting or failing to select the words, "Unhappy" and "Angry" as most probably exposed during the film. Os are classified according to:

a) *words exposed during stage 1:*

	"UNHAPPY"		"ANGRY"	
	selected	not selected	selected	not selected
Angry words	46	24	25	45
Happy words	42	28	29	41
Neutral words	39	31	30	40
No words present	40	29	24	45
χ^2 (d.f. = 3)	1.60		1.44	
P	> 0.50		> 0.50	

b) *word masked by face during Stage 2:*

	"UNHAPPY"		"ANGRY"	
	selected	not selected	selected	not selected
"Angry"	51	29	36	44
"Happy"	43	36	28	51
"Yagph"	49	31	30	50
No word present	24	16	14	26
χ^2 (d.f. = 3)	1.54		1.97	
P	> 0.50		> 0.50	

c) *type of lettering from which masked word was composed:*

	"UNHAPPY"		"ANGRY"	
	selected	not selected	selected	not selected
Angular	73	46	54	65
Contoured	70	50	40	80
No word present	24	16	14	26
χ^2 (d.f. = 2)	0.26		3.92	
P	> 0.80		> 0.10	

APPENDIX 2.7

Comparisons between ratings of the face, used in Experiment 2.1, before and during the experimental session.

(i) Ratings, by the pre-experimental group (N = 23) and the experimental group (N = 10) not exposed to verbal stimulus material at any stage, for the following dimensions:

a) *Happy-Unhappy*

	Pre-experimental group	Experimental group 28 (Table 2.3)
Judged mean	4.39	4.80
standard deviation	1.27	1.37
single sample t	1.48 (d.f.=22)	1.92 (d.f.=9)
p (two tails)	0.15	0.10

b) *Angry-Not angry*

	Pre-experimental group	Experimental group 28 (Table 2.3)
Judged mean	4.26	4.40
standard deviation	1.51	1.43
single sample t	0.83 (d.f.=22)	0.88 (d.f.=9)
p (two tails)	0.58	0.60

(ii) Means and standard deviations for pre-experimental ratings of the face, in accordance with the following dimensions, composed from adjectives making significant contributions ($\alpha = 0.05$) to analysis (i), Appendix 2.6. Departure from neutrality (4.0) has been examined by use of a single sample t test

Dimension	Predicted bias	Mean	Standard deviation	t	d.f.	p
irreligious-religious	irreligious	3.17	1.64	2.41	22	0.012 (one tail)
superstitious-realistic	realistic	4.83	1.90	1.52	11	0.077 (one tail)
not studious-studious	studious	4.67	1.37	1.68	11	0.058 (one tail)
sophisticated-naive	naive	4.74	1.66	2.14	22	0.021 (one tail)
untidy-tidy	untidy	3.30	1.64	2.04	22	0.025 (one tail)
unpretentious-ostentatious	unpretentious	3.30	1.55	2.15	22	0.020 (one tail)
verbose-concise	concise	4.39	1.70	1.10	22	0.140 (one tail)
cowardly-courageous	none	4.50	1.45	1.20	11	0.255 (two tails)

(iii) The distribution of choices from Questionnaire C, in accordance with ratings on the critical dimensions, concluding Stage 2:

a) *Unhappy*

Dimension *Happy-Unhappy*, Stage 2

		1-4	5	6	7	χ^2
Choice & rank Questionnaire C	1	9	9	28	29	19.5
	2	7	9	13	15	4.9
	3	3	3	7	5	1.4
	4	3	7	7	2	4.0
	5	1	3	5	2	2.1
	Not chosen	48	29	28	7	28.0
TOTALS		71	60	88	60	59.9

b) *Angry*

Dimension *Angry-Not angry*, Stage 2

		1-3	4	5-7	χ^2
Choice & rank Questionnaire C	1	26	5	7	19.2
	2	19	7	2	15.5
	3	9	5	5	1.4
	4	4	10	0	13.4
	5	6	1	2	4.2
	Not chosen	33	55	84	20.5
TOTALS		97	83	100	74.2

APPENDIX 2.8

Summary tables of analyses of variance reported in Chapter II, Experiment 2.1, for ratings on specified dimensions in accordance with a 7 point scale.

1. *Analyses excluding the 4 groups viewing the no-word film during Stage 2.*

(i) *Happy-Unhappy*

(a) Raw data:

Source	S.S.	d.f.	M.S.	F	p
A (emotional quality of words, Stage 1)	13.90	3	4.63	2.64	0.049
B (word in film, Stage 2)	2.51	2	1.25	<1.0	n.s.
C (structural attribute of word)	5.40	1	5.40	3.08	0.076
AxB	8.53	6	1.42	<1.0	n.s.
AxC	17.77	3	5.92	3.38	0.019
BxC	4.98	2	2.49	1.42	0.243
AxBxC	13.26	6	2.21	1.26	0.276
Within cell	378.40	216	1.75		
TOTAL	444.75	239			

(b) Transformed data:

Source	S.S.	d.f.	M.S.	F	p
A (emotional quality of words, Stage 1)	2.03	3	0.68	2.10	0.099
B (word in film, Stage 2)	0.27	2	0.13	<1.0	n.s.
C (structural attribute of word)	1.22	1	1.22	3.81	0.049
AxB	1.73	6	0.29	<1.0	n.s.
AxC	2.72	3	0.91	2.82	0.039
BxC	1.10	2	0.55	1.71	0.182
AxBxC	1.39	6	0.23	<1.0	n.s.
Within cell	69.50	216	0.32		
TOTAL	79.96	239			

(ii) *Angry-Not angry*

Source	S.S.	d.f.	M.S.	F	p
A (emotional quality of words, Stage 1)	14.83	3	4.94	1.92	0.126
B (word in film, Stage 2)	6.46	2	3.23	1.25	0.287
C (structural attribute of word)	0.60	1	0.60	<1.0	n.s.
AxB	22.64	6	3.77	1.46	0.191
AxC	11.70	3	3.90	1.51	0.211
BxC	1.23	2	0.61	<1.0	n.s.
AxBxC	19.48	6	3.25	1.26	0.277
Within Cell	557.00	216	2.58		
TOTAL	633.94	239			

2. *Analyses in which the word in the film (Stage 2) is structurally angular, and which include the 4 control groups viewing the no-word film.*

(i) *Happy-Unhappy*

Source	S.S.	d.f.	M.S.	F	p
A (emotional quality of words, Stage 1)	20.02	3	6.67	3.49	0.017
B (word in film, Stage 2)	6.52	3	2.17	1.14	0.336
AxB	17.11	9	1.90	<1.0	n.s.
Within cell	275.30	144	1.91		
TOTAL	318.95	159			

(ii) *Angry-Not angry*

Source	S.S.	d.f.	M.S.	F	p
A (emotional quality of words, Stage 1)	16.03	3	5.34	1.90	0.132
B (word in film, Stage 2)	8.23	3	2.74	<1.0	n.s.
AxB	36.73	9	4.08	1.45	0.173
Within cell	405.80	144	2.82		
TOTAL	466.79	159			

3. *Analyses in which the word in the film (Stage 2) is structurally contoured, and which include the 4 control groups viewing the no-word film.*

(i) *Happy-Unhappy*

Source	S.S.	d.f.	M.S.	F	p
A (emotional quality of words, Stage 1)	8.47	3	2.82	1.53	0.207
B (word in film, Stage 2)	8.02	3	2.67	1.45	0.229
AxB	23.61	9	2.62	1.43	0.173
Within cell	264.90	144	1.84		
TOTAL	305.00	159			

(ii) *Angry-Not angry*

Source	S.S.	d.f.	M.S.	F	p
A (emotional quality of words, Stage 1)	11.53	3	3.84	1.65	0.180
B (word in film, Stage 2)	3.88	3	1.29	<1.0	n.s.
AxB	11.38	9	1.26	<1.0	n.s.
Within cell	336.00	144	2.33		
TOTAL	362.79	159			

APPENDIX 3.1

Values of s_D expressed in degrees of visual angle, calculated from data obtained in several previous experiments. The value marked * was obtained by leaving the mean of the best fitting normal ogive free to vary (Vickers et al, 1972).

Experimenter	Comments	Value of s_D in degrees of visual angle
Henmon (1906)		
Pairs of horizontal lines, with varying absolute or relative differences in length, exposed until response made by O.	Observer H, Experiment I	0.0191
	Observer S, " "	0.1366
	Observer H, " II	0.0252
	Observer S, " "	0.0270
Garrett (1922)		
Two sections, varying in length, of a horizontal line, exposed for 6 different intervals.	4.0 sec. exposure	0.0933
	2.5 sec. exposure	0.0823
	2.0 sec. exposure	0.0707
	1.5 sec. exposure	0.0734
	1.0 sec. exposure	0.0889
	0.5 sec. exposure	0.1225
Festinger (1943)		
Pairs of vertical lines of varying lengths, exposed for 500 msec, with varying emphases in instructions. "Usual" instructions were intended to produce a compromise between accuracy and speed.	Observer, H.S., *usual* instructions	0.0594
	" " *accuracy* "	0.0492
	" " *speed* "	0.0515
	" J.B. *usual* "	0.0573
	" " *accuracy* "	0.0526
	" " *speed* "	0.0529
	" B.W. *usual* "	0.0515
	" N.P. *speed* "	0.0512*
Botwinick et al (1958) *Pairs of lines of varying lengths, exposed for 2 different intervals, to Os from 2 widely separated age groups.*	Older Os, 2.0 sec. exposure	0.1413
	" " 0.15 " "	0.3002
	Younger " 2.0 " "	0.1394
	" " 0.15 " "	0.2009
Vickers (1967)		
Pairs of vertical lines of varying lengths, exposed until response made by O.	experiment IXc	0.1035
	Mean	0.0891

APPENDIX 3.2

Inspection time λ (msec), mean overall response latency *L* (msec), and index of noise s_D (deg. visual angle), obtained for 10 Os performing simple discrimination tasks as defined in Experiments 3.1, 3.2 and 3.3. Measures of λ and s_D are derived from the standard deviation associated with the theoretical cumulative ogive with a mean of zero, best fitting individual data. The goodness of fit obtained is indicated by χ^2 and its corresponding probability.

	Experiment 3.1					*Experiment 3.2*					*Experiment 3.3*				
Observer	λ	χ^2	d.f	1-p	*L*	λ	χ^2	d.f.	1-p	*L*	s_D	χ^2	d.f.	1-p	*L*
1	73.8	11.0	16	<0.25	481.5	85.1	17.6	14	<0.90	486.2	0.27	8.1	14	<0.25	522.3
2	88.7	11.4	17	<0.25	576.5	86.6	12.0	14	<0.50	582.7	0.34	20.1	15	<0.90	719.2
3	89.9	33.4	17	>0.99	557.8	87.4	11.8	14	<0.50	486.4	0.27	8.6	14	<0.25	526.0
4	94.0	11.1	17	<0.25	646.8	94.6	1.3	15	<0.01	387.1	0.29	3.2	14	<0.01	460.5
5	95.3	8.7	17	<0.05	570.3	98.7	14.5	15	<0.75	474.9	0.34	9.2	15	<0.25	490.8
6	98.6	5.8	17	<0.01	635.7	96.2	2.8	15	<0.01	619.1	0.36	3.2	16	<0.01	717.1
7	119.3	13.0	18	<0.25	761.3	88.3	9.9	14	<0.25	720.2	0.28	10.5	15	<0.25	671.1
8	124.3	19.3	18	<0.75	759.1	89.4	15.8	14	<0.75	610.8	0.30	6.1	15	<0.02	667.7
9	143.8	18.1	18	<0.75	613.4	169.0	20.8	18	<0.75	635.0	0.27	6.2	14	<0.05	675.1
10	143.9	7.3	18	<0.02	477.6	161.8	25.6	18	<0.90	521.2	0.45	11.2	17	<0.25	505.4
Mean	107.2				608.0	105.7				552.4	0.32				595.5
S.D.	23.0				93.0	30.2				93.2	0.05				97.4

The Pearson goodness-of-fit χ^2 test (Hays, 1963)

It is appreciated that the use of χ^2 involves assumptions of independence between the response categories, a difficult assumption to make with confidence, given the nature of the experimental task which necessitates taking repeated measures from the same O. Every attempt has been made, however, to ensure that O's response on any trial was not influenced by a response on any other trial. Level of discrimination difficulty has been randomized to control against order effect and each observation may only be categorized into one of the stimulus classes. The range of stimulus classes would appear sufficiently extensive to qualify as "exhaustive", in so far as they have largely ensured that correct responses ranged from p = 0.5 to 1.0. Clearly, however, categories are not "exclusive", since error responses have been derived directly from correct responses, only half of the psychometric function being represented.

Because expected frequencies in the various categories are known, under the phi-gamma hypothesis, it was clearly not possible to determine beforehand the grouping of data necessary to give equal probability intervals, as recommended by Hays (1963, p.586 f.f.). It has therefore been necessary to combine frequencies from some extreme class intervals where expected frequencies were very small. Since, however, it is recognized that this operation interferes with the randomness of the sample, it has only been resorted to where failing to do so would result in an expected frequency of less than approximately 3. It is also acknowledged that because intervals do not contain equal expected frequencies, the χ^2 test is slightly less sensitive to departures from normality in the middle of the class interval range.

Both number of errors and number of correct responses have been used in analysis and, in order to avoid under-estimating χ^2, the contribution of each category has been considered separately, i.e. where it has been necessary to combine error categories, this has not been done for the corresponding correct-response categories.

Since one parameter ($\sigma_{(X-Y)}$) has been estimated, the mean of the underlying distribution being fixed at zero, the degrees of freedom have been reduced by one. Thus utilizing all 20 response categories, without any combinations, would result in 18 degrees of freedom.

Finally, it is recognized that, within the context of this experiment, the experimenter is required to *accept* a null hypothesis, since it is clearly the intention to demonstrated that the sample distributions of single Os are the same as the population distribution, here defined as a normal cumulative ogive. Whilst it is acknowledged that failing to reject Ho, based on a particular grouping, does not imply that a different grouping would not have resulted in the rejection of Ho, it is none-the-less argued that a low χ^2, and high probability value, does provide some evidence of possible agreement.

APPENDIX 3.3

The correlation coefficient, and corresponding probability value reflecting a relationship between stimulus exposure duration or difference, and mean response latency, for 10 Os performing simple discrimination tasks as defined in Experiments 3.1, 3.2, and 3.3.

	Experiment 3.1		*Experiment 3.2*		*Experiment 3.3*	
Observer	Pearson r	p(two tails)	Pearson r	p(two tails)	Pearson r	p(one tail)
1	-0.93	<0.001	-0.88	<0.001	-0.95	<0.001
2	-0.71	0.002	-0.84	0.003	-0.99	<0.001
3	-0.96	<0.001	-0.87	0.001	-0.95	<0.001
4	-0.76	0.010	-0.77	0.010	-0.83	0.002
5	-0.91	<0.001	-0.89	<0.001	-0.94	<0.001
6	-0.92	<0.001	-0.93	<0.001	-0.97	<0.001
7	-0.89	<0.001	-0.92	<0.001	-0.92	<0.001
8	-0.86	0.002	-0.83	0.003	-0.98	<0.001
9	-0.50	0.135	-0.51	0.127	-0.88	<0.001
10	-0.34	0.343	-0.70	0.022	-0.90	<0.001

APPENDIX 3.4

Comparison between latencies for correct and incorrect responses for 10 Os in Experiments 3.1, 3.2 and 3.3, for different stimulus exposure durations in Experiments 3.1 and 3.2, and for stimulus differences in Experiment 3.3. In all cases, the prediction is that latency for errors will exceed that for correct responses.

(i) *Individual data:*

Mean response latency (msec)

	Experiment 3.1		*Experiment 3.2*		*Experiment 3.3*	
Observer	correct	error	correct	error	correct	error
1	471.6	531.9	479.6	574.0	511.3	592.6
2	565.4	618.8	575.2	649.1	687.3	854.1
3	527.1	670.2	461.5	694.1	506.0	658.0
4	619.7	748.2	385.4	398.7	457.2	481.7
5	555.7	623.6	469.2	508.8	483.3	520.6
6	627.8	664.1	600.4	731.4	687.5	842.4
7	719.4	880.1	679.9	1027.2	652.0	781.3
8	736.4	818.1	592.6	734.6	644.2	789.1
9	606.2	629.3	626.1	661.6	667.9	722.5
10	485.3	457.6	508.9	556.3	492.6	548.5
Mean	591.5	664.2	537.9	653.6	578.9	679.6
S.D.	84.5	119.4	86.2	159.9	90.8	130.7

(ii) *Data pooled across stimulus exposure duration: Experiment 3.1*

Mean response latency (msec)

Exposure (msec)	Correct	Error	Total
8	643.9	663.4	653.4
16	635.5	675.3	653.5
24	633.5	682.6	653.2
32	606.8	657.4	621.4
40	597.4	683.3	619.7
48	589.9	704.4	610.5
56	580.4	654.2	588.8
64	564.1	599.0	566.9
72	553.8	565.5	554.5
80	553.9	651.7	558.0
Mean	595.9	653.7	608.0
S.D.	32.0	39.5	37.3

(iii) *Data pooled across stimulus exposure duration: Experiment 3.2*

Mean response latency (msec)

Exposure (msec)	Correct	Error	Total
12	642.9	633.0	638.2
24	604.0	661.2	624.6
36	583.2	654.8	602.6
48	546.4	647.1	556.8
60	527.0	638.9	538.1
72	510.3	619.3	516.3
84	511.4	659.6	516.0
96	506.2	684.7	509.4
108	507.2	527.3	508.2
120	512.2	384.3	510.4
Mean	545.2	611.0	552.1
S.D.	46.0	85.6	48.5

(iv) *Data pooled across stimulus difference: Experiment 3.3*

Difference between line lengths (mm)	Mean response latency (msec) Correct	Error	Total
0.3	661.8	669.1	665.5
1.2	663.9	665.5	664.5
2.1	629.2	697.8	649.1
3.0	593.2	731.7	612.6
3.9	595.1	673.2	605.2
4.8	574.3	640.6	577.9
5.7	559.7	733.1	568.1
6.6	545.3	592.8	548.8
7.5	534.3	579.1	535.2
8.4	530.5	583.9	531.3
Mean	588.7	656.7	595.6
S.D.	46.9	54.2	49.2

APPENDIX 3.5

ANALYSIS OF VARIANCE SUMMARY TABLES

(i) *Mean response latencies (msec), Experiment 3.1*

Source	S.S.	d.f.	M.S.	Test	F	p
A (stimulus exposure duration)	695,842	9	77,316	A/AxC	10.88	<0.001
B (position of run in session)	223,087	4	55,772	B/BxC	4.81	0.004
C (observers)	4,328,190	9	480,910			
AxB	85,740	36	2,382	AxB/AxBxC	<1.0	n.s.
AxC	575,758	81	7,108			
BxC	417,086	36	11,586			
AxBxC	1,036,450	324	3,199			
TOTAL	7,362,153	499				

(ii) *Mean response latencies (msec), Experiment 3.2*

Source	S.S.	d.f.	M.S.	Test	F	p
A (stimulus exposure duration)	1,178,040	9	130,893	A/AxC	7.69	<0.01
B (position of run in session)	25,240	4	6,310	B/BxC	<1.0	n.s
C (observers)	4,339,250	9	482,138			
AxB	44,475	36	1,235	(AxB)/(AxBxC)	<1.0	n.s
AxC	1,379,380	81	17,029			
BxC	273,665	36	7,602			
AxBxC	648,061	324	2,000			
TOTAL	7,888,111	499				

(iii) *Mean response latencies (msec), Experiment 3.3*

Source	S.S.	d.f.	M.S.	Test	F	p
A (stimulus difference)	1,210,390	9	134,488	A/AxC	21.84	<0.001
B (position of run in session)	38,266	4	9,567	B/BxC	1.13	0.358
C (observers)	4,744,620	9	527,180			
AxB	71,085	36	1,975	(AxB)/(AxBxC)	<1.0	n.s.
AxC	498,681	81	6,157			
BxC	305,849	36	8,496			
AxBxC	689,402	324	2,128			
TOTAL	7,558,293	499				

APPENDIX 3.6

Estimates of s_D (deg visual angle) based on performance in two successive runs within Experiment 3.3. For these estimates therefore, the probability of a correct response, at any single stimulus difference, is derived from only 20 trials.

Observer	Runs 1-2	Runs 2-3	Runs 4-5
1	0.27	0.27	0.28
2	0.37	0.28	0.31
3	0.27	0.28	0.27
4	0.31	0.30	0.27
5	0.32	0.36	0.34
6	0.39	0.29	0.33
7	0.27	0.30	0.28
8	0.28	0.30	0.31
9	0.26	0.27	0.29
10	0.37	0.40	0.44
Mean	0.31	0.31	0.31
S.D.	0.05	0.04	0.05

APPENDIX 4.1

INSTRUCTIONS AND SUMMARY DATA FOR THE PILOT STUDY REPORTED IN CHAPTER IV.

(i) *Instructions to Os*, regarding the expected effects of the colour - coded capsules that they were required to swallow.

green and white/red and white capsules:

"The civil airlines are concerned about the effects of readily obtained drugs upon the perceptual sensitivity of their pilots. Because regulations prevent pilots from drinking alcohol for 24 hours prior to take-off, some pilots are believed to take tranquillizer drugs before going to bed, in order to ensure relaxation after a fatiguing flight. The next morning, because of mild after-effects, they may use a stimulant drug to ensure that they are wide-awake and functioning efficiently.

I am investigating the possible effects of these drugs upon perceptual sensitivity, using a simple signal detection task. This capsule contains a low dosage of *amylobarbitone/dexamphetamine sulphate*, which is used as *a sedative and minor tranquillizer/an antidepressant stimulant*, acting on the central nervous system.

It takes 20 minutes to obtain full effects, which will include *a reduction in excitement or anxiety and a feeling of drowsiness/a feeling of excitement, increased pulse rate, some hand-tremor, and a dry mouth.*

It will *depress/heighten* your perceptual sensitivity, so that signals will be *less/more* easily detected.

As with any drug the effects will wear off within a few hours as the drug is changed to an inactive substance by the metabolic processes of the body."

green and white capsules:

"I am investigating the possible effects of a recently developed drug upon perceptual sensitivity, using a simple signal detection task. This capsule contains a low dosage of a drug which, for obvious reasons, I cannot tell you anything about until the conclusion of the experiment.

It takes 20 minutes to obtain full effects and will change your perceptual sensitivity, but, as with any drug, this will wear off within a few hours as the drug is changed to an inactive substance by the metabolic processes of the body."

(ii) *Analysis of variance summary tables for the pilot study reported in Chapter IV.*

(a) *Sensitivity:*

Source	S.S.	d.f.	M.S.	F	p
Between groups (placebo treatment)	0.06	2	0.03	<1.0	n.s.
Within groups	1.95	27	0.07		
TOTALS	2.01	29			

(b) *Response bias:*

Source	S.S.	d.f.	M.S.	F	p
Between groups (placebo treatment)	0.48	2	0.24	5.51	0.010
Within groups	1.18	27	0.04		
TOTALS	1.66	29			

(c) *Pulse rate*

Source	S.S.	d.f.	M.S.	F	p
Between subjects	10,153.50	39			
A (placebo treatment)	5,410.50	3	1,803.50	13.69	<0.001
Subjects within groups	4,743.00	36	131.75		
Within subjects	2,724.00	40			
B (measures 1 and 2)	858.05	1	858.05	18.78	<0.001
AxB	221.35	3	73.78	1.62	0.202
B x subjects within groups	1,644.60	36	45.68		
TOTALS	12,877.50	79			

APPENDIX 4.2

Estimates of s_D (degrees of visual angle) together with the goodness of fit and associated probability, as indicated by the Pearson χ^2 test, from 20 Os each taking part in two sessions during Experiment 4.1.

	Session 1				*Session 2*			
Observer	s_D	χ^2	d.f.	1-p	s_D	χ^2	d.f.	1-p
1	0.28	11.64	14	<0.50	0.28	4.20	15	<0.01
2	0.33	1.56	15	<0.01	0.29	3.36	15	<0.01
3	0.21	11.50	13	<0.50	0.21	6.22	13	<0.10
4	0.34	10.88	15	<0.25	0.21	10.33	13	<0.50
5	0.41	8.49	17	<0.05	0.27	11.41	14	<0.50
6	0.42	13.96	17	<0.50	0.36	3.68	16	<0.01
7	0.31	5.95	15	<0.02	0.27	9.92	14	<0.25
8	0.42	15.31	17	<0.50	0.27	6.92	15	<0.05
9	0.55	5.57	18	<0.01	0.42	12.60	17	<0.25
10	0.39	10.52	16	<0.25	0.28	5.41	15	<0.02
11	0.27	11.26	14	<0.50	0.27	9.24	14	<0.25
12	0.36	8.51	16	<0.10	0.27	10.79	15	<0.25
13	0.35	10.49	16	<0.25	0.37	9.65	17	<0.10
14	0.42	8.33	17	<0.05	0.28	2.25	15	<0.01
15	0.56	11.62	18	<0.25	0.32	7.45	16	<0.05
16	0.29	2.61	14	<0.01	0.27	6.12	15	<0.02
17	0.56	6.05	18	<0.01	0.35	9.97	16	<0.25
18	0.27	4.20	14	<0.01	0.27	16.01	15	<0.75
19	0.43	8.11	17	<0.05	0.29	5.68	15	<0.02
20	0.37	7.85	16	<0.05	0.28	6.58	15	<0.05

APPENDIX 4.3

ANALYSIS OF VARIANCE SUMMARY TABLES FOR EXPERIMENT 4.1

(i) the index of noise s_D (degrees of visual angle) represents the dependent variable. Each group is observed in both sessions (Factor C) but is assigned to only one combination of factors A (placebo treatment) and B (sex).

Source	S.S.	d.f.	M.S.	F	p
Between subjects	0.18110	19			
A (placebo treatment: Exp. v. control)	0.00178	1	0.00178	<1.0	n.s.
B (sex)	0.02332	1	0.02332	2.40	0.138
A x B	0.00034	1	0.00034	<1.0	n.s.
Subj.w.groups (error (between))	0.15566	16	0.00972		
Within subjects	0.12862	20			
C (session 1 and 2)	0.07516	1	0.07516	35.47	<0.001
A x C	0.00001	1	0.0001	<1.0	n.s.
B x C	0.01946	1	0.01946	9.18	0.008
A x B x C	0.00008	1	0.00008	<1.0	n.s.
C x sub.w.groups (error (within))	0.03390	16	0.00212		
TOTALS	0.30972	39			

(ii) Heart Rate (beats per minute) represents the dependent variable. Each group is observed in both sessions (factor C), with three HR measures in each (Factor D); each group is assigned to only one combination of factors A (placebo treatment) and B (sex).

Source	S.S.	d.f.	M.S.	F	p
Between subjects	16,381.62	19			
A (placebo treatment; exp. v. control)	95.41	1	95.41	<1.0	n.s.
B (sex)	4,048.40	1	4,048.40	5.49	0.031
A x B	429.41	1	429.41	<1.0	n.s.
Subj.w.groups	11,808.40	16	738.03		
Within subjects	9,260.20	100			
C (session 1 & 2)	407.01	1	407.01	2.18	0.148
A x C	210.67	1	210.67	1.18	0.294
B x C	414.41	1	414.41	2.32	0.144
A x B x C	1,209.70	1	1,209.70	6.77	0.018
C x subj.w.groups	2,857.74	16	178.61		
D (HR measure 1,2,3)	3,002.20	2	1,501.10	107.65	<0.001
A x D	26.82	2	13.41	<1.0	n.s.
B x D	89.72	2	44.86	3.22	0.052
A x B x D	3.72	2	1.86	<1.0	n.s.
D x subj.w.groups	446.20	32	13.94		
C x D	7.82	2	3.91	<1.0	n.s.
A x C x D	25.55	2	12.78	<1.0	n.s.
B x C x D	27.72	2	13.86	<1.0	n.s.
A x B x C x D	40.85	2	20.43	1.33	0.278
C x D x sub.w.groups	490.07	32	15.31		
TOTALS	25,641.80	119			

(iii) Mean overall latency *L* (msec) represents the dependent variable. Each group is observed in both sessions (Factor C) but is assigned to only one combination of factors A (placebo treatment) and B (sex).

Source	S.S.	d.f.	M.S.	F	p
Between Subjects	277,953,898	19			
A (placebo treatment; exp. v. control)	546,391	1	546,391	<1.0	n.s.
B (sex)	134,212	1	134,212	<1.0	n.s.
A x B	67,815	1	67,815	<1.0	n.s.
Subj.w.groups	277,205,480	16	17,325,342		
Within subjects	68,600,268	20			
C (session 1 & 2)	5,318,060	1	5,318,060	<1.36	0.260
A x C	2,512	1	2,512	<1.0	n.s.
B x C	277,056	1	277,056	<1.0	n.s.
A x B x C	322,382	1	322,382	<1.0	n.s.
C x subj.w.groups	62,680,258	16	3,917,516		
TOTALS	346,554,166	39			

APPENDIX 4.4

TABLE OF MEAN HEART RATE (b.p.m.) FOR EXPERIMENT 4.1

Session	HR measure	Experimental Group Male	Experimental Group Female	Experimental Group TOTALS	Control Group Male	Control Group Female	Control Group TOTALS	*Overall* Male	*Overall* Female	*Overall* TOTALS
1	1	78.6	107.8	*93.2*	88.4	94.8	*91.6*	83.5	101.3	*92.5*
	2	71.6	96.2	*83.9*	80.2	85.2	*82.7*	75.9	90.7	*83.3*
	3	68.8	91.4	*80.1*	78.2	82.4	*80.3*	73.5	86.9	*80.2*
TOTALS		*73.0*	*98.5*	*85.7*	*82.3*	*87.5*	*84.9*	*77.6*	*93.0*	*85.3*
2	1	84.0	89.6	*86.8*	82.0	97.8	*89.9*	83.0	93.7	*88.3*
	2	75.0	78.8	*76.9*	80.4	86.8	*83.6*	77.7	82.8	*80.3*
	3	71.2	77.8	*74.5*	73.4	83.6	*78.5*	72.3	80.7	*76.5*
TOTALS		*76.7*	*82.1*	*79.4*	*78.6*	*89.4*	*84.0*	*77.7*	*85.7*	*81.7*
Overall	1	81.3	98.7	*90.0*	85.2	96.3	*90.7*	83.3	97.5	*90.4*
	2	73.3	87.5	*80.4*	80.3	86.0	*83.2*	76.8	86.8	*81.8*
	3	70.0	84.6	*77.3*	75.8	83.0	*79.4*	72.9	83.8	*78.4*
TOTALS		*74.9*	*90.3*	*82.6*	*80.5*	*88.4*	*84.4*	*77.7*	*89.4*	*83.5*

APPENDIX 4.5

ANALYSIS OF VARIANCE SUMMARY TABLES FOR EXPERIMENT 4.2

(i) The index of noise s_D (degrees of visual angle) represents the dependent variable. Each group is observed in both Sessions (Factor C) but is assigned to only one combination of factors (A) (shock) and (B) (sex).

Source	S.S.	d.f.	M.S.	F	p
Between subjects	1.6012	19			
A (shock treatment; exp.v control)	0.6468	1	0.6468	11.77	0.004
B (sex)	0.0618	1	0.0618	1.12	0.306
A x B	0.0130	1	0.0130	<1.0	n.s.
Subj.w.groups (error (between))	0.8796	16	0.0550		
Within subjects	0.3386	20			
C (Session 1 & 2)	0.0138	1	0.0138	1.60	0.222
A x C	0.1556	1	0.1556	18.12	0.001
B x C	0.0008	1	0.0008	<1.0	n.s.
A x B x C	0.0310	1	0.0310	3.61	0.073
C x subj.w.groups (error (within))	0.1374	16	0.0086		
TOTALS	1.9398	39			

(ii) Heart-Rate (beats per minute) represents the dependent variable. Each group is observed in both sessions (Factor C), with 3 HR measures in each (Factor D); each group is assigned to only one combination of factors A (shock) and B (sex).

Source	S.S.	d.f.	M.S.	F	p
Between subjects	18,635,92	19			
A (shock treatment; exp. v. control)	69.01	1	69.01	<1.0	n.s.
B (sex)	1,883.00	1	1,833.00	1.76	0.201
A x B	49.41	1	49.41	<1.0	n.s.
Subj.w.groups	16,684.50	16	1,042.78		
Within subjects	7,843.16	100			
C (session 1 & 2)	143.01	1	143.01	<1.0	n.s.
A x C	385.21	1	385.21	1.70	0.209
B x C	110.21	1	110.21	<1.0	n.s.
A x B x C	7.01	1	7.01	<1.0	n.s.
C x sub.w.groups	3,615.04	16	225.94		
D (HR measure 1,2,3)	1,399.64	2	699.82	18.28	<0.001
A x D	259.62	2	129.81	3.39	0.045
B x D	76.32	2	38.16	<1.0	n.s.
A x B x D	45.02	2	22.51	<1.0	n.s.
D x subj.w.groups	1,225.07	32	38.28		
C x D	43,12	2	21.56	1.50	0.237
A x C x D	48.62	2	24.31	1.69	0.199
B x C x D	2.72	2	1.36	<1.0	n.s.
A x B x C x D	21.22	2	10.61	<1.0	n.s.
C x D x sub.w.groups	461.33	32	14.42		
TOTALS	26,479.08	119			

(iii) Mean overall latency *L* (msec) represents the dependent variable. Each group is observed in both Sessions (Factor C) but is assigned to only one combination of factors A (shock) and B (sex)

Source	S.S.	d.f.	M.S.	F	p
Between subjects	441,984.6	19			
A (shock treatment; exp. v. control)	1,416.1	1	1,416.1	<1.0	n.s.
B (sex)	2,102.5	1	2,102.5	<1.0	n.s.
A x B	16,484.0	1	16,484.0	<1.0	n.s.
Subj.w.groups	421,982.0	16	26,373.9		
Within subjects	101,949.7	20			
C (Session 1 & 2)	29,921.0	1	29,921.0	10.82	0.005
A x C	7,075.6	1	7,075.6	2.56	0.126
B x C	19,872.0	1	19,872.0	7.19	0.016
A x B x C	828.1	1	828.1	<1.0	n.s.
C x subj.w.groups	44,253.0	16	2,765.8		
TOTALS	543,934.3	39			

APPENDIX 4.6

Mean latencies (msec) for both correct and error responses registered by 2 atypical Os for 10 different discrimination levels during both sessions of Experiment 4.2.

Observer	stimulus difference (m.m.)	session 1			session 2		
		correct	error	overall	correct	error	overall
	0.3	584	591	587	559	568	564
	1.2	544	608	577	530	573	552
	2.1	562	588	575	568	590	581
	3.0	549	649	597	590	562	582
	3.9	545	532	541	577	569	574
X	4.8	594	615	600	567	557	563
	5.7	591	601	592	620	556	594
	6.6	574	624	586	590	606	595
	7.5	563	627	578	569	600	579
	8.4	586	660	598	548	557	550
	TOTAL	571	608	583	573	574	573
	0.3	738	798	766	849	863	858
	1.2	768	705	743	846	850	848
	2.1	749	698	734	840	801	818
	3.0	667	757	693	822	841	827
	3.9	703	733	713	836	819	830
Y	4.8	688	718	696	824	752	807
	5.7	706	728	710	841	847	843
	6.6	691	806	705	839	843	840
	7.5	679	879	703	868	835	862
	8.4	696	771	712	810	881	819
	TOTAL	706	750	718	836	833	835

APPENDIX 5.1

Matrix of correlation coefficients found between various personality measures obtained from 40 Os during Experiment 5.1. The Pearson r has been used for all comparisons except those involving I.Q. where the Spearman rank correlation coefficient is more appropriately applied.

		Cattell (16 P.F.)					Eysenck (E.P.I.)			ACER
		Q4	Anxiety	Extra version	Neuro ticism	M.D.	Extra version	Neuro ticism	Lie	I.Q.
Taylor M.A.S.		+0.71***	+0.74***	-0.51***	+0.79***	-0.49***	-0.22	+0.83***	+0.14	-0.11
16 P.F.	Q4		+0.85***	-0.44***	+0.77***	-0.61***	-0.08	+0.65***	+0.12	-0.03
	Anxiety			-0.58***	+0.89***	-0.58***	-0.21	+0.65***	+0.01	-0.05
	Extraversion				-0.73***	+0.28*	+0.55**	-0.34**	-0.27*	+0.04
	Neuroticism					-0.52***	-0.47***	+0.69***	+0.11	-0.09
	M.D.						+0.08	-0.50***	+0.12	-0.09
E.P.I.	Extraversion							-0.25	-0.11	+0.07
	Neuroticism								+0.09	-0.20
	Lie									-0.11

***$p < 0.01$ (two tails)
**$p < 0.05$ (two tails)
*$p < 0.10$ (two tails)

APPENDIX 5.2

Summaries of analysis of variance of inspection time λ (in msec), obtained from 40 Os categorized in accordance with three different personality dimensions.

(i) *scores on the Taylor M.A.S.*

Source	S.S.	d.f.	M.S.	F	p
Between (degree of anxiety)	7,081.13	3	2,360.38	6.81	0.001
Linear	98.0	1	98.0	<1.0	n.s.
Quadratic	6,760.0	1	6,760.0	19.50	<0.001
Other trends	223.13	1	223.13	<1.0	n.s.
Error	12,478.80	36	346.63		
TOTALS	19,560.0	39			

(ii) *Extraversion (E.P.I.)*

Source	S.S.	d.f.	M.S.	F	p
Between (degree of extraversion)	2,722.94	3	907.65	1.94	0.139
Linear	0.0	1	-	-	n.s.
Quadratic	2,722.50	1	2,722.50	5.82	0.020
Other trends	0.44	1	0.44	<1.0	n.s.
Error	16,837.0	36	467.69		
TOTALS	19,560.0	39			

(iii) *Neuroticism (E.P.I.)*

Source	S.S.	d.f.	M.S.	F	p
Between (degree of neuroticism)	4,090.13	3	1,363.38	3.17	0.035
Linear	392.0	1	392.0	<1.0	n.s.
Quadratic	3,385.60	1	3,385.60	7.88	0.008
Other trends	312.53	1	312.53	<1.0	n.s.
Error	15,469.80	36	429.72		
TOTALS	19,560.0	39			

APPENDIX 5.3

Summaries of analysis of variance of noise s_D *(in degress of visual angle)*, obtained from 40 Os categorized in accordance with two different personality dimensions.

(i) *Scores on the Taylor M.A.S.*

Source	S.S.	d.f.	M.S.	F	p
Between (deg. of anxiety)	0.0028	3	0.0010	<1.0	n.s.
Linear	0.0001	1	0.0001	<1.0	n.s.
Quadratic	0.0022	1	0.0022	<1.0	n.s.
Other trends	0.0005	1	0.0005	<1.0	n.s.
Error	0.1290	36	0.0036		
TOTALS	0.1318	39			

(ii) *Extraversion (E.P.I.)*

Source	S.S.	d.f.	M.S.	F	p
Between (deg. of extraversion)	0.0008	3	0.0002	<1.0	n.s.
Linear	0.0001	1	0.0001	<1.0	n.s.
Quadratic	0.0002	1	0.0002	<1.0	n.s.
Other trends	0.0005	1	0.0005	<1.0	n.s.
Error	0.1310	36	0.0036		
TOTALS	0.1318	39			

APPENDIX 5.4

Summaries of analysis of variance of immediate memory δ(in degrees of visual angle), obtained from 40 Os categorized in accordance with two different personality dimensions.

(i) *Scores on the Taylor M.A.S.*

Source	S.S.	d.f.	M.S.	F	p
Between (deg. of anxiety)	0.0101	3	0.0034	<1.0	n.s.
Error	0.2640	36	0.0073		
TOTALS	0.2741	39			

(ii) *Extraversion (E.P.I.)*

Source	S.S.	d.f.	M.S.	F	p
Between (deg. of extraversion)	0.0187	3	0.0063	<1.0	n.s.
Linear	0.0176	1	0.0176	2.48	0.120
Other	0.0011	2	0.0006	<1.0	n.s.
Error	0.2554	36	0.0071		
TOTALS	0.2741	39			

APPENDIX 5.5

Summary table for analysis of variance of mean overall latency L (in msec), obtained from 40 Os, categorized in accordance with scores on the Taylor M.A.S., during sessions concerned with the indices λ, s_D and d, during Experiment 5.1

Source	S.S.	d.f.	M.S.	F	p
Between Observers	1,021,162	39			
A (degree of anxiety)	19,246	3	6,416	<1.0	n.s.
error (between)	1,001,916	36	27,831		
Within Observers	616,753	80			
B (sessions)	207,358	2	103,679	19.54	<0.001
A x B	27,400	6	4,567	<1.0	n.s.
error (within)	381,995	72	5,306		
TOTALS	1,637,915	119			

APPENDIX 6.1

Summary tables for analyses of variance

(a) the latency for the emergence of the initial percept (msec) and

(b) mean percept duration (msec) obtained from 40 Os, categorized in accordance with scores on two different personality dimensions during Experiment 6.1.

(a) *Latency for the emergence of the initial percept*

(i) *Scores on the Taylor M.A.S.*

Source	S.S.	d.f.	M.S.	F	p
Between (degree of anxiety)	856,368	3	285,456	<1.0	n.s.
Error	13,789,600	36	385,045		
TOTALS	14,645,968	39			

(ii) *Extraversion (E.P.I.)*

Source	S.S.	d.f.	M.S.	F	p
Between (degree of extraversion)	137,760	3	45,920	<1.0	n.s.
Error	14,508,200	36	403,007		
TOTALS	14,645,960	39			

(b) *Mean percept duration*

(i) *Scores on the Taylor M.A.S.*

Source	S.S.	d.f.	M.S.	F	p
Between (degree of anxiety)	7,727,230	3	2,575,750	<1.0	n.s.
Error	100,114,000	36	2,780,930		
TOTALS	107,841,230	39			

(ii) *Extraversion (E.P.I.)*

Source	S.S.	d.f.	M.S.	F	p
Between (degree of extraversion)	1,262,590	3	420,864	<1.0	n.s.
Error	106,578,200	36	2,960,510		
TOTALS	107,840,790	39			

APPENDIX 6.2

Matrix of correlation coefficients (Pearson r) found between various behavioural descriptors: estimates for 22 Os during Experiments 5.2 and 6.1.

	Perceptual Alternation Measures		
	initial percept duration	mean percept duration	S.D.
s_D	-0.27	+0.05	-0.01
$L_{(s_D)}$	+0.28	+0.15	+0.19
$b_{y.x}$ for $Lc_{(s_D)}$	-0.43**	-0.41*	-0.46**
L (opt)	+0.30	+0.25	+0.27
L (opt) $\div \lambda$	+0.33	+0.37*	+0.40*
No. of errors	+0.23	+0.08	-0.12
h	-0.24	-0.12	+0.05
Initial percept duration		+0.57**	+0.58***
Mean percept duration			+0.95***

***$p < 0.01$ (two tails)
**$p < 0.05$ (two tails)
*$p < 0.10$ (two tails)

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