An experimental investigation of some aspects of sensory discrimination

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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.

ABSTRACT

The point of departure for this study was the suggestion that the method of constant stimulus differences with successive presentation of stimuli, provides a paradigm situation for the study of short term retention of non verbal stimulus material. Past work in this field was critically reviewed and it was concluded that studies of the psychophysical time error throw little light on the problem of short term storage because of the conceptual confusion surrounding the design and interpretation of such studies.

Two series of experiments were designed and carried out, one series with the aim of clarifying the role of the interstimulus interval variable in the method of constant stimulus differences and the other with the aim of explaining the relationship between magnitude estimation and category rating scales. In the analysis of the results of these experiments, particular attention was directed towards determining the relative discriminability (response uncertainty) of the individual members of the sets of stimuli used. In all of the experiments evidence was found of an underlying lawful relationship between position of the stimulus in the stimulus array and response uncertainty; this relationship had the

form of an asymmetrical inverted U. On the basis of this evidence it was inferred that performance in sensory discrimination tasks must be mediated by some form of internalised representation, model or schema of the stimulus array.

An attempt was made to elucidate the properties of the postulated model or schema and to ascertain its role in determining performance in sensory discrimination tasks. By taking into consideration the properties of the model or schema and the nature of the restrictions imposed upon S, it was possible to advance explanations, for which empirical support was obtained, to account for central tendency effects in judgement, the time error, the order effect, the relationship between category rating scales and magnitude estimation scales and the role of anchor stimuli. No evidence could be obtained for an explanation of the phenomenon of psychophysical hysteresis suggested by a consideration of the properties of the model. An explanation to account for performance in choice reaction time tasks based on a consideration of the properties of the model was outlined and, in an additional experiment, evidence consistent with this explanation was obtained.

An attempt was made to integrate the empirical findings from the study and the theoretical conclusions which they seemed to justify, with other current views. It was suggested that models or schema of the type postulated must mediate other types of more complex performance involving information extraction and storage, and that quantification of the properties of such models or schema might lead to a better understanding of these situations.

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I.D.J.

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CHAPTER I

NON VERBAL SHORT TERM MEMORY

Over the last decade or so the topic of immediate or short-term memory has been one of the most active areas of investigation within the field of experimental psychology. It is, nevertheless, true that the very large bulk of studies in this area utilise verbal stimulus material which is often highly over-learned or embedded in existing associational structures before the commencement of the experiments. Variables of this kind undoubtedly affect the outcome of the experiments and at present their operation is not fully understood. There is, therefore, reason for caution in generalising, from studies employing verbal stimulus material, to the question of short-term memory in general.

It would accordingly seem desirable to extend the range of stimulus material utilised in immediate memory studies and, in particular, to gather data concerning short term storage of non-verbal stimulus material. It might be expected that studies of this kind would not only extend the range of specific findings about short-term storage but, since the effects peculiarly associated with verbal stimuli would be eliminated, it seems plausible that the results of studies of this kind might be less equivocally interpreted and provide findings of greater generality.

In addition to the importance of studies of this kind in adding to the general understanding of short-term storage, it can be argued that they might throw light on some other problems, for example, the problems of habituation and arousal, and of vigilance.

The phenomenon of the arousal or orientation response and its habituation is one to which contemporary theorists (e.g. Berlyne, 1960) attach a great deal of psychological significance but the problem of information storage underlying this phenomenon has received relatively little attention. In general the arousal or orientation response occurs as a result of stimulus inputs which are, to some extent, discrepant from previous ones. This implies that at any one time an organism must be storing large amounts of information concerning recent patterns of stimulation; the maintenance and adjustment of this store appears to represent a problem about which we have, at present, very little specific information.

The weight of present thinking concerning the question of performance decrement in vigilance or watch keeping tasks seems to favour a number of inter-related causal factors rather than one unitary explanation (Buckner & McGrath, 1963). One factor which does not seem to have been considered is that of short-term storage. It has been demonstrated (Gundy, 1964) that the efficiency of signal detection is a function of the amount of information that S has about the characteristics of the signal. If such information were subject to loss in storage this might be expected to lead to a performance decrement; if, in addition, the original stimulus information was maintained or reconfirmed by a correct detection, the conditions for an even more drastic decline in performance would be set up, since increasing time on task would hinder the detection of signals, which in turn would prevent the maintenance of the information necessary to detect more signals and so on. This interpretation is speculative but nevertheless consistent with some of the findings in this area. However, it serves to illustrate the point that an understanding of short-term storage of non-verbal material might reasonably be expected to have very wide implications.

An ideal paradigm situation for the study of short-term storage of non-verbal stimuli seems to be provided by the psychophysical method of constant stimulus differences with successive stimulus presentation. In this method one stimulus is presented and then, after a fixed inter-stimulus interval (ISI), a second is presented for comparative judgement. The relevance of findings from this area to an understanding of short-term storage in general has been acknowledged by such recent writers as Peterson (1963) and Posner (1963). However, the most detailed consideration of this area as related to the general question of storage or memory is undoubtedly due to the Gestalt theorists (e.g. Koffka, 1935).

Since the views of the Gestalt theorists have so influenced thinking and research in this area they are worthy of some consideration. The Gestalt view is that all stimuli are centrally represented by stimulus traces spatially distributed in the brain. These traces persist beyond the actual duration of the stimulus and are subject to autochthonous processes such as assimilation, concentration, sinking, and so on. The operation of these autochthonous processes provides a purported explanation of the observed behaviour.

In the case of data concerning loudness judgements from the method of constant stimulus differences, it had been noted by Kohler (1923) that as ISI increased, the proportion of "louder" judgements increased. This result was attributed to a sinking or decay of the trace of the first stimulus. An alternative formulation advanced by Lauenstein attributed the effect to an assimilation of the trace of the first stimulus to the level representing the ISI. Subsequently a great deal of research was directed towards substantiating or choosing between these two theories although reviewers have all subsequently expressed dissatisfaction with both (e.g. Guilford, 1954, Koester, 1945, Osgood, 1953, Woodworth & Schlosberg, 1955).

A major weakness in the use of the notion of the decay or sinking of the stimulus trace has been the ambiguity of these terms. There has been a failure to make explicit whether these terms mean a loss of information from, or degeneration of the trace, or a systematic change towards some lower value, or attenuation of the trace. What is already known about memory processes would lead us to expect degeneration of the trace, but there is no prior reason to expect attenuation.

Although the Gestalt theorists were the first to emphasize the relevance of findings from the method of constant stimulus differences to an understanding of memory processes, it is clear in retrospect that their theoretical formulations did not adequately conceptualise the situation. This is one reason why many of the previous studies conceived within this conceptual framework and designed to illustrate memory functions are of limited value. It will, therefore, be necessary to review the whole field of studies in which the method of constant stimulus differences has been employed and ISI is a variable.

Summary

The relative paucity of information concerning short-term storage of non-verbal stimulus material and the consequences of this for our understanding of short-term storage in general, are pointed out. Several specific problem areas which might be elucidated by an understanding of non-verbal short-term storage are discussed. Mention is made of the treatment of this topic by Gestalt theorists and of the limitations of their approach.

CHAPTER II

INTERSTIMULUS INTERVAL AS AN INDEPENDENT VARIABLE IN THE METHOD OF CONSTANT STIMULUS DIFFERENCES

The Original Recognition of the Problem.

The importance of temporal variables in sensory discrimination tasks was acknowledged by Fechner in his "Elements of psychophysics" (1966, first published 1860). In a discussion of temporal relationships he mentioned the two factors on which interest has subsequently come to be focused, "the time allowed to elapse between the perception of one magnitude and of the other" and "temporal order, whether one or the other is first perceived". Since Fechner was primarily interested in the measurement of sensory performance, he regarded these variables as sources of constant errors influencing his results, and was concerned to eliminate them, - "if the errors are really constant they can be taken out by suitable means and at the same time their amount can be exactly determined".

Fechner was not unaware of the possible intrinsic significance of constant errors,

> "one must not see a disadvantage in these complications of our methods as caused by the presence of constant errors, but rather an important advantage, in as much as the determination of constant errors itself becomes a part of the psychophysical measurements that can be made. After all their influence is typical of the factors associated with sensations and should be measured. At the same time, however, the opportunity exists to exclude them from the measure of differential sensitivity with which we are at present concerned. Constant errors, therefore, should not merely be discarded as idle waste; they should be carefully separated from the measure of sensitivity and investigated one after another in every area, according to the conditions, laws, and variables that apply".

The Conceptual Framework.

Since Fechner's time a great deal of effort has been expended on attempts to elucidate the characteristics of constant errors in sensory discrimination tasks and these studies have primarily been undertaken within the conceptual framework of classical psychophysics. It can be shown that, despite the energy expended in this area, the return in terms of clarification of the basic issues has been very meagre and the whole topic continues to be beset by confusion, which to a very large extent seems to be a natural corollary of the inadequacies of the basic conceptual model of classical psychophysics.

The classical psychophysical model can be considered at two levels, firstly as a convention for treating the data of certain types of discrimination experiments, and secondly as a purported description of the operation of the discrimination mechanism. Recent developments (e.g. Swets, Tanner and Birdsall 1961) must raise grave doubts about this latter aspect of the model. It does seem, however, that the purported explanatory powers of the classical psychophysical model have lent an air of reality and tangibility to some psychophysical concepts which are really only summary descriptions of certain aspects of the data. This seems to be particularly so of the notion of the point of subjective equality (PSE) (Fig. II: 1), which can, in the case of data from the method of constant stimulus differences using two categories of judgement, be precisely defined as the x intercept of the response curve or psychophysical function at $p = 0.5$, when p is the proportion of judgements "greater". The PSE can also, perhaps misleadingly, be thought of as that value of the variable stimulus (V) which is judged equal to the standard (St). It follows then that the discrepancy between the PSE and St could be regarded as error and this has usually been called the "constant error".

The PSE as defined in terms of the x intercept is a function of two logically independent variables, the value of the y intercept for $x = St$, and the slope of the psychophysical function or response curve. The slope of the response curve is, of course, determined by the variability of judgement or the variable error.

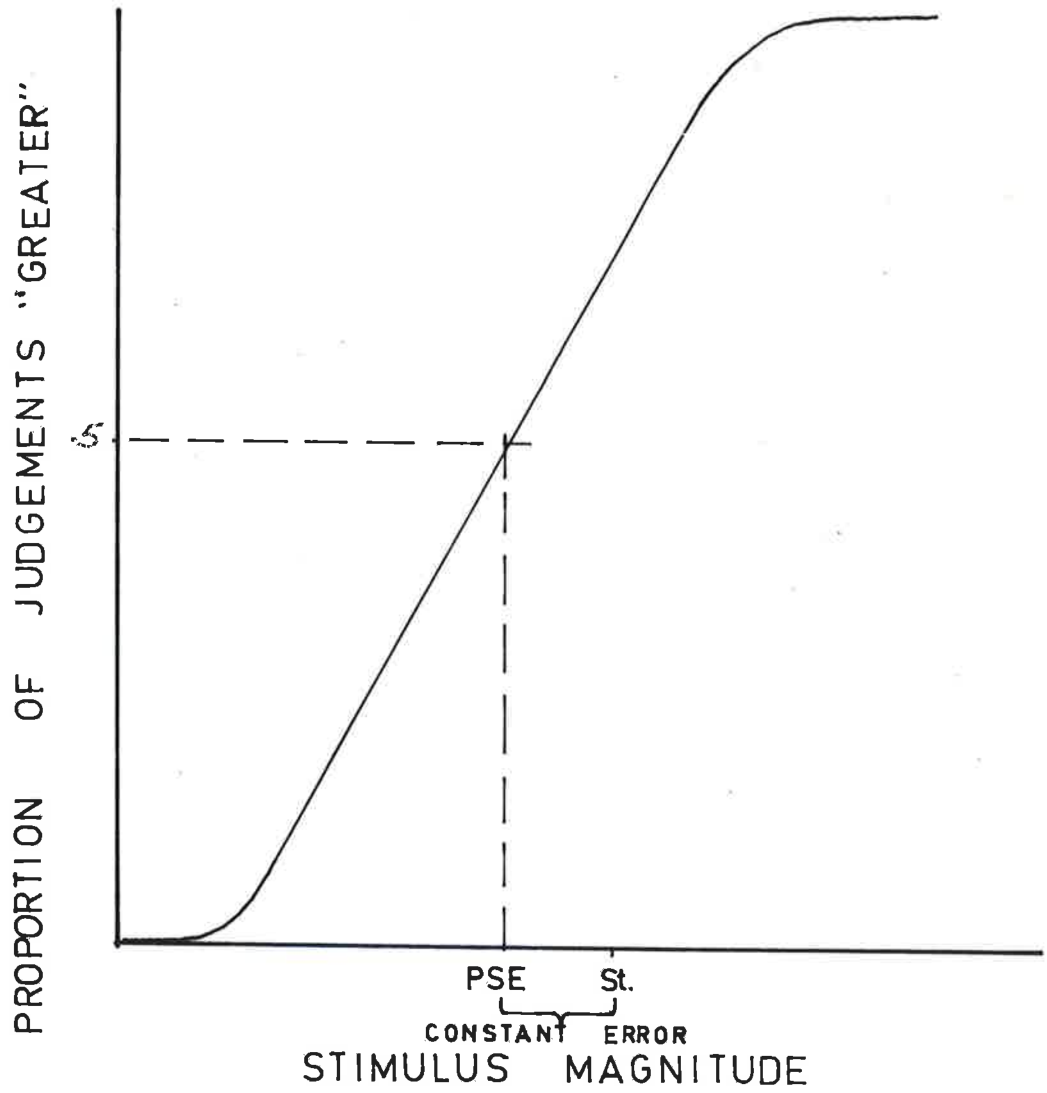

FIG. II:1 HYPOTHETICAL PSYCHO-PHYSICAL FUNCTION

The "constant" error, as conventionally defined, is therefore logically dependent upon the variable error and furthermore it has recently been shown (Ross 1964) that these two variables are empirically related. For this reason it is urged that the use of the term "constant" error for the PSE - St discrepancy should be abandoned and its use should be confined solely to measures directly reflecting the value of the y intercept for x = St.

The notion of the "constant" error as conventionally defined has also generated other confusions. It has been appreciated since Fechner's time that the "constant" error is influenced by both the interval between successive presentations of stimuli for comparison, and the order in which the two stimuli are presented. Although these are logically independent variables, the fact that they may both influence the PSE - St discrepancy has led to a tendency to speak of this discrepancy as the time order error (TOE). Far from clarifying the situation this usage has generated pseudo problems. For example in the method of absolute judgement or single stimuli, in which only one stimulus is presented per trial, the midpoint of the response scale does not usually coincide with the mid-point of the range of stimuli employed. By analogy with the findings from the method of constant stimulus differences, this fact has sometimes (Fernberger 1931, Wever and Zener 1928) been referred to as a TOE despite the obvious non-involvement of either temporal or order variables.

It might be argued that since in the case of the method of constant stimulus differences, the value of the y intercept for x = St, or the constant error, reflects a tendency to use one type of response in preference to another, this measure should be called response bias. It can be shown, however, that comparable constant errors are found when other methods employing different types of responses are used, for example with the comparative category rating methods, and this generality of the phenomenon independent of any particular response system suggests that it is not a simple manifestation of response bias.

In view of the above considerations much of the previously published work on the TOE or PSE - St discrepancy is of limited value in illuminating the behaviour of constant errors and their relationship to other variables such as ISI. Values of the PSE - St discrepancy do not provide satisfactory estimates of the constant error although they do provide correct information about the sign of the constant error.

An alternative way of measuring the constant error has sometimes been advocated (e.g. by Guilford 1954), this is by means of the index D%. This is defined as $D\% = \frac{100\ (L - G)}{L + G}$ where L = number of judgements "less", and G = number of judgements "greater". Since the number of judgements "greater", and "less" will depend on both the constant error and the spacing of the series of variable stimuli used, this index is of limited generality and permits precise comparisons only between sets of data in which the identical series of variable stimuli have been used. The above considerations suggest that the most satisfactory index of the constant error is one which reflects the inequality between "greater" and "lesser" judgements when a St is compared with itself.

The effect of the manipulation of order of stimulus presentation, when observed, is to produce a difference in slope between the response curves or psychophysical functions for the two orders of stimulus presentation. This difference invariably takes the form of a greater slope for the St - V function and hence reflects greater discrimination under these circumstances. The question does not seem to have been raised as to whether the relative difference in discrimination between the two orders is, itself, a function of ISI. It is proposed to restrict the use of the term order error or order effect to this difference in discrimination between the two orders of stimulus presentation.

A further way in which it might be expected for ISI manipulations to play a role is in the overall precision of discrimination, or the slope of the response functions. To the extent which comparative judgements are dependent upon memory factors, we might expect decreasing discrimination with an increase in ISI.

In the light of the foregoing discussion it can be seen that what has previously been loosely regarded as the problem of the time error or TOE, is logically a complex of associated problems. A more rigorous analysis of the situation reveals three independent aspects of performance, the constant error, the order error, and overall precision of discrimination; the real problem is to determine and explain the effects of the manipulation of time or ISI on each of these aspects of performance.

Previous Empirical Work.

The following review of the literature aims to encompass the findings concerning the effect of the ISI variable on performance with the method of constant stimulus differences with successive order of stimulus presentation. This has been suggested as a paradigm for the study of short term retention of simple non verbal stimulus material, although the studies to be reviewed have not been conceived in that light. The review does not purport to be an exhaustive coverage of the very extensive TOE literature, as the bulk of studies in this area have not been primarily concerned with the ISI variable. There has, for example, been a considerable interest in the effects of interpolated extraneous stimuli on performance in this situation which has been influenced by Lauenstein's theoretical views. Since such studies do not cast direct light on the problem they will not be considered.

Even in the case of studies in which the effects of manipulation of ISI have been the primary concern, interpretation is often difficult because of the conceptual confusion which has characterised the area. For this reason it is as well to treat estimates of the magnitude of constant errors with reserve although the sign of such errors can usually be regarded as reliable. An additional consideration to be borne in mind in assessing studies in this area is the influence of a number of procedural variables which have been shown to produce reliable effects.

Procedural Variables

Multiple or non-fixed standards.

A finding of some generality in sensory discrimination tasks is the central tendency effect first described by Hollingworth (1909). "The term central tendency refers to the fact that estimates of stimuli at the extremes are shifted towards the indifference point at the center" (Johnson 1955). It is this phenomenon which appears to underly the findings from a number of studies in which several, rather than one St, have been employed in each experimental session. Typically the result of such a procedure is to produce a displacement of the constant error towards the direction of some central value of the range of Sts employed. This has been demonstrated with lifted weights (Bartlett 1939, Woodrow 1933), pitch (Harris 1952, Koester and Schoenfeld 1946), and auditory intensity (Needham 1935). The effects produced on constant errors by use of a number of Sts are accentuated as ISI is increased (Koester and Schoenfeld 1946, Needham 1935). A further result of the use of a multiple or roving St is, not unexpectedly, a decrease in the precision of judgement or increase in the variable error (Woodrow 1933).

If the constant error is regarded as a manifestation of the intrinsic bias of the perceptual or storage mechanism it seems clear that the operation of this bias will be obscured or distorted in experiments using multiple Sts. For this reason the results from such experiments would appear to be of limited value in elucidating the problem of the constant error, although Guilford's (1954) suggestion that the same principle might eventually explain TOE and central tendency effects could well be borne in mind.

Asymmetry of range of variable stimuli.

An apparently related procedural variable which has been shown to influence the constant error is that of the asymmetry of the V stimuli around St. This variable has been investigated by Doughty (1949, 1952) with respect to both pitch and loudness discrimination. He showed that asymmetry of the V stimuli range influenced the constant error but not the difference limen. Doughty interpreted his findings as primarily due to response factors and a tendency for Ss to avoid disproportionate numbers of either "greater" or "lesser" responses. There seems little question, however, that this result is a further manifestation of the central tendency phenomenon and it seems clear that when there is asymmetry of the V stimuli around the St, this must be taken into account in assessing the results of this type of experiment.

Effects of practice.

A third procedural variable influencing the results of studies using the method of constant stimulus differences is S's prior familiarity with the task. A general finding seems to be a decline in the constant error with continued experimentation; this has been observed with loudness judgements (Needham 1934), pitch judgements (Koester 1945), and temporal duration judgements (Woodrow 1935, Woodrow and Stott 1936), and according to Woodrow (1935) this effect was also observed by Kohler. Woodrow (1935) also found a decrease in the variable error associated with judgements of temporal duration. This latter finding is in accord with expectations and an example of perceptual learning (Gibson 1953).

The relevance of the experience variable for the constant error would seem to have certain implications for the interpretation of studies in this area since the operation of this variable seems likely to obscure the manifestation of any intrinsic bias in the sensory mechanism. For this reason we must accord a special significance to studies in which this variable has been controlled by making only one observation per S. Because of the effort involved in gathering data in this way, such studies are understandably rare, but a series of such studies using the method of adjustment has been reported by King (1963a, 1963b, 1963c, 1965, 1966a, 1966b).

King investigated the central tending of reproduction of St stimuli after intervals of from 1.5 secs. to 28 days. Judgements were made of visual brightness, loudness, visual flash rate, pitch, and visual and auditory temporal duration. In the case of temporal judgements a consistent underestimation of St was observed, but there was some question as to whether this result might not be an artifact of the method of adjustment since reproductions must all, of necessity, be made in ascending order. With other types of stimuli this variable can be controlled by counter balancing adjustments in ascending and descending orders and positive errors of reproduction were observed in the case of loudness, visual flash rate, and pitch; no pronounced trend in the size or direction of these positive errors, over the period of 15 secs.

to 28 days, was noted. No systematic errors of reproduction of brightness were observed. King provides no date about the variance of judgements.

Stimulus Variables

The effects of manipulating ISI is in many cases to produce changes in performance which are highly specific to a particular stimulus dimension. Such differential effects have come to assume, as shall subsequently be shown, a great deal of theoretical significance..

Pitch.

It is not clear whether a consistent constant error occurs in judgements of pitch, although such an error has been reported (King 1966a, Tresselt 1948). There does seem to be general agreement that any constant error for pitch is independent of ISI (Inomata 1964, Koester 1945, Morikiyo 1959, Postman 1946). Although the major preoccupation of studies in this area has been with the constant error, it seems clear that the variable error or precision of pitch judgements does increase over time (Bachem 1954, Harris 1952, Koester 1945), although Postman (1946) failed to confirm this. Bachem, whose study was directed towards the question of absolute pitch, found that some of his Ss, who were selected for possession of absolute pitch, showed little decline in retention of stimuli, falling within the musical range, for periods of up to 1 week.

Auditory intensity.

Kohler's 1923 study of the effects of ISI on performance in an auditory intensity discrimination situation has probably been the most influentual single study in the whole field. His data show a positive constant error with ISIs of 1.5 and 3.0 secs. but a negative error at 4.5 and 6 sec. This relationship between the constant error and the ISI has come to be known as the P function of the time error and has been the subject of much investigation. Two investigations of this relationship seem to stand out from the others on the grounds of methodological thoroughness. These are those of Koester (1945) and Postman (1946). Unfortunately their results are contradictory and the difference in results can not obviously be explained by references to procedural differences between the two investigations. Koester concluded that "constant errors are somewhat larger for judgements of loudness than they are for pitch; but as in the case of pitch, these do not show any systematic change in direction or size as a function of increasing time interval". Postman's results were largely consistent with Kohler's in showing a positive error for the 1 and 2 sec. ISI and a negative error for the 4 and 6 sec. ISI. Reference to other studies of this problem reveal more contradictions; for example Peak (1939) found a positive constant error for 177 ms and 285 ms ISI while Harris (1949) found a negative constant error with a zero ISI and for larger intervals no consistent constant error at all.

The relationship between the variable error of intensity judgements and ISI appears to have received little systematic attention. The studies of Harris (1949) and Postman (1946) show no systematic trend, the former study for ISIs of up to 1 sec. and the latter for intervals of up to 6 sec.

Temporal duration.

The nature of the errors associated with judgements of temporal duration is complicated by an apparently unique feature of this stimulus dimension, that is the well established relationship between the sign of the constant error to the point on the scale at which the measurements are being made. Such a relationship has been suggested for other stimulus dimensions but not reliably demonstrated. The point at which the sign of the constant error changes is spoken of as the temporal indifference point and the most acceptable estimate of this point has been provided by Woodrow (1934) in a study utilising only one judgement per S. Woodrow's estimate of the temporal indifference point was .6 sec; intervals of less than this value give rise to positive constant errors and intervals greater to negative ones.

An interest in the determination of the indifference point and factors influencing it has dominated research in this area and few studies have been concerned with the influence of ISI on constant errors. Nakajima (1958) has reported negative constant errors decreasing in size with increase in ISI in a temporal discrimination task. Small and Campbell (1962) have also reported a relationship between size and direction of constant errors and ISI in a study of auditory temporal discrimination. Because of the extreme shortness of the stimuli (4-400m sec.) and some of the ISIs (.05 sec.) used in this experiment, there is reason to suppose that the reported effects are due to specific auditory mechanisms at the receptor level rather than to more central factors.

One study (McGavren 1965) provides quite detailed evidence of the relationship between ISI and variable errors in an auditory temporal duration task. McGavren showed an optimal ISI of 1.5 sec.; intervals shorter and larger than this produced poorer performance.

Lifted Weights.

Although the significance of temporal factors in discrimination tasks first came to attention within the context of experiments on lifted weights, surprisingly little systematic evidence about the effects of ISI on performance in this situation is available. It seems to be generally conceded that a consistent negative constant error is found in judgements of lifted weights (e.g. Guilford and Park 1931, Weinstein 1955a). However, even this generalisation is contradicted; Ross (1964), for example, found both positive and negative constant errors in a variety of weight lifting tasks and was unable to explain the direction of the error. There seems to be no systematic data in the literature illustrating the effects of ISI on variable and constant errors in lifted weight situations.

Visual size.

Most experiments using visual stimulus material have been concerned to test specific hypotheses relating to the context in which the stimulus is presented, and these provide only incidental information about the operation of the ISI variable. The influence of such contextual variables has generally been interpreted in terms of contrast and assimilation affects (e.g. Inomata 1959, Marchetti 1942, McClelland 1943, Watson 1957). Two studies (Inomata 1964 and Karlin 1953) are concerned primarily with the ISI variable on judgements of visual magnitude, although Inomata employed a comparative rating method rather than the method of constant stimulus differences. Both studies are in agreement in reporting negative constant errors, but whereas Inomata found an increase in the size of the constant error with increasing ISI, Karlin found a decrease in the constant error when increasing ISI from 1 to 3 sec.

Other stimulus dimensions.

Previous reviews of this area (e.g. Guilford 1954) have drawn attention to TOEs in affective judgements and judgements of odor and taste. The range of situations in which the phenomenon has been found has been still further extended by recent research. Geertsma (1958) found a positive constant error in judgements of hurtfulness of electric stimulation with a 2.5 sec. ISI but a negative one for a 14.5 sec. ISI.

Subject Variables

A number of recent studies have been concerned to elucidate the operation of subject variables on constant errors in sensory discrimination tasks.

Birch, Belmont and Karp (1965a) have compared the constant errors of a brain damaged and intact group in an auditory intensity discrimination task. For ISIs of up to 5 sec. the intact group demonstrated a negative constant error, whereas the brain damaged Ss showed a positive constant error, diminishing with increasing ISI. In a second study (Birch, et al. 1965b), this group showed that a white middle class group performed similarly to the normal group in the previous experiment but a lower class negro group performed similarly to the brain damaged group.

Axelrod and Eisdorfer (1962) used age as a variable in an auditory intensity discrimination task. They found negative constant errors in both a young and elderly group; in the case of a young group there was an increase in negativity from 1 to 2 sec., but a subsequent levelling off for ISIs of up to 6 sec. In the elderly group there was a uniform increase in negativity with increasing ISI.

Weinstein (1955a, 1955b) has investigated constant errors in tactile size and weight discrimination situations for both normal and brain damaged Ss. He found a significant relationship between site of lesion and size of the constant error in judgements of weight.

Theories

Mention has already been made of the inadequacies of theories in this area which are based on oversimplified views of the stimulus trace, and which, in particular, fail to distinguish between degeneration and attenuation of the trace. Apart from this type of approach current theoretical formulations are limited to those of Michels and Helson (1954) and Stevens (1957). Both of these share the view that the so-called time error or TOE is independent of the effects of time, despite a large volume of evidence to the contrary. Helson (1964) has said, in the absence of any supporting evidence, that "it is now agreed that effects of time require an interval of greater than 3 sec. between standard and variable whereas TOE appears in much shorter intervals" and "TOE must be regarded as a manifestation of decentred position of adaptation level". Stevens' view is that "not only is the time order error produced by other factors than time, but it also has nothing to do with order".

Michels and Helson

Michels and Helson see the cause of the St - PSE discrepancy as being due to the determination of the PSE by the adaptation level, which is a weighted log mean of stimuli used and will, therefore, rarely coincide with the value of St. In a comparative judgement situation, judgements are referred to a comparative adaptation level in the determination of which, the first stimulus on each trial receives a special weighting. Therefore comparative adaptation level will be largely determined by the value of St in St-V trials, and by the individual values of V in V-St trials. As a consequence the slopes of the psychophysical functions produced by the two orders of presentation will differ and the St-V function will be steeper than the V-St function.

Helson and Michel's theory has the advantage of dealing explicitly with the order variable and recognising its undoubted importance; the theory also claims to make predictions providing a good fit to sets of empirical data, however it takes no account of the ISI variable which is, according to the weight of evidence, a variable of importance. For this latter reason it is difficult to regard Michels and Helson's formulation as being at all satisfactory.

Stevens

Stevens believes that the TOE is the failure of the middle of the stimulus range to coincide with the middle of the response range in category judgement situations and is characteristic of Class I or prothetic stimulus continua. It is, in his view, a result of the asymmetry of sensitivity or subjective inequality of j.n.d.s on prothetic continua. The result of this is, according to Stevens, that category rating scales are typically non linear since the categories tend to be narrower at the bottom end and broader near the top end. The TOE is a secondary consequence of this non linearity.

Stevens' view of the TOE is a very restricted one and primarily based on a consideration of the data from category rating tasks rather than from the method of constant stimulus differences. His distinction between prothetic and metathetic stimulus continua and the view that the TOE is characteristic of only the former, seems to be potentially valuable but has been severly criticised (Warren and Warren 1963). However Stevens' rejection of the relevance of both the ISI and order variables limits the scope and applicability of his formulation to the problem of performance in the method of constant stimulus differences.

Conclusions

Despite the very early recognition of the importance of the ISI variable in determining performance in the method of constant stimulus differences, little advance has been made in understanding the mode of operation of this variable. This seems largely to be due to the influence of two complementary factors; firstly, the utilisation of an inadequate conceptual basis for the planning and interpretation of empirical work, and, secondly, the large volume of empirical findings, many of which are either contradictory or not easily integrated with each other. Attempts by theorists to impose some degree of order on this chaotic situation have, of necessity, failed.

It would seem that an understanding of this area can only advance when the basic problem has received an adequate empirical definition as a result of studies conceived and interpreted within a sound conceptual framework.

Summary

The literature dealing with the operation of the ISI (inter-stimulus interval) variable in the method of constant stimulus difference is reviewed. Fechner's original acknowledgement of the problem is mentioned and the inadequacies of the conceptual framework on which subsequent research in this area has been based, are pointed out. An attempt is

made to summarise the salient empirical findings concerning the operation of procedural, stimulus, and subject variables in this area. The inadequacies of two contemporary theoretical formulations which purport to encompass this area are pointed out.

CHAPTER III

THE INITIAL APPROACH TO THE PROBLEM

In the light of the considerations raised by the review of past studies of the ISI variable in the method of constant stimulus differences, it would appear that one pre-requisite for an understanding in this area is an adequate empirical description of the phenomena which have to be explained. At the same time it appears plausible that, although Stevens' (1957) and Michels & Helson's (1954) views about the TOE are both clearly inadequate and contradictory, some further understanding of the differences between category rating scales and ratio scales might well throw some incidental light on the operation of the ISI variable. Each of these separate proposals will now be considered in greater detail.

Developments of the Method of Constant Stimulus Differences.

The method of constant stimulus differences appears to provide an excellent paradigm situation for the study of short term storage of non-verbal material. The conventional form of this procedure, however, is dictated by the conceptual framework of classical psychophysics which tends, as has been shown, to obscure rather than elucidate the role of the ISI variable. Although it would seem necessary for our purpose to maintain the essentials of this method, i.e. the comparative judgement of successive stimuli, there seems to be no good reason for being strictly bound to the secondary conventional features of this method and, indeed, there seem to be good arguments for discarding some of these features. For this reason two procedural variations which seemed to represent an improvement of the conventional method of constant stimulus differences were developed and given some preliminary testing.

The Method of Difference Estimation

A salient feature of the constant methods is their tediousness for S and E, primarily because of the large number of trials required for data analysis. The necessity for so many trials seems to be due, at least in part, to the limited amount of information which S is able to transmit on each trial. Conventionally S is restricted to either two or three categories of response, allowing in the former case a maximum information transmission of 1 bit per trial. However, the average amount of information transmitted per trial will usually be appreciably less than this because most of the comparison stimuli will be consistently judged in one category or the other. There is good reason to suppose that, even with clearly spaced comparison stimuli, S may be able to transmit appreciably more than 1 bit of stimulus information per trial and, if this is so, restrictions placed on S's freedom to respond represent an unnecessary curtailment of information.

In order to overcome these difficulties some preliminary investigations were made to see whether Ss could report their comparison judgements of two successive stimuli by means of a scale and cursor, since this form of response would, in principle, seem to permit the transmission of large amounts of information per trial. A horizontal scale, consisting of a row of 50 1 cm. squares alternately coloured red and black, was used, over which S could move a cursor, the exact position of which could be read off at the back by E. Instructions to S said that the middle position of the cursor always represented the magnitude of the first stimulus and the cursor was set at this position at the beginning of each trial; S was instructed to report about the second stimulus by shifting the cursor to that square on the scale which he felt best expressed the magnitude of the second stimulus compared with the first.

This method of reporting appeared to provide S with a stable frame of reference within which to make his report and, at the same time, to provide few restraints on performance. It is true that only twenty-five judgement categories were provided for the S in each direction but, since we know that at best Ss can only reliably employ about seven to eight categories (Miller 1956) and, since the range of stimuli employed was small, the limitations in number of categories did not appear to effectively constrain S's performance. The method appeared, on the basis of preliminary investigation, to justify further use.

The data were analysed by drawing up individual confusion matrices and calculating the average information transmitted per judgement (i.e. contingent uncertainty; Garner, 1962). This form of data analysis makes no assumptions about the underlying metric of the scale employed by S and is unaffected by the modulus used by S.

The Method of Difference Detection

One of the major problems associated with the use of the conventional method of constant stimulus differences is the selection of the range and spacing of the V stimuli. If a V stimulus is consistently judged as being in one category or the other it really provides no information about S's acuity, so an attempt must be made to select a range of stimuli about which S will always be in some doubt. This can only be done with prior knowledge of S's acuity which involves us in a vicious circle. In practice it is usually found that the range of individual differences of acuity is so great that no matter how carefully selected the V stimuli might be, they are always unsatisfactory for at least a proportion of Ss.

This difficulty can largely be overcome by using only two values of V stimuli, both of which are well within the range of uncertainty and slightly restructuring the nature of S's task by informing him of the objective proportion of trials on which the second stimulus will be "greater", "lesser", or "equal" to the first. This arrangement has the additional advantage that the proportion of "equal" (St-St) trials can easily be increased beyond the proportion normally used for "catch" trials and, as has been pointed out, performance on such trials is particularly informative concerning constant errors. A slight disadvantage of this method is that the scoring of performance is in terms of numbers of correct trials of each kind, which restricts comparison of performance to situations in which data has been gathered under strictly comparable conditions. Preliminary investigations with this method seemed to justify its further, more systematic, use.

Category Rating Scales and Magnitude Estimation Scales

It is Stevens' (1957) contention that for prothetic or Class I continua category rating scales are non linear (concave downwards) relative to magnitude estimation or ratio scales.

"The chief factor that produces non-linearity in the category scale of Class I is variation in the subject's sensitivity to differences. Near the lower end of the scale where discrimination is good the categories tend to be narrow, and by consequence the slope of the function is steep. Near the upper end, where a given stimulus difference is less easy to detect, the categories broaden and the slope declines."

By contrast scales produced by "ratio methods" such as magnitude estimation, directly reflect subjective magnitude and are, according to Stevens, uninfluenced by the relativity of discrimination.

To date Stevens seems to have been prepared to support his arguments concerning the relationship between stimulus magnitude and discriminability in the category scaling situation, and the independence of these two variables in the ratio scaling situation, by an appeal to indirect evidence, e.g. the non-linear relationship between the two types of scales (Stevens & Galanter, 1957). However, it would appear possible to make a direct test of Stevens' assertions if a satisfactory index of discriminability were available.

The conventional index of discriminability, the variance of judgements or estimates, is not appropriate for use with data from magnitude estimation tasks for two main reasons. Since with this method no modulus is prescribed and each S adopts his own modulus, the same stimulus may be estimated as say 12 units of intensity by one S and 200 by another. This prevents meaningful comparison or combination of variances between Ss. The second inadequacy of the variance as a measure of discriminability in this situation is its relationship to the stimulus magnitude; the variance of magnitude estimates of a stimulus with a mean estimate of say 200 will, of course, be very much greater than that of a stimulus with a mean of 5. The variance is only really a satisfactory index of discriminability when the means and variances are independent.

Fortunately these objections cannot be raised at another measure of dispersion, the use of which involves no prior assumptions about the underlying metric. This measure is the conditional uncertainty (Garner 1962). This is defined as "the average amount of uncertainty in one variable when the other variable is held constant". In the magnitude estimation task, holding the stimulus variable constant and determining the response uncertainty for each stimulus should provide us with satisfactory comparable indices of discriminability (response uncertainty) over the whole stimulus range.

The use of this measure, therefore, seems to provide a means of directly testing Stevens' views about relative discriminability of stimuli in both category rating and magnitude estimation tasks.

Summary

Two salient aspects of the problems discussed in the previous chapter are selected for experimental attack, namely an adequate empirical account of the effects of the ISI variable in the method of constant stimulus differences, and a classification of the relationship between ratio and category rating scales. Two procedural variations of the method of constant stimulus differences which appear to overcome some of the drawbacks of this method are discussed. A means of making a direct test of Stevens' hypotheses concerning performance in magnitude estimation and category rating tasks is also discussed.

CHAPTER IV

TEMPORAL DIFFERENCE ESTIMATION

The following experiment had two major aims; to make a more rigorous examination of the method of difference estimation which had, in a preliminary try out, provided indications of potential usefulness, and to investigate short term (1-6 sec.) storage of information concerning the duration of brief (.6-1.2 sec.) auditory stimuli.

Method

Four separate stimulus schedules were pre-recorded on tape using a fixed intensity (80 d.b., s.p.l.) 300 ∼ tone; one schedule for each of the ISIs 1, 2, 4 and 6 sec. Each schedule consisted of 112 trials arranged in eight consecutive blocks of 14 trials.

A St stimulus of 0.9 sec. was utilised; this was chosen so as to be well outside the indifference interval but short enough to prevent the use of counting. The value of 1 sec. as a St was avoided since it was felt that this value might have been previously learnt by some <u>Ss</u>. Six V stimuli arranged from 0.6 sec. to 1.2 sec. in 0.1 sec. steps were utilised. Each block of 14 trials consisted of 2 presentations of St-St, 6 presentations of St-V (one for each individual value of V) and 6 presentations of V-St (one for each individual value of V). A separate random order of trials was used for each block.

Psychology I students (n = 24), fulfilling a course requirement, were utilised as Ss. They were tested individually and completed each schedule in a predetermined counterbalanced order with an interval of at least one day between sessions.

Each experimental session was commenced with six or seven habituation trials to enable Ss to become familiar with the task; the results of these trials were excluded from the analysis.

The task was self-paced with E presenting a new trial as soon as the previous one had been completed; a short rest period was introduced halfway through each session. The duration of each session was between 25-40 minutes. Stimuli were presented to S through muffed ear phones. The muffs, together with a continuously operating exhaust fan, served to shield S from extraneous noise.

S was required to respond on each trial by shifting a cursor on a scale in the following way. The scale, which was placed opposite S in a horizontal position, consisted of 50 1 cm squares alternately coloured red and black; the cursor could be moved along this scale by S and its exact position read off on the reverse side by E.

S was instructed that the middle position of the scale, at which the cursor was always set at the commencement of each trial, represented the magnitude of the first stimulus, and that he was to report about the second stimulus by shifting the cursor to that square on the scale, which he felt best expressed the magnitude of the second stimulus compared with the first. The ends of the scale were labelled "longer" and "shorter" to prevent confusion.

The S was instructed by means of a card on which the instructions were typed (Appendix A) and which was read aloud by E. It is important to note that the instructions did not make explicit whether S was to make ratio judgements or interval judgements. The exact instructions were "on each trial you are to shift the cursor to the square which you feel best expresses the length of the second sound as compared with the first". This consideration is of some importance in view of the continuing controversy over the ability of Ss to make either interval or ratio judgements and the precise properties of the underlying metric utilised by Ss. In this case this controversy has been successfully side stepped by analysing the data in information theory terms which make no prior assumptions about the underlying metric.

The data from the St-V and V-St trials were treated by drawing up separate confusion matrices for each S for each order and ISI. Estimates of the mean amount of information transmitted per trial (contingent uncertainty; Garner 1962) were calculated for each matrix.

Results

The contingent uncertainty estimates were subjected to a three way analysis of variance (Subjects, Orders i.e. St-V v V-St, and ISIs) with sub-classification of the Subjects variable into Groups and Individual differences. The Groups were differentiated on the basis of the sequence in which they completed the schedules employing the different ISIs.

The summary of this analysis* (Table IV:1) shows that the only main effect to reach significance is that of Order ($p < .001$). The mean information transmitted per trial in the St-V order was 1.47 bits whereas only 1.22 bits was transmitted in the V-St order. Quite surprisingly the manipulation of the

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*Throughout this study the following conventions have been observed in the selection of error terms against which to test individual sources of variance for significance; sources of variance other than those involving subjects have always been tested against the next highest order interaction with Individual differences. In cases when the source of variance involves Groups of subjects, such sources have been tested against the corresponding within Groups or Individual differences variance.

TABLE IV: 1

SUMMARY OF ANALYSIS OF VARIANCE OF
CONTINGENT UNCERTAINTY IN
TEMPORAL DIFFERENCE
ESTIMATION TASK

Source	d.f.	S.S.	M.S.	F	p
Subjects (S)	23	15.3485			
Groups (G)	3	3.2093	1.070	1.76	ns
Indiv. Dif.(ID)	20	12.1392	.6070		
ISIs	3	.0252	.008400	<1	ns
Orders (O)	1	3.0795	3.080	37.6	.001
S x T	69	3.1247			
G x T	9	.3742	.04158	<1	ns
ID x T	60	2.7505	.04584		
S x D	23	1.8414			
G x O	3	.2051	.06837	<1	ns
ID x O	20	1.6363	.08182		
ISI x O	3	.0775	.02583	1.26	ns
S x ISI x O	69	1.3505			
G x ISI x O	9	.1175	.01306	<1	ns
ID x ISI x O	60	1.2330	.02055		
Total	191	24.8473			

ISI variable had no effect (Table IV:2).

TABLE IV: 2

MEAN CONTINGENT UNCERTAINTY PER TRIAL (IN BITS) AT VARIOUS ISIs

ISI (secs.)	1	2	4	6
$\overline{X}$ contingent uncertainty	1.34	1.34	1.36	1.33

A further analysis of the data was undertaken by determining the number of trials in each session in which Ss indicated that the second stimulus was shorter than the first. This analysis was directed at elucidating the characteristics of the constant error and the data were treated by a two way analysis of variance (Subjects and ISIs) with a sub-classification of the Subjects variable into Groups and Individual differences. This analysis (Table IV:3) indicates that both ISI ($p < .01$) and the interaction Groups x ISI are significant ($p < .001$) sources of variance.

TABLE IV: 3

SUMMARY OF ANALYSIS OF VARIANCE OF TOTAL JUDGEMENTS "SHORTER" IN TEMPORAL DIFFERENCE ESTIMATION TASK

Source	d.f.	S.S.	M.S.	F	p
Subjects (S)	23	5,249.24			
Groups (G)	3	884.53	294.8	1.35	ns
Indiv. Dif. (ID)	20	4,364.71	218.2		
ISIs	3	323.28	107.8	3.09	.01
S x ISI	69	3,377.97			
G x ISI	9	1,286.51	142.9	4.10	.001
ID x ISI	60	2,091.46	34.86		
Total	95	8,950.49			

The interpretation of the ISI effect is aided by inspection of (Table IV:4).

TABLE IV: 4

MEAN NUMBER OF TRIALS PRODUCING "SHORTER" JUDGEMENTS AT VARIOUS ISIs (112 TRIALS/SESSION)

ISI (secs.)	1	2	4	6
$\overline{X}$ "shorter" judgements	52.9	57.5	56.1	57.2

This indicates that the major difference is between the 1 and 2 sec. ISI. Since at the 1 sec. ISI there are more "longer" judgements than "shorter", we may speak of a negative time error at this interval.

At the other ISIs there is a slight preponderance of "shorter" judgements but hardly sufficiently great to be regarded as of any consequence. Apart from noting the change in constant error between 1 and 2 secs., it is not possible to be more explicit about the "P" function of the constant error.

Since the experimental treatment of the Groups of Ss differed only in respect to the sequence in which the stimulus schedules were completed, the significant Groups x ISIs interaction clearly reflects the effects of sequence. This interaction is clarified by reference to Table IV:5.

TABLE IV: 5

MEAN NUMBER OF TRIALS PRODUCING "SHORTER" JUDGEMENTS AT VARIOUS EXPERIMENTAL SESSIONS (112 TRIALS/SESSION)

Order of session	1	2	3	4
$\bar{X}$ "shorter" judgements	52.1	54.1	59.7	57.8

It can be seen that there is a tendency for the constant error to be negative at first but to disappear or even to become positive in subsequent experimental sessions.

Discussion

The most surprising feature of the results of this experiment is the demonstrated independence of the variable error, or precision of judgement, and ISI. This finding is substantially in line with McGavren's (1965) finding, although in that study there was some evidence of optimal performance at an ISI of 1.5 sec. Since a decline in precision of judgement with increasing ISI is so generally found with other stimulus continua, this finding suggests a qualitatively different mechanism must underly temporal discrimination.

The experiment has shown an effect of ISI on constant errors although the data do not permit any precision of interpretation of this effect. This finding does seem consistent with Nakajima's (1958) conclusion that, in tasks of this kind, a negative constant error associated with very short ISIs decreases in size with increased length of ISI.

Although it has been demonstrated that continued practice affects the constant error but not the precision of judgement, the results do not permit a highly specific interpretation of this effect. The results are consistent with the view that there is an initial negative constant error which disappears with continued practice. If this interpretation is correct it would seem to represent an interesting case of an increase in veridicality of perception or judgement as a result of practice but without knowledge of the results.

Another feature of the contingent uncertainty results, worthy of mention, is the high proportion of the total variance accounted for by the Order variable. This is consistent with other studies but the results provide no clue as to why this should be so.

Since one of the aims of this experiment was to provide a trial of the method of difference estimation, some assessment of the method is called for. Impressionistically the method seemed to be accepted by Ss and carried out without difficulty. During analysis of the data it appeared as if a relationship existed between the amount of output information and transmitted information (conditional stimulus uncertainty and contingent uncertainty, Garner 1962). This was subsequently confirmed by closer analysis; for example, with a 1 sec. ISI and for trials in the St-V order these two variables provide a product moment correlation of 0.52 ($t=2.85$, $p < .01$). Two interpretations of this result seem possible although on the available evidence it is not possible to choose between them. Firstly, Ss who choose to utilise only a very small portion of the response scale may have selected a scale too small to allow them to exhaust the information at their disposal or, secondly, Ss with low precision of judgement, and therefore capable of less information transmission, automatically chose to work with a small portion of the response scale.

Having in mind that the former interpretation could be correct, it would seem worthwhile if the method were subsequently used to give specific instructions to Ss to utilise as large a portion of the response scale as is possible.

Summary

An experiment employing 24 Ss in a temporal difference estimation task is described and discussed. The results show that a major portion of the variance is accounted for by the Order variable, i.e. whether the St is presented first or second on any one trial. A negative constant error was found at an ISI of 1 sec. but not for larger ISIs. Neither length of ISI nor practice affected the variable error. There appeared to be a decline in constant errors with practice. It is concluded that the difference estimation technique is worthy of further use.

CHAPTER V

TEMPORAL DIFFERENCE DETECTION

The two main aims of this experiment were to provide a more rigorous trial of the method of difference detection which has been previously mentioned (Chapter III), and to investigate the short term storage of information concerning auditory temporal durations.

Method

The stimulus material for each of four sessions was pre-recorded on magnetic tape. Four stimulus schedules, one for ISIs of 1, 2, 4 and 6 seconds and each consisting of 144 trials were prepared. The same St as used in the previous experiment was employed, namely 0.9 sec.; only two V stimuli 0.7 and 1.1 sec. were used. Each stimulus schedule consisted of 48 trials of two stimuli in each of the following orders St - St, St - V, and V - St. There were equal numbers of both values of V in the St - V and V - St trials. The order of trials was randomised within blocks of 24 trials, each block containing eight trials in each order.

Since only two values of V were used it was important to select values which would present a reasonable amount of difficulty in being discriminated from St. The values chosen were selected after preliminary experimentation had indicated that they were satisfactory in this respect.

The stimulus schedules were recorded using a fixed intensity (80 d.b., s.p.l.) 300 ~ tone and played back to Ss through muffed ear phones in an experimental room in which an exhaust fan was continuously operating.

Twenty four Psychology I students, fulfilling a course requirement, served as Ss. Each S completed each stimulus schedule in a predetermined counter balanced order with an interval of at least one day between sessions. Six or seven habituation trials, the results of which were not included in the analysis, were given at the commencement of each session. The task was self paced with E presenting a new trial as soon as the old one had been completed. A short rest interval was introduced half way through the experimental session which lasted between 25-40 minutes.

Except for essential differences in the stimulus schedules and instructions, the conditions of this experiment were identical and therefore in all ways comparable with the previous experiment. In the instructions (Appendix B) Ss were told that they could respond "longer", "shorter", or "equal" to each trial and that there were equal proportions of trials in which the two stimuli were longer, shorter, and equal.

Results

Independent analyses of the results of trials in which there was a difference between the two stimuli presented (difference trials), i.e. St - V and V - St trials, and trials in which there was no difference between the two stimuli presented (no-difference trials), i.e. St - St trials, have been carried out. Analysis of the results of no-difference trials can be expected to be particularly informative about the constant error, while analysis of the difference trials should provide information about the variable error or precision of judgement.

The number of correct responses on difference trials was determined and analysed by four way analysis of variance. The main effects were Subjects, Differences, Orders and ISIs and the Subjects variable was further broken down into Groups and Individual differences components. It will be recalled that Groups are distinguished solely on the basis of the sequence in which they completed the stimulus schedules. The Differences variable refers to the magnitude of the difference to be detected on a particular trial, i.e. 0.2 sec. in either 0.7 sec. or 0.9 sec.; the Orders variable refers to the distinction between St - V and V - St trials.

A summary of this analysis of variance is found in Table V:1.

TABLE V: 1

SUMMARY OF ANALYSIS OF VARIANCE OF CORRECT RESPONSES ON DIFFERENCE TRIALS IN TEMPORAL DIFFERENCE DETECTION TASK.

Source	d.f.	S.S.	M.S.	F	p
Subjects (S)	23	2,129.560			
Groups (G)	3	331.716	110.6	1.23	n.s.
Indiv. Dif. (ID)	20	1,797.844	89.89		
Differences (D)	1	739.815	739.8	60.0	.001
Orders (O)	1	1,975.628	1,976.	104	.001
ISIs	3	64.591	21.53	3.22	.05
S x D	23	278.497			
G x D	3	31.945	10.65	<1	
ID x D	20	246.552	12.33		
S x O	23	393.935			
G x O	3	13.383	4.461	<1	
ID x O	20	380.552	19.03		
S x ISI	69	411.096			
G x ISI	9	9.982	1.109	<1	
ID x ISI	60	401.114	6.685		
D x O	1	56.273	56.27	1.34	n.s.
D x ISI	3	21.195	7.065	1.24	n.s.
O x ISI	3	35.300	11.77	1.59	n.s.

TABLE V: 1 --<u>Continued</u>

Source	d.f.	S.S.	M.S.	F	p
S x D x O	23	1,020.539			
G x D x O	3	178.279	59.43	1.41	n.s.
ID x D x O	20	842.260	42.11		
S x D x ISI	69	365.742			
G x D x ISI	9	24.669	2.741	<1	
ID x D x ISI	60	341.073	5.685		
S x O x ISI	69	494.388			
G x O x ISI	9	49.815	5.535	<1	
ID x O x ISI	60	444.573	7.410		
D x O x ISI	3	20.362	6.787	<1	
S x D x O x ISI	69	1,136.076	16.46		
Total	383	9,142.997			

It can be seen that the only significant sources of variance are the three main effects, Differences ($p < .001$), Orders ($p < .001$), and ISIs ($p < .05$). The operation of these variables can be more clearly understood by reference to Tables V: 2, V: 3, and V: 4. The effect of the Differences variable is as we might expect and reflects the relativity of judgement, that is <u>Ss</u> are consistently better at detecting a difference of 2:7 than one of 2:9. The Orders variable which, once again, accounts for a major portion of the variance is due to better performance

TABLE V: 2

MEAN NUMBER OF CORRECT RESPONSES, ON DIFFERENCE TRIALS IN TEMPORAL DIFFERENCE DETECTION TASK, AS RELATED TO SIZE OF DIFFERENCE.

	Size of difference	
	2 : 7	2 : 9
$\bar{X}$ correct	36.8	31.2

TABLE V: 3

MEAN NUMBER OF CORRECT RESPONSES, ON DIFFERENCE TRIALS IN TEMPORAL DIFFERENCE DETECTION TASK, AS RELATED TO ORDER OF STIMULUS PRESENTATION.

	Order of stimulus presentation	
	St - V	V - St
$\bar{X}$ correct	38.5	29.5

TABLE V: 4

MEAN NUMBER OF CORRECT RESPONSES, ON DIFFERENCE TRIALS IN TEMPORAL DIFFERENCE DETECTION TASK, AS RELATED TO ISI.

	ISI (Secs.)			
	1	2	4	6
$\bar{X}$ correct	66.7	70.8	67.7	62.0

on St - V trials than on V - St trials. The significance of the ISIs variable seems to reflect an optimal performance at the 2 sec. ISI.

The data from no-difference trials have been analysed in terms of the number of "shorter" and "longer" responses on trials of this type. These data have been analysed by a three way analysis of variance with Subjects, Responses ("shorter" V "longer"), and ISIs as main effects. The Subjects variable has again been broken down into a Groups and Individual differences component. This analysis is summarised in Table V: 5. It may be seen that ISIs ($p < .05$), Responses x ISIs ($p < .05$), and Groups x Responses x ISIs ($p < .001$) are significant sources of variance.

Interpretation of the significance of the ISI variable is facilitated by reference to Table V: 6. It would appear that rather fewer "equal" responses occur on no-difference trials at the 4 and 6 sec. ISIs. This finding may be interpreted as indicating some greater precision of judgement at 1 and 2 sec. ISIs as compared with the 4 and 6 sec. ISIs.

The Responses x ISIs interaction is also illustrated in Table V: 6. There is a preponderance of "longer" judgements at 1, 4 and 6 secs., but of "shorter" judgements at 2 secs.

TABLE V: 5

SUMMARY OF ANALYSIS OF VARIANCE OF NUMBERS OF "SHORTER" AND "LONGER" RESPONSES ON NO-DIFFERENCE TRIALS IN TEMPORAL DIFFERENCE DETECTION TASK

Source	d.f.	S.S.	M.S.	F	p
Subjects (S)	23	875.995			
Groups (G)	3	193.516	64.51	1.89	n.s.
Indiv. Dif. (ID)	20	682.479	34.12		
Responses (R)	1	76.255	76.26	2.07	n.s.
ISIs	3	98.599	32.87	3.66	.05
S x R	23	839.870			
G x R	3	102.391	34.13	<1	
ID x R	20	737.479	36.87		
S x ISI	69	675.276			
G x ISI	9	135.672	15.07	1.68	n.s.
ID x ISI	60	539.604	8.993		
R x ISI	3	154.141	51.38	3.94	.05
S x R x ISI	69	1,280.234			
G x R x ISI	9	497.964	55.33	4.24	.001
ID x R x ISI	60	782.270	13.04		
Total	191	4,000.370			

TABLE V: 6

MEAN NUMBER OF EACH KIND OF RESPONSE, ON NO-DIFFERENCE TRIALS IN TEMPORAL DIFFERENCE DETECTION TASK, AS RELATED TO ISI

Response	ISI (secs.)			
	1	2	4	6
"longer"	9.1	8.2	11.6	9.4
"shorter"	6.8	9.2	8.1	9.3
"equal"	32.1	30.6	28.3	29.3

The significant Groups x Responses x ISIs interaction is clarified by reference to Table V: 7. It would appear that an initial negative constant error tends to disappear with increased practice with the task.

TABLE V: 7

MEAN NUMBER OF EACH KIND OF RESPONSE, ON NO-DIFFERENCE TRIALS IN TEMPORAL DIFFERENCE DETECTION TRIALS, AS RELATED TO ORDER OF SESSION

Response	Order of session			
	1	2	3	4
"longer"	11.8	10.0	8.3	8.2
"shorter"	2.5	8.1	8.6	9.0
"equal"	28.7	29.9	31.1	30.8

Discussion

The results of this experiment again confirm the consistent finding that the operation of the order variable accounts for a large proportion of the variance in experiments of this type. The results fail to supply any evidence of a persistent decline in the precision of judgement with increasing ISI but they do confirm McGavren's (1965) finding of an optimal ISI; in this case 2 secs. as opposed to McGavren's finding of 1.5 secs. This is an interesting feature of the results which, on the basis of the present information, remains unexplained but, nevertheless, raises some intriguing questions. Is this effect peculiar to temporal judgements, or is it a general feature of psychophysical judgements which is usually obscured by the confounding of judgement time with ISI and duration of stimulus presentation? In a temporal discrimination situation S must wait until the stimulus is completed before he can commence the judgemental process whereas with other stimulus continua this is presumably not necessary. This means that the nominal ISI, in experiments using other than temporal stimuli, consistently underestimates the judgement time. The suggestion being advanced here is that the accurate perception or judgement of the first stimulus is a process extended in time, which may be interfered with if insufficient time is allowed. The findings of this and McGavren's experiment suggest that the duration of such a process might be between 1 and 2 secs.

This experiment again provides evidence of the effects of both ISI and practice on constant errors. In this experiment a negative constant error was found at all ISIs except 2 secs., whereas in the previous experiment a negative constant error occurred only at the 1 sec. ISI. The evidence concerning the practice variable is more consistent; in both cases it can be seen that an initial negative constant error disappears with practice.

By way of assessment of the method of difference detection it can be said that, impressionistically, the task appeared to be one which was readily accepted and carried out by Ss. A particular advantage of this method would seem to be that it would easily lend itself to self administration by S, thus saving time for E. It would, in principle, appear possible to place the whole experimental procedure, including instructions, on tape and to allow S to complete his own record sheet.

Comparison of the Difference Estimation and Difference Detection Tasks.

Having regard to the degree of experimental precision attained in these two experiments, the results appear to be very consistent. The major discrepancy in the results of the two experiments is the demonstration of an optimal ISI with the difference detection task but not with the difference estimation task. The possibility is therefore raised that this discrepancy is in some way systematically related to the difference between the two methods.

During the course of the experiment, and after discussing it with some Ss, it became clear to E that, although the stimulus intervals had been selected to be so short as to prevent counting, some Ss were, in fact, counting or using various other strategies to estimate and retain the length of the stimuli. Therefore the last 12 Ss to complete each experiment were specifically questioned, about their technique in carrying out the task, at the completion of the experiment. As a result of this questioning Ss were divided into those who used a purely passive approach to memorising the first stimulus of each trial as against those who used some form of active approach characterised by recoding the essential information in the first stimulus as soon as it was received. The nature of some of the active approaches was highly idiosyncratic, for example, thinking of the duration of the first stimulus in terms of a distance moved by the arm. The bulk of Ss using an active approach reported coding the length of the first stimulus by counting, by categorising into one of a small number of categories, or in terms of the length of a line. This last possibility seemed to be frequently suggested by the presence of the scale in the difference estimation task.

The number of Ss using each kind of approach in each experiment is tabulated in Table V: 8.

TABLE V: 8

NUMBER OF Ss EMPLOYING "ACTIVE" AND "PASSIVE" APPROACHES TO TEMPORAL DIFFERENCE DETECTION AND ESTIMATION TASKS

	"Active"	"Passive"
Difference estimation	9	3
Difference detection	4	8

The hypothesis of independence of the two variables may be rejected at the .05 level ($\chi^2 = 4.20$).
It may be concluded, therefore, that the demand characteristics of the two tasks are somewhat different and each task systematically encourages one approach rather than the other.

This finding in turn raises the question as to whether or not there is a significant difference in the performance of Ss using the two different approaches. Unfortunately the small numbers in both groups, plus the fact that the order in which the stimulus schedules were completed was not controlled between groups, prevents a precise statistical analysis. Nevertheless the performance of Ss using both approaches on each task have been graphically represented in Figs. V: 1 & 2, and the results are suggestive. Firstly the difference between the two approaches does not appear to account for optimal

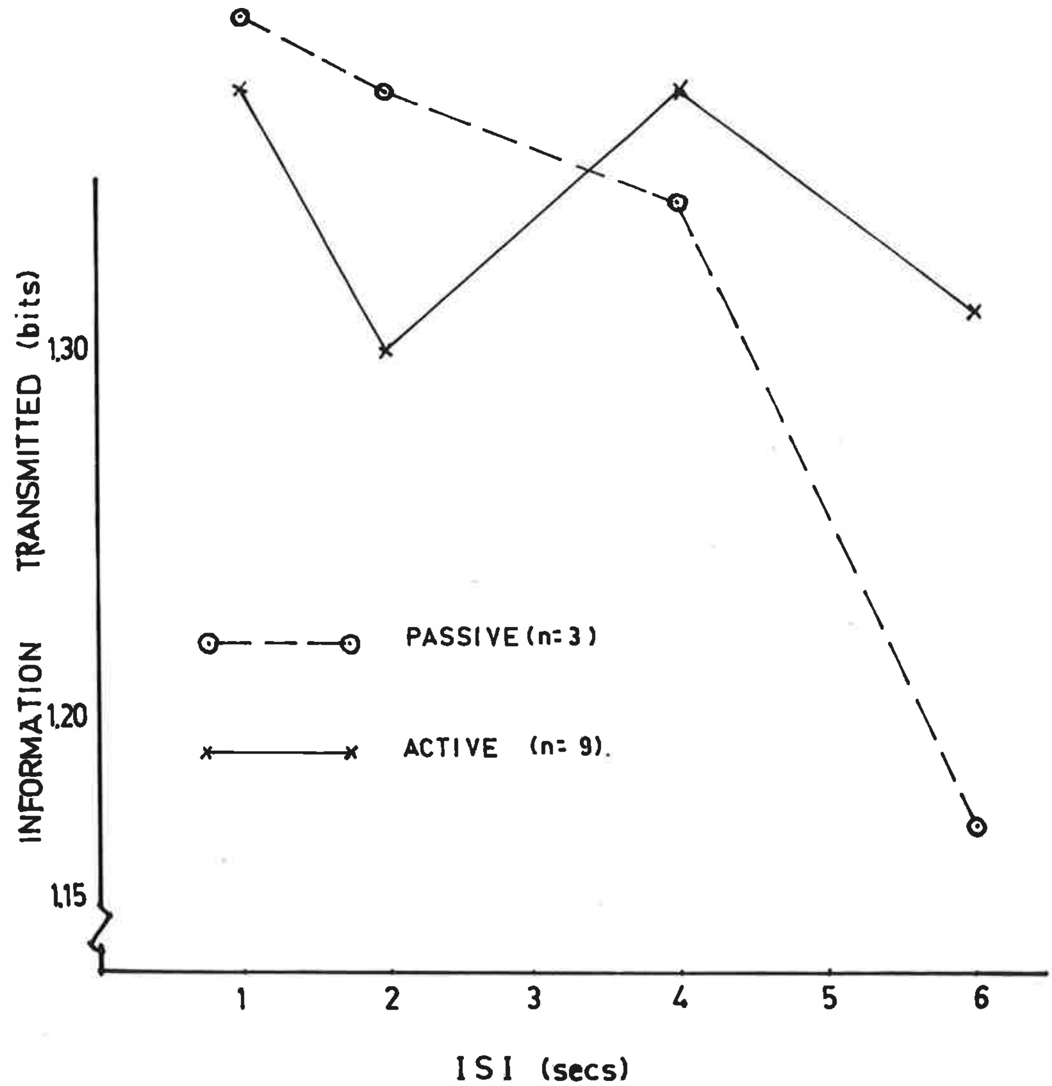

FIG. V:1 RELATIONSHIP BETWEEN MEAN INFORMATION TRANSMITTED PER TRIAL, ISI, AND APPROACH EMPLOYED BY S (TEMPORAL DIFFERENCE ESTIMATION TASK) performance at the 2 sec. ISI in the difference detection task; in the case of both tasks there does seem to be an active decline in performance, as ISI increases, for Ss using the "passive" approach, which is not matched by Ss using the "active" approach.

In the absence of more systematic evidence this interpretation is at best speculative but it does raise the point that performance in tasks of this kind may be mediated by conscious use of schematic representations of the stimulus situation. Furthermore it seems to follow that information coded in this way would be relatively immune to deterioration in storage. For this reason there might be reason to favour the difference detection, rather than the difference estimation task, in a study of short term storage. This task would appear to minimise the possibility of performance being determined by use of such mediating processes, although it is acknowledged that an understanding of such processes may be important in its own right.

Summary

The performance of 24 Ss in a temporal difference detection task is analysed and discussed. The Order variable is shown to account for a large proportion of the experimental variance. There is evidence of optimal precision of judgement with an

ISI of 2 sec. A predominantly negative constant error is shown to occur. An initial negative constant error is shown to decline with experience with the task. Some comparison is made of the difference detection and estimation tasks and it is argued that the former task may be, in some respects, more satisfactory.

CHAPTER VI

AUDITORY INTENSITY DIFFERENCE DETECTION

The aim of this experiment was to obtain precise information concerning the operation of the ISI variable on performance in a situation involving discrimination of auditory intensities. A decision was made to employ the difference detection method because this method lends itself to self administration by S and prior use of the method had indicated that it might be more satisfactory than the difference estimation method.

Method

The method and procedure utilised in this experiment were essentially the same as described for the temporal difference detection task (Chapter IV), with the following exceptions. A 300 ~ tone of fixed intensity (80d.b., s.p.l.) was employed as the St and the two values of the V stimulus were 3.75 d.b. plus and minus the value of St; preliminary pilot experiments had indicated that these values would provide a satisfactory level of difficulty. All stimuli were of 1 second duration.

A further group of 24 Psychology I students, fulfilling a course requirement, acted as Ss but in this case the task was self-administered. The instructions for the experiment were pre-recorded and played at the beginning of each stimulus schedule; S was also provided with a card (Appendix C) on which the instructions were printed. The inter-trial interval was 5 sec. and each trial was prefaced by a spoken "now" 1 sec. before it commenced. Responses for each trial were recorded by S on a pro-forma record sheet.

Results

The form of analysis of the results was identical with that used for the temporal difference detection experiment, i.e. separate analyses of variance of numbers of correct responses on difference trials, and numbers of "louder" and "softer" responses on no-difference trials. A summary of the former analysis of variance is to be seen in Table VI: 1; there are six sources of variance significant at better than the .001 level, namely Differences, Orders, ISIs, Differences x Orders, Differences x ISI and Orders x ISI.

The finding of a significant effect due to Differences in this experiment almost certainly reflects the poor calibration of the attenuators used to control stimulus intensity. These attenuators (L. M. Ericsson AIL) were calibrated in 5 d.b. steps and such a large step was shown in preliminary trials to be rather too great for the required purposes.

TABLE VI: 1.

SUMMARY OF ANALYSIS OF VARIANCE OF NUMBERS OF CORRECT RESPONSES ON DIFFERENCE TRIALS IN AUDITORY INTENSITY DIFFERENCE DETECTION TASK

Source	d.f.	S.S.	M.S.	F	p
Subjects (S)	23	461.708			
Groups (G)	3	83.208	27.74	1.47	
Indiv. Dif. (ID)	20	378.500	18.93		
Differences (D)	1	3,116.760	3,117.	402.	.001
Orders (O)	1	1,504.167	1,504.	309.	.001
ISIs	3	75.271	25.09	6.41	.001
S x D	23	198.115			
G x D	3	43.032	14.34	1.85	n.s.
ID x D	20	155.083	7.754		
S x O	23	115.208			
G x O	3	17.875	5.958	1.22	n.s.
ID x O	20	97.333	4.867		
S x ISI	69	287.354			
G x ISI	9	52.354	5.817	1.49	n.s.
ID x ISI	60	235.000	3.917		
D x O	1	1,046.761	1,047.	167.	.001
D x ISI	3	60.219	20.07	6.39	.001
O x ISI	3	83.604	27.87	7.90	.001
S x D x O	23	137.614			
G x D x O	3	12.114	4.038	<1	
ID x D x O	20	125.500	6.275		

TABLE VI: 1--Continued

Source	d.f.	S.S.	M.S.	F	p
S x D x ISI	69	228.906			
G x D x ISI	9	40.323	4.480	1.43	n.s.
ID x D x ISI	60	188.583	3.143		
S x O x ISI	69	256.521			
G x O x ISI	9	44.854	4.984	1.41	n.s.
ID x O x ISI	60	211.667	3.528		
D x O x ISI	3	11.218	3.739	<1	
S x D x O x ISI	69	282.407	4.093		
Total	383	7,865.833			

Accordingly an attempt was made to mark off $\frac{3}{4}$ of the 5 d.b. steps by visual means. The results of the experiment indicate that in doing this, equal steps above and below St have not been achieved. The Order effect is due to significantly more correct trials in the St-V order than in the V-St order (44.7 per session as against 36.8).

Reference to Table VI: 2 illustrates the operation of the ISI variable. It may be seen that not only is this a significant source of variance but there is an apparently regular decline in accuracy of judgement with increasing ISI.

TABLE VI: 2

MEAN NUMBER OF CORRECT RESPONSES, ON DIFFERENCE TRIALS IN AUDITORY INTENSITY DIFFERENCE DETECTION TASK, AS RELATED TO ISI

	ISI (secs.)			
	1	2	4	6
$\bar{X}$ correct responses	83.5	82.8	79.9	79.4

The mode of operation of the two interactions, Differences x ISI and Orders x ISI, is illustrated in Tables VI: 4 & 5. No obvious interpretation of these two effects can be suggested but it can be seen that in both cases the decline in performance with increasing ISI is greatest for the most difficult stimulus conditions. That is it appears as if the poorer the level of performance, the more easily it is disrupted by increase in ISI.

This consideration also appears to apply with respect to the Differences x Orders interaction, illustrated in Table VI: 3. A difference of -3.75 d.b. produces a lower level of performance than a difference of + 3.75 d.b.; performance in the V-St order is worse than performance in the St-V order, but when both of these conditions apply simultaneously in the case of -3.75 d.b. differences on V-St trials, there is a more than proportionate drop off in performance. On such trials the correct response would be "louder", and it would appear that the preponderance of "softer"

TABLE VI: 3

MEAN NUMBER OF CORRECT RESPONSES, PER SESSION, ON DIFFERENCE TRIALS IN AUDITORY INTENSITY DIFFERENCE DETECTION TASK, AS RELATED TO ORDER AND DIFFERENCE

		Order of stimulus presentation	
		St-V	V-St
Difference to be detected	St & + 3.75 d.b.	23.5	22.9
	St & - 3.75 d.b.	21.1	13.9

TABLE VI: 4

MEAN NUMBER OF CORRECT RESPONSES, ON DIFFERENCE TRIALS IN AUDITORY INTENSITY DIFFERENCE DETECTION TASK, AS RELATED TO ISI AND DIFFERENCE

		ISI (secs.)			
		1	2	4	6
Difference to be detected	St & + 3.75 d.b.	46.3	46.8	46.3	46.2
	St & - 3.75 d.b.	44.2	36.1	33.6	33.2

TABLE VI: 5

MEAN NUMBER OF CORRECT RESPONSES, ON DIFFERENCE TRIALS IN AUDITORY INTENSITY DIFFERENCE DETECTION TASK, AS RELATED TO ISI AND ORDER

		ISI (secs.)			
		1	2	4	6
Order	St-V	44.2	45.3	44.8	44.3
	V-St	39.3	37.6	35.1	35.1

responses or positive constant error observed in difference trials in this experiment is largely due to the poorer level of performance on these particular trials. The positive constant error observed in this experiment would, therefore, appear to be largely determined by the particular spacing of the V stimuli used.

A summary of the analysis of variance of the results of no-difference trials is presented in Table VI: 6; it will be seen that Responses and ISIs are the only significant sources of variance ($p < .001$). The operation of these variables is illustrated in Table VI: 7. The significance of the Responses variable can be accounted for by the larger overall number of "softer" responses; this means that the constant error in this experiment has been positive and this is also so for each individual ISI. It will be observed that as the ISI increases, the number of "equal" and therefore correct responses on no-difference trials decreases; this feature, which reflects the decline in precision of judgement with increasing ISI, accounts for the significance of the ISI variable.

Analysis of variance is insensitive to trend effects and although the Responses x ISIs interaction is not significant, inspection of Table VI: 7 suggests that as ISI increases, the relative discrepancy between the numbers of "softer" and "louder" responses decreases, or in other words, the size of the constant error decreases.

TABLE VI: 6

SUMMARY OF ANALYSIS OF VARIANCE OF NUMBERS OF "SOFTER" AND "LOUDER" RESPONSES ON NO-DIFFERENCE TRIALS IN AUDITORY INTENSITY DIFFERENCE DETECTION TASK

Source	d.f.	S.S.	M.S.	F	p
Subjects (S)	23	1,364.417			
Groups (G)	3	283.792	94.60	1.75	n.s.
Indiv. Dif. (ID)	20	1,080.625	54.03		
Responses (R)	1	192.000	192.0	15.8	.001
ISIs	3	400.833	133.6	22.7	.001
S x R	23	245.250			
G x R	3	1.375	.4583	<1	
ID x R	20	243.875	12.19		
S x ISI	69	379.417			
G x ISI	9	26.875	2.986	<1	
ID x ISI	60	352.542	5.876		
R x ISI	3	23.167	7.722	<1	
S x R x ISI	69	688.583			
G x R x ISI	9	97.625	10.85	1.10	n.s.
ID x R x ISI	60	590.958	9.849		
Total	191	3,293.667			

TABLE VI: 7

MEAN NUMBER OF EACH TYPE OF RESPONSE, ON NO-DIFFERENCE TRIALS IN AUDITORY INTENSITY DIFFERENCE DETECTION TASK, AS RELATED TO ISI

Response	ISI (secs.)			
	1	2	4	6
"louder"	2.7	4.1	5.0	7.3
"softer"	5.0	6.3	7.7	8.2
"equal"	40.3	37.6	35.3	32.5

Discussion

Several observations on the general nature of the experiment seem to be justified. Firstly the difference to be detected of 3.75 d.b. which had appeared to be satisfactory in preliminary experiments was, in fact, rather too large, since the number of errors made was in some circumstances quite small. The precision of the experiment would have been improved if the difficulty of the detection task had been increased. The results of the experiment and observation by E during the course of the experiment demonstrate that it is quite feasible to design psychophysical experiments of this kind to be self administered by S with a consequent economy of effort.

The major findings of the experiment concern the effects of the ISI variable on both variable and constant errors. It seems clear that as ISI increases there is both a decline in the precision of judgement and the size of the constant error. The constant error observed in this experiment was positive whereas previous studies involving comparisons of auditory intensities have usually reported negative constant errors. The reason for this discrepancy cannot be explained on the basis of the available information but the most likely explanation would seem to be bound up with the fact that the V stimuli have not been placed symmetrically about St, even on a log scale. Inadvertently the V stimuli have been chosen so that there is a very much larger difference between St and the more intense V stimulus than between St and the less intense V stimulus.

No evidence was obtained during this experiment of any effects on either constant or variable errors attributable to practice. This is in marked contrast to the results from the temporal discrimination tasks where it was shown that constant errors tend to be diminished with practice. This finding, together with the different effects of ISI on discrimination performance on the two stimulus continua, supports the view that there are qualitative differences in the processes underlying discrimination on the two continua. An additional observation also supports this view. At the completion of the experiment Ss were again classified on the basis of interview responses into those who adopted "active" and "passive" approaches to the task. Six of the 24 Ss reported using some form of "active" approach. A comparison of the numbers using the two approaches in this experiment and both of the temporal discrimination experiments is presented in Table VI: 8.

TABLE VI: 8

NUMBER OF SUBJECTS USING "ACTIVE" AND "PASSIVE" TECHNIQUES IN TEMPORAL DURATION, AND AUDITORY INTENSITY DISCRIMINATION EXPERIMENTS

	"Active"	"Passive"
Auditory intensity	6	18
Temporal duration	13	11

$\chi^2 = 4.269 \quad p < .05$

The table yields a $\chi^2 = 4.269$ ($p < .05$) indicating a significantly greater number of Ss using an "active" approach in the temporal discrimination task. It would, therefore, appear that there is something in the nature of this stimulus continuum which influences Ss to use some form of conscious coding of the stimulus material. Unlike the temporal discrimination tasks inspection of the data comparing performance of "active" and "passive" Ss in the auditory intensity task gives no suggestion of any essential differences in performance.

Summary

A difference detection task using auditory intensities as stimuli and carried out by 24 *S*s is described and the data analysed. It was shown that ISI had effects on both variable and constant errors: the variable error increased with increasing ISI: the constant error, which was consistently positive, diminished with increasing ISI. Both constant and variable errors were shown to be unaffected by practice.

CHAPTER VII

RELATIVE DISCRIMINABILITY OF AUDITORY INTENSITIES IN A MAGNITUDE ESTIMATION TASK

The fact that category rating scales of prothetic stimulus continua are non linear as compared with ratio scales has been attributed by Stevens (1957) to the relativity of discrimination and the consequent inequalities in discriminability, for equal stimulus differences, over different parts of the stimulus range. Since magnitude estimates are purported to be uninfluenced by the relativity of discrimination, it may be inferred that the consistency of magnitude estimates of stimuli and hence discriminability of those stimuli, would be independent of their position on the stimulus scale. The aim of this experiment was to determine if this is indeed so.

Experiment One

Method

The data for this experiment were gathered from a group of Psychology IIA students (n = 35) at the commencement of a routine laboratory period. The Ss were naive with respect to the purpose of the experiment. The stimuli were produced by amplification of the signal from an audio signal generator. The generator produced a 1,000 ~ signal of fixed amplitude; intensity of the signal was manipulated by an attenuator incorporated in the circuit and ten different stimulus intensities each spaced 5 d.b. apart were used in this experiment. The intensity of the softest stimulus was such that it could just be clearly heard in all parts of the laboratory; an automatic timer enabled stimuli to be presented for a standard duration of 2 sec.

The following instructions were read to Ss: "Your aim in this experiment is to estimate the loudness of sounds. We are going to call the loudness of this sound ten". The 20 d.b. attenuated stimulus was then presented once. "You should describe the loudness of the other sounds which occur during the experiment by assigning to them an appropriate number. Thus if they are louder than the sound you just heard you give a number greater than ten; if they are softer you give a number smaller than ten. You have got to give the loudness of each sound the number which you think is most appropriate. Use whatever numbers seem best to you - fractions, decimals or whole numbers. Try not to worry about being consistent; try to give each sound the appropriate number regardless of what you did on the previous trial". At the completion of the instructions there was one additional presentation of the 20 d.b. stimulus, together with the instruction that it be called "ten".

The experiment consisted of 110 trials made up of eleven blocks of ten trials; in each block each stimulus was presented once and a different random order of stimuli was used for each block. Only the results of the final 100 trials were utilised in the major analysis. Responses were recorded on pro-forma record sheets by individual Ss.

Results

Scale values were computed for each stimulus value by determining the mean scale values for each S. The medians of these scale values were then determined and are presented in Table VII: 1. The use of the

TABLE VII: 1

MEDIAN OF SUBJECTS' MEAN MAGNITUDE ESTIMATES OF AUDITORY INTENSITIES (First Experiment)

Stimulus Intensity (d.b. of attenuation)

45	40	35	30	25	20	15	10	5	0
1.1	2.0	3.2	4.9	7.0	9.3	12.1	14.8	18.5	22.1

median as a measure of central tendency is the procedure recommended by Stevens (1961) and it is justified on the grounds that it produces a more stable measure of central tendency than the mean. The obtained scale values from this experiment have been plotted on log log coordinates in Fig. VII: 1. Inspection of this function suggests that it is regularly curvilinear, although Stevens has predicted that such functions should be linear.

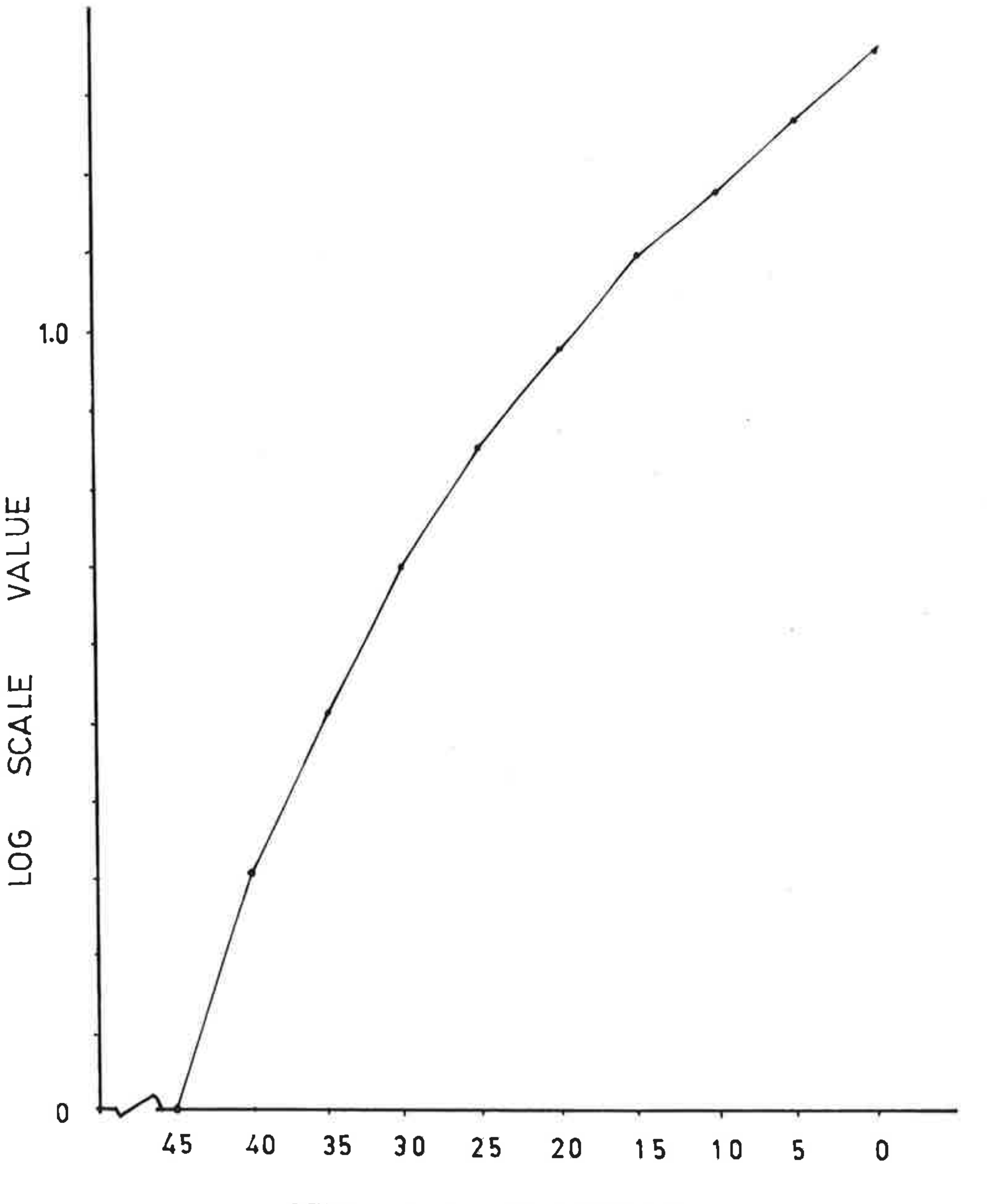

FIG. VII:1 RELATIONSHIP BETWEEN LOG SCALE VALUES AND LOG STIMULUS INTENSITY (MAGNITUDE ESTIMATION TASK: FIRST EXPERIMENT)

Consistency of magnitude estimates was determined by drawing up individual confusion matrices for each _S_ and computing the conditional (response) uncertainty associated with each stimulus. The means of these values, together with the associated standard errors, are presented in Table VII: 2; the same data

TABLE VII: 2

MEAN RESPONSE UNCERTAINTY IN BITS ASSOCIATED WITH EACH VALUE OF STIMULUS TOGETHER WITH STANDARD ERRORS OF THOSE MEANS (First Experiment)

	Stimulus Intensity (d.b. of attenuation)									
	45	40	35	30	25	20	15	10	5	0
$\overline{X}$	1.09	1.69	2.06	2.24	2.25	2.07	2.27	2.18	2.05	1.76
S.E.M.	.12	.088	.080	.074	.095	.11	.088	.088	.099	.13

are represented graphically in Fig. VII: 2. It can be seen that the function is not a straight line parallel to the X axis, as might be predicted from Stevens' views, but rather is it curvilinear with some perturbation associated with the stimulus utilised as the reference value (i.e. 20 d.b.).

A further analysis was carried out to obtain a picture of the conditional uncertainty associated with the response scale. Since each _S_ utilised his own modulus, this analysis was rather more complex than the previous one. The stimulus uncertainty was computed for each response used by each _S_. The response scale above and below the value ten was then divided into five equal parts for each S and the mean stimulus uncertainty for responses within each of these parts was computed. A grand mean was then determined showing the mean stimulus uncertainty associated with responses in each fifth of both halves of the response scale. This information is tabulated in Table VII: 3, and graphically represented in Fig.VII: 3.

TABLE VII: 3

MEAN STIMULUS UNCERTAINTY PER RESPONSE IN BITS ASSOCIATED WITH EACH FIFTH OF THE RESPONSE SCALE ABOVE AND BELOW THE RESPONSE "10" TOGETHER WITH STANDARD ERRORS OF THESE MEANS
(First Experiment)

	Part of response scale									
	Below "10"					Above "10"				
$\bar{X}$	1.04	1.30	1.30	1.13	.87	.65	.82	.73	.70	.47
S.E.M.	.087	.097	.10	.088	.11	.10	.091	.077	.076	.076

The graph suggests that there is a curvilinear relationship between these two variables for each half of the response scale and demonstrates quite markedly that there is a consistently higher uncertainty associated with the use of the bottom half of the response scale.

Discussion

Since the major aim of this experiment has been to study the variance or uncertainty of judgements, a relatively large number of repetitions of each individual stimulus have been employed. Stevens has typically utilised data from only two repetitions of each individual stimulus and it might reasonably be objected that the findings obtained in this experiment merely reflect prolonged repetition of individual stimuli. In anticipation of this objection the data from the first two repetitions of each stimulus have been analysed in order to determine the number of Ss giving the same response to each individual stimulus on these first two trials. This information is tabulated in Table VII: 4, and it can be seen that the general picture derived from a consideration of the first two repetitions is consistent with the picture derived from the experiment as a whole.

TABLE VII: 4

NUMBERS OF Ss GIVING THE SAME RESPONSE TO VARIOUS STIMULI ON THE FIRST TWO REPETITIONS IN MAGNITUDE ESTIMATION TASK
(First Experiment n = 35)

	Stimulus (d.b. attenuation)									
	45	40	35	30	25	20	15	10	5	0
No.	22	11	6	2	12	8	6	6	8	16

Since the stimulus uncertainty and response uncertainty measures are merely two aspects of the same data and are not logically independent (Dawes 1963), no unequivocal interpretation of these findings can be made. It could be suggested, for example, that the markedly higher stimulus uncertainty values associated with responses below the standard of 10 reflect less facility in the use of the small numbers, particularly decimals and fractions, which most Ss chose to employ. On the other hand it might equally well be maintained that the primary phenomenon is that of relatively small response uncertainty values being associated with stimuli at the bottom end of the stimulus array. This question can only be answered by independently manipulating either stimulus or response factors while maintaining the other constant. The second magnitude estimation experiment aimed to resolve this equivocality and it was decided to do this by manipulation of the response system while maintaining stimulus factors constant.

Experiment Two

Method

The method employed was essentially the same as that used in the first experiment but with the provision that in the initial instructions Ss were told to call the 20 d.b. or standard stimulus "100".

Forty Ss completed the experiment in two independent groups of twenty. These Ss were drawn from the same population as those used in the previous experiment but had had no previous class contact with E. For this reason it might be expected that the level of rapport achieved by E with this group was rather less than that achieved with the previous group.

Results

Stimulus uncertainty and response uncertainty values were calculated for this data in the same way as previously described. These data are presented in Tables VII: 5 & 6 and Figs. VII: 4 & 5.

TABLE VII: 5

MEAN RESPONSE UNCERTAINTY IN BITS ASSOCIATED WITH EACH VALUE OF STIMULUS (Second Experiment)

Stimulus (d.b. of attenuation)

45	40	35	30	25	20	15	10	5	0
1.77	2.10	2.30	2.38	2.37	2.37	2.40	2.34	2.11	2.01

TABLE VII: 6

MEAN STIMULUS UNCERTAINTY PER RESPONSE IN BITS ASSOCIATED WITH EACH FIFTH OF THE RESPONSE SCALE ABOVE AND BELOW THE RESPONSE "100" (Second Experiment)

Part of response scale

Below 100					Above 100				
1.11	1.37	1.22	1.10	.91	.78	.73	.85	.61	.32

It can be seen that, although the response uncertainty measures are higher and the stimulus uncertainty measures are lower than those from the previous experiment, a fact which may perhaps be attributed to motivational differences, the general form of the two functions is the same. That is, there is relatively less response uncertainty about stimuli at the bottom of the stimulus

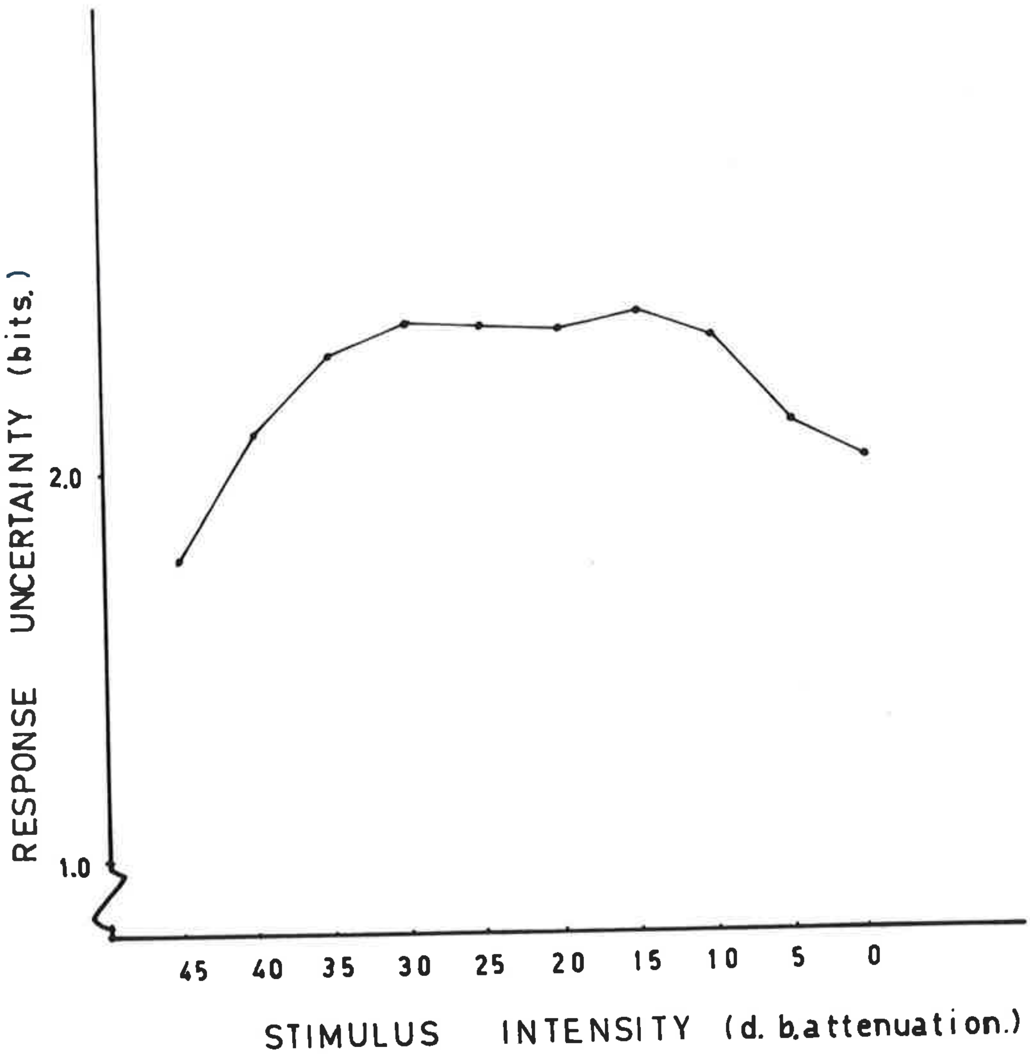

FIG. VII:4 RELATIONSHIP BETWEEN RESPONSE UNCERTAINTY AND STIMULUS INTENSITY (SECOND EXPERIMENT)

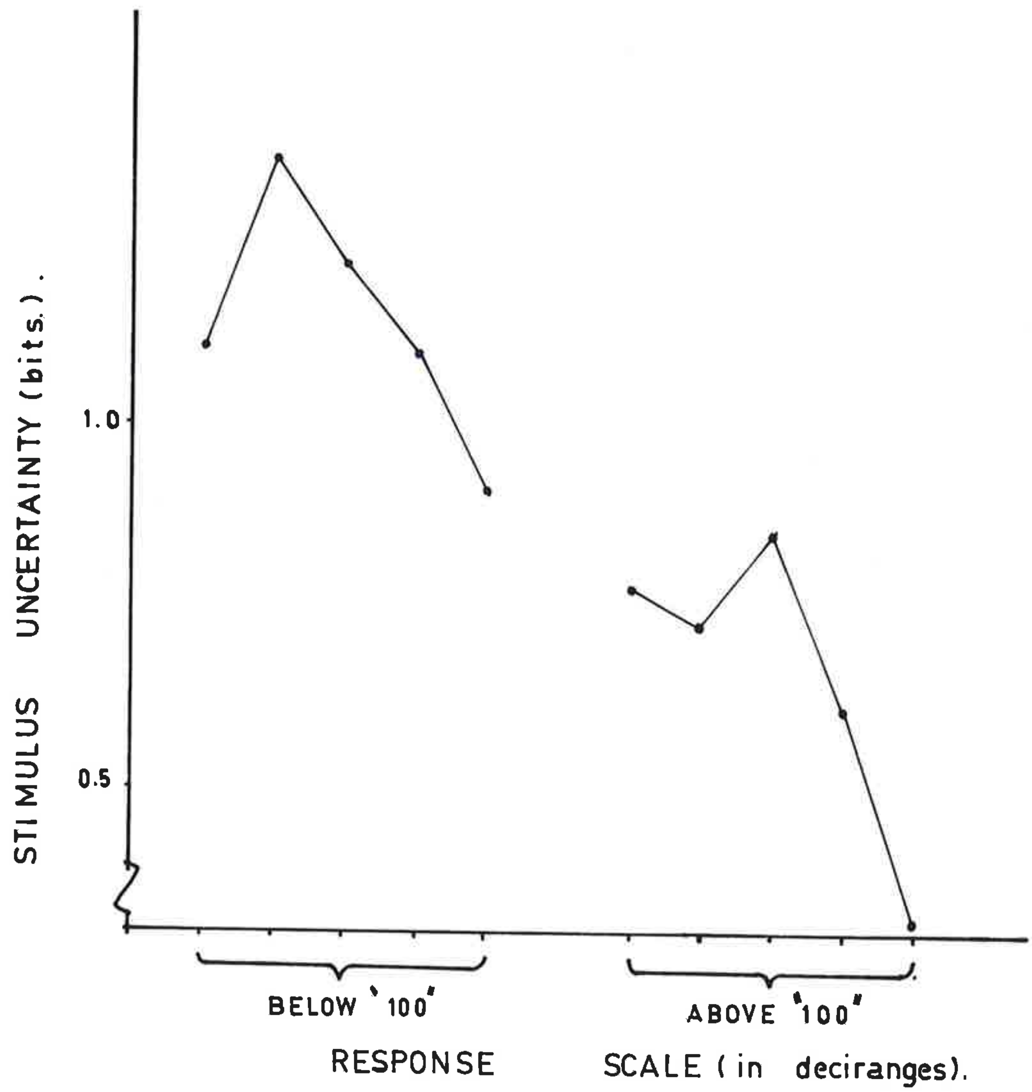

FIG. VII:5 RELATIONSHIP BETWEEN STIMULUS UNCERTAINTY AND POSITION OF RESPONSE ON RESPONSE SCALE (SECOND EXPERIMENT) array and relatively more stimulus uncertainty about responses below the standard of 100. It would, therefore, seem that we are justified in concluding that the asymmetry of the response uncertainty function reflects genuine stimulus factors. In Table VII: 7 details have been provided of the number of Ss giving the same response to the various individual stimuli on their first two repetitions in this experiment.

TABLE VII: 7

NUMBER OF Ss GIVING THE SAME RESPONSE TO VARIOUS STIMULI ON THE FIRST TWO REPETITIONS IN MAGNITUDE ESTIMATION TASK
(Second Experiment n = 40)

Stimulus (d.b. attenuation)

45	40	35	30	25	20	15	10	5	0
15	3	4	-	7	2	2	2	4	10

The pattern is clearly similar to that shown in the results of the first experiment although once again the overall level of performance is not as good.

Discussion

The results of this experiment are in many respects surprising since they are clearly inconsistent with Stevens' analysis of the magnitude estimation task. The finding that the relationship between scale values and stimulus values is apparently not linear in this case can only be noted and no obvious explanation of this apparent discrepancy suggests itself.

What does appear to be of considerable significance is the finding that the function linking response uncertainty and stimulus value has the shape of an inverted U. Since at the commencement of the experiment all stimuli, with the exception of St, were equally unfamiliar to Ss, it can only be concluded that over the course of the experiment Ss have differentiated out some stimuli rather better than others, or in other words that some sort of learning has taken place. A consideration of the findings from the first two repetitions of each stimulus indicates that this learning or differentiation must take place very rapidly since it is already in evidence at this stage of the experiment.

To the extent that the different stimuli in the stimulus array have associated with them different response uncertainty values, it would seem that S must have built up some internalised schematic representation or model of the stimulus array. The function describing the relationship between stimulus value and response uncertainty can be thought of as representing the properties or structure of this schema or model.

The most obvious feature of the schema or model is its asymmetry; that is there is relatively less uncertainty associated with stimuli at the bottom end of the stimulus array than those at the top; the question might well be asked as to why this should be. The stimuli in this stimulus array are equally spaced on a d.b. scale and are all, therefore, at the same relative distance from those stimuli adjoining them, however the stimuli at the bottom end of the array are at relatively greater distances from the bottom most stimulus and should, therefore, be relatively better differentiated from it, than the stimuli at the top end of the array are from the top most stimulus. If the bottom most and top most stimuli of the array were in some way serving as reference points by means of which the remaining stimuli were located we would expect a relationship between response uncertainty and position in the stimulus array such as has been obtained.

At the commencement of the task it is clear that S must use the standard or 20 d.b. stimulus as a reference point and the dip in the response uncertainty curve associated with this value (rather more marked in the case of the first experiment than the second) would seem to indicate that at least to some extent he continues to do so over the course of the experiment. However the evidence would seem to suggest that this stimulus is quickly replaced as the primary reference point by the two extreme stimuli of the array and quite probably continues to lose its significance as a reference point over the course of the experiment. Nevertheless some better differentiation of this stimulus than its neighbours appears to persist over the course of the experiment and, if this is thought of as an example of retention, it is quite remarkable in view of the interference which one might expect to result from the many presentations of the other stimuli.

It may be noted in Tables VII 4 & 7 that over the first two trials there is less response uncertainty about the 25 d.b. stimulus than the 20 d.b. stimulus which served as a standard. No unequivocal interpretation of this finding can be made but it does seem to suggest that the standard is being confused with a stimulus which lies nearer to the subjective mid-point of the stimulus array; that is a point which is at the same relative difference from the bottom most stimulus as it is from the top most stimulus. If this interpretation were correct we would not expect to find such a constant error in an experiment in which the subjective mid-point of the response array was chosen as the standard.

The findings of this experiment seem to have some relevance for a number of current psychological issues. Firstly they seem to support the view recently advanced by workers such as Ebenholz (1965), Jensen (1962) and Murdock (1960) that in all tasks involving learning of items differentiated in terms of a single dimension, items are differentially learned according to their position on the dimension. Items at the extreme ends are rather better learned than the others; this gives rise to an inverted U shaped relationship between amount of learning and position on the stimulus dimension. In the context of serial rote learning the effect is the well known serial position effect.

The second implication of the findings bears on the Gibson-Bruner controversy about the nature of perceptual learning: the Gibsons (Gibson, J.J. and E.J., 1955) have favoured a "differentiation" view while Bruner (1957) has favoured an "enrichment" view. These results seem to indicate quite firmly that some of the stimuli have been differentiated from each other purely as a result of repetition. This is not to say that some form of associational learning between stimuli and responses might not also have taken place but the form of data analysis does not lend itself to answering this question.

One implication of the response uncertainty-stimulus magnitude function concerns the properties of the distribution of judgements which will be made about the individual stimuli. If three stimuli, A, B and C, are considered and the stimulus uncertainty of A $>$ B $>$ C, it must follow that in making judgements of B it will be confused more often with A than with C. In other words judgements of B will not be symmetrically distributed but will be skewed in the direction of A. When distributions are appreciably skewed the use of the mean or the median as a measure of central tendency introduces a systematic bias. An effect of this kind seems to underly one feature of magnitude estimation functions. It has been pointed out by Ross and DiLollo (1966) that, on closer inspection, many magnitude estimation functions are not linear on log log coordinates but show definite evidence of two discontinuities, one below and one above the mid-point. That is the function is a composite one, made up of three separate linear functions; the results of this experiment suggest how these discontinuities come about. The three separate functions are each associated with three different reference points, the two end stimuli of the array and the original reference stimulus. The systematic bias involved in the use of the median as a measure of central tendency will operate in opposite directions for each of these adjoining functions and consequently at the point at which the functions join, a discontinuity will be observed.

Summary

Two experiments involving magnitude estimations of auditory intensities are described and the results analysed. The results lend no support to Stevens' views that the consistency of magnitude estimates of stimuli is independent of their position in the stimulus range. The results are interpreted as supporting the view that in tasks of this kind performance is mediated by an internalised schematic representation or model of the stimulus array. The properties of this model or schema are described.

CHAPTER VIII

RELATIVE DISCRIMINABILITY OF AUDITORY INTENSITIES IN A CATEGORY RATING TASK

Since a close analysis of the consistency of magnitude estimates of auditory intensities showed (Chapter VII) that this variable was lawfully related to the position of the stimulus on the stimulus scale and not independent of it, as Stevens has suggested, the question is raised as to the relationship between consistency of category ratings and scale position. Established theoretical positions might lead to two different predictions being made about the relationship between these two variables.

Helson (1964) has employed the construct of adaptation level as the basis of a theoretical formulation, the generality of which is purportedly wide. As operationally defined, in quantitative terms, the construct has had some measure of success in predicting the outcome of certain types of psychophysical experiments but it may be noted that even in this respect the construct has been criticised (e.g. Parducci, 1965). It would appear that for Helson the status of the concept of the adaptation level goes far beyond that of mere operational definition and it is to be strongly inferred from his writings that he attributes to this construct some palpable psychological reality, and sees it as mediating all behaviour. Since the adaptation level is regarded as having such signal importance and is represented as serving as a kind of standard or reference point against which all other stimulus inputs are assessed, it would seem reasonable to expect that the consistency or precision of judgement would be greatest for stimuli at the adaptation level and increase as the value of the stimulus departed from this level.

An alternative prediction has been made by Stevens (1957); category judgements are, according to him, influenced by the relativity of judgement and a given difference is more noticeable or discriminable at the bottom end of the scale than at the top. It might be expected, therefore, that in a category rating task the maximum consistency of judgement would be associated with the smallest stimulus values and that precision of judgement would decrease as stimulus value increases.

The aim of the following experiment was to obtain a set of data which could be analysed to reveal which, if either, of these two predictions would be substantiated.

Method

The conditions and procedure of this experiment were, with the exception of the instructions, in all ways identical with those employed in the first repetition of the previous experiment; Ss (n = 36) were drawn from the same population.

The instructions were read aloud and were as follows: "Your aim in this experiment is to make judgements about the intensities of sounds. You are to make your judgements about each sound by assigning it to one of seven categories from "one" for the softest or faintest sounds, to "seven" for the loudest or most intense sounds. On each trial assign to the sound that number between one and seven which you think is most appropriate. To help you in the task and to give you some idea of the range of stimuli to be employed, I will demonstrate the loudest and softest sounds to be used." A demonstration of the loudest and softest sounds then followed.

Results

Results from individual Ss were summed and are tabulated in Table VIII: 1. This table also contains the obtained mean stimulus uncertainty and response uncertainty per trial, and scale values derived from the group data; no analyses of the data from individual Ss has been carried out but there are no reasons for expecting that a purely group analysis obscures any important relationships.

In Fig. VIII: 1 the relationship between the scale values, for the same set of stimuli, arrived at by magnitude estimation (Chapter VII) and category

TABLE VIII: 1

NUMBERS OF PARTICULAR CATEGORY RESPONSES OF AUDITORY LOUDNESS ARRANGED ACCORDING TO STIMULUS INTENSITY
(n = 36; 10 responses per stimulus per S)

Response	Stimulus intensity (d.b. attenuation)										n	$\bar{X}$ Stimulus uncertainty per trial
	45	40	35	30	25	20	15	10	5	0		
1	347	235	72	13	4	1					672	1.53
2	13	115	244	191	64	20					647	2.09
3		10	36	137	202	151	37	2			575	2.16
4			7	15	75	155	158	30		1	441	2.04
5			1	4	14	31	147	184	18		399	1.79
6					1	2	18	142	215	50	428	1.64
7								2	127	309	438	.91
n	360	360	360	360	360	360	360	360	360	360		
Scale value	1.04	1.38	1.95	2.46	3.09	3.58	4.41	5.31	6.30	6.85		
$\bar{X}$ Response uncertainty per trial	.22	1.07	1.31	1.45	1.66	1.66	1.60	1.41	1.19	.61		

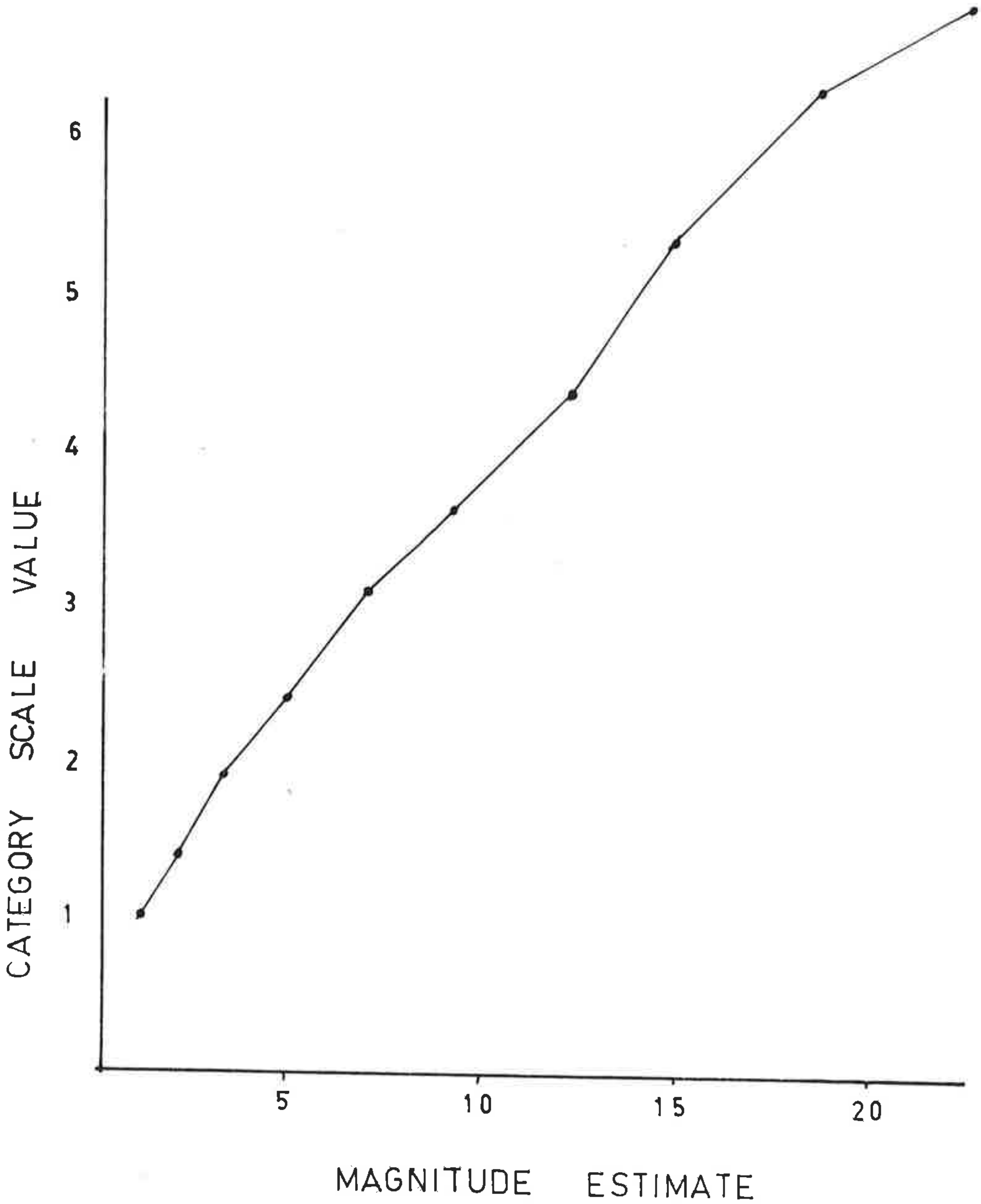

FIG. VIII:1 RELATIONSHIP BETWEEN CATEGORY SCALE VALUES AND MAGNITUDE ESTIMATES OF LOUDNESS

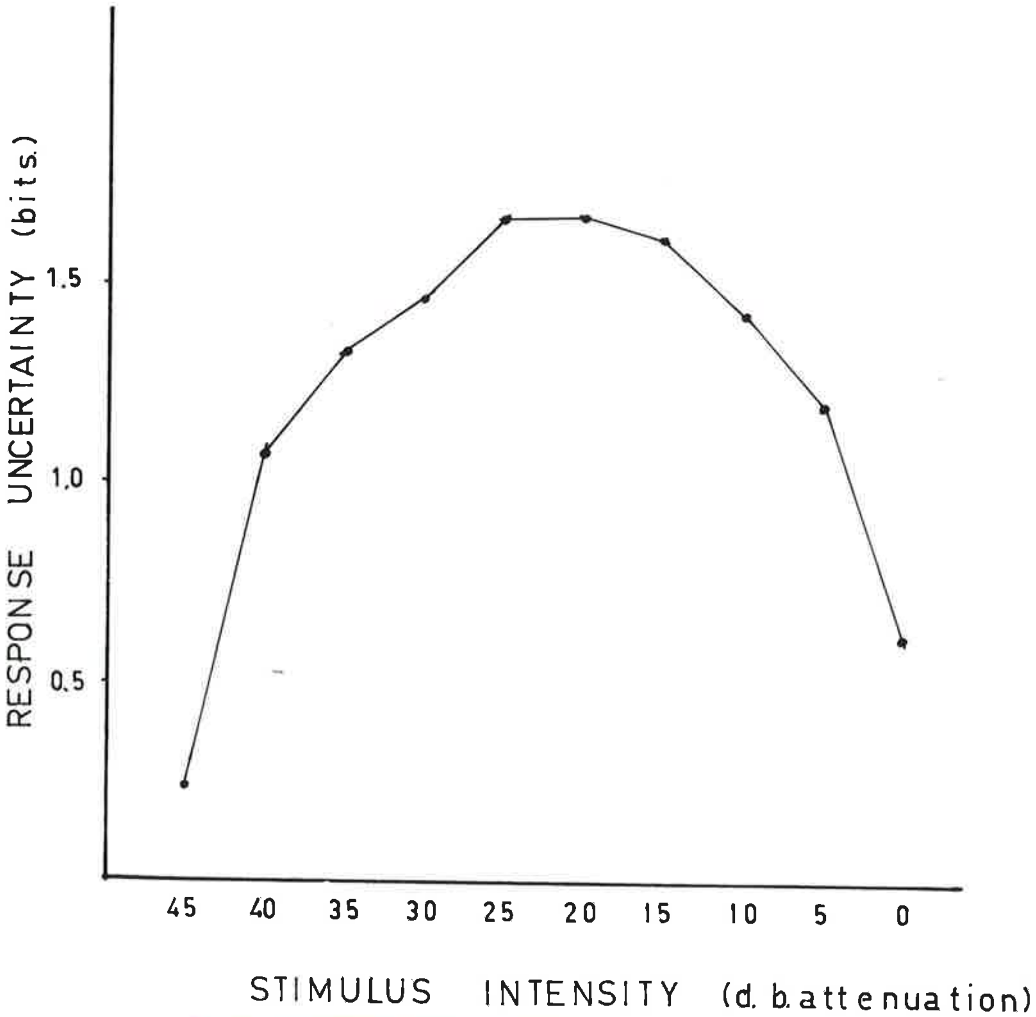

FIG. VIII:2 RELATIONSHIP BETWEEN RESPONSE UNCERTAINTY AND STIMULUS INTENSITY (CATEGORY RATING TASK) rating have been shown. It will be seen that the obtained curve is concave downwards as predicted by Stevens.

In Fig. VIII : 2 the relationship between mean response uncertainty per trial and stimulus value have been plotted: it will be seen that this function has an inverted U shape. It is not a continuously increasing function of stimulus value as predicted by Stevens, nor does the function exhibit a minimal value at the adaptation level as would be predicted by Helson.

Inspection of Table VIII : 1 shows that the relationship between value of response and mean stimulus uncertainty per trial is of the same inverted U shaped kind.

Discussion

The results obtained from this experiment appear to replicate in certain respects those found by Garner (1953) in an analysis of absolute judgements of loudness and by Eriksen & Hake (1955) in an analysis of absolute and category judgements of the size of squares. In all three of these experiments, the one described above and those of Garner and of Eriksen and Hake the same inverted

U shaped function linking response uncertainty and stimulus value has emerged.

This would seem to indicate that although the absolute judgement and rating methods have sometimes been regarded as being only superficially similar (Garner 1962) they are in fact essentially the same. Furthermore this similarity appears to exist between those methods in which the response system of S is restricted as in category rating and absolute judgement and those in which S is free to choose his own response system (e.g. magnitude estimation). It will be recalled that in the previous experiment on magnitude estimation of loudness the same inverted U shaped function was observed. This relationship appears to be inconsistent with the accounts of the judgemental situation offered by either Stevens or Helson since the discriminability of individual stimuli is clearly related to their position within the stimulus array and is least rather than greatest at the centre of the array (the adaptation level).

The question arises as to what type of psychological mechanism might produce the relative differences in the differentiation of the stimuli which is reflected in the observed relationship between stimulus value and response uncertainty. It will be recalled that during the instructions Ss were provided with examples of both the softest and loudest stimuli to be used and it could be argued that it was this experience alone which accounts for this differentiation. Having regard to the results of the previous experiment it would seem more reasonable to attribute this differentiation primarily to S's experience of the stimuli during the course of the experiment, while still acknowledging that the initial instructions may also have had some similar effect.

Helson has suggested that Ss use some middle value of the stimulus range (the adaptation level) as a form of reference point on which to base their judgements. These results suggest that, if indeed S does use reference points on which to base his judgements, he must use the two end values of the stimulus range. If it is assumed that S does use some internalised representation of the values of the two end stimuli on which to base his judgements it would follow that there is not one function linking stimulus value and scale value but two, one function associated with stimuli in the bottom part of the stimulus range judged with reference to the smallest stimulus and one associated with stimuli in the top part of the stimulus range and judged with reference to the greatest stimulus. It would appear that when S is required to divide up his response scale in this situation, he does so by allocating equal scale distances to the two semi-scales which make up the composite scale. This means that the middle of the response scale will be assigned to a stimulus which is the same relative distance from the two end stimuli. This condition will be met if the middle scale value is assigned to a stimulus equal to the log mean of the two end stimuli. As a consequence of this division of the response scale, one scale unit at the top of the response scale will be equivalent to a greater distance on the stimulus scale than one scale unit at the bottom of the response scale; that is the top part of the response scale is compressed relative to the bottom.

An additional consideration would seem to further complicate the nature of the scale value - stimulus value function. Because the response scale is fixed in a category rating task, the distribution of responses is in effect truncated at both ends of the scale; there can, for example, be no response smaller than "one" or greater than "seven", even though on occasions, S may wish to employ them. It frequently happens during the conduct of experiments of this kind that Ss will facetiously give a response like "minus one" or "eight" and underlying the use of such responses would appear to be S's appreciation of the limitations on his performance which are imposed by the form of the response scale.

The effect of such a truncated response scale will be to give rise to relatively heightened scale values at the bottom end of the stimulus scale and relatively depressed scale values at the top end.

When both of these factors are taken into account it can be seen that the empirical function linking stimulus values and scale values might be expected to have the form of a rather irregular curve which, at least to a first approximation, might be described as being concave downwards, but with some evidence of irregularities associated with stimulus value at the extreme end of the range. Inspection of a large number of such empirical curves confirms that they do seem to have such a general shape.

An additional way in which the effects of the truncation of the response distributions at both ends of the category scale reveals itself is in the relatively greater slope of the two arms of the response uncertainty-stimulus intensity function in the category rating task as compared with the magnitude estimation task. This can be checked by comparing Figs. VII:2 & VIII: 2. Since S is, in this task, more restricted in the responses which can be used to stimuli at the end of the stimulus array, there is a corresponding reduction in the response uncertainty associated with these stimuli as compared to a situation in which no such restrictions operate.

The results of this experiment and the previous magnitude estimation experiments are substantially the same with respect to the response uncertainty - stimulus magnitude relationship and it would, therefore, appear that the process or mechanism of discrimination employed in these two situations is also substantially the same. It is, therefore, to be inferred that the differences between magnitude estimation scales and category rating scales do not reflect, as Stevens has suggested, any fundamental difference in the nature of the discriminations which S is called upon to make in the two situations but rather do they reflect differences in the properties of the response systems which S utilises in the two situations.

The factors which seem to determine the properties of the response system in category rating tasks have already been mentioned. In the magnitude estimation task, although S is given an initial reference stimulus near the middle of the stimulus range, the two end stimuli of the array soon came to act as the major reference points and in this situation too the scale obtained is really a composite one. The important difference between this situation and the category rating situation is that no restrictions are placed on S's response system and the response scale appears to be chosen so that it has consistent properties over the whole range, whereas in the category rating situation the top semi-scale is compressed relative to the bottom semi-scale. As a consequence of this, when the category scale values are plotted against the ratio scale values, the function is concave downwards.

Summary

An experiment involving the category rating of auditory stimulus intensities is described and the results are analysed. It is shown that the function linking stimulus value and response uncertainty has the shape of an inverted U and it is suggested that S's use internalised representations of the two end values of the stimulus range as reference points on which to base their judgements. It is argued that it is this fact, together with the use of a truncated response scale, which gives rise to the slope of the characteristic function linking scale value and stimulus value in category rating tasks. An attempt is made to explain the characteristic relationship between scale values derived by magnitude estimation methods and category rating methods in terms of the restrictions placed on the response system in the latter method.

CHAPTER IX

THE EFFECTS OF ANCHOR STIMULI

In the previous chapter a suggested explanation was advanced to account for performance in category rating tasks, since the results of an experiment had shown certain aspects of performance which appeared to be inconsistent with what might be predicted on the basis of adaptation level theory. A type of experiment which has very frequently been used by the protagonists of adaptation level theory is one involving the use of so called anchor stimuli. An anchor is a stimulus which is irrelevant to the discrimination task in hand and whose value lies well outside the range of relevant stimuli; the anchor is introduced either sequentially, as for example in a lifted weights experiment, or as part of the background, as for example in an experiment on visual perception. Anchors have pronounced effects on the central tendency of category ratings; anchors of low value tend to lead to increased category ratings of the same stimulus, while anchors of high value tend to lead to decreased category ratings. In adaptation level theory these results are explained in terms of the effects of the anchor on the adaptation level and it must be conceded that the outcome of experiments of this type are predicted quite well by the theory.

Since it has been argued in the previous chapter that the notion of an adaptation level is without empirical support, an alternative explanation must be advanced to account for the operation of anchors.

The most obvious explanation to suggest itself is that the anchor operates by hindering the differentiation of the stimuli at the end of the relevant stimulus range nearest to the anchor. Poor differentiation would lead to a wider spread of responses but, since the distribution of responses is truncated, this would have the effect of displacing the mean response value upwards in the case of a low anchor and downwards in the case of a high anchor.

The following experiment had as its aim the testing of this alternative explanation.

Auditory Intensity Experiment

Method

Sixteen Psychology IA students served as Ss in this experiment which was carried out at the commencement of two normal laboratory periods spaced one week apart. The apparatus for delivering the auditory stimuli was as has previously been described (Chapter VII), but in the second experimental session the apparatus was modified to permit presentation of an anchor of two seconds duration, followed after a one second silent interval by the stimulus to be judged.

In the first experimental session ten stimulus values were used spaced 2.5 d.b. apart over a range of -12.5 d.b. to -35 d.b. The instructions were identical with those used in the previous experiment (Chapter VIII). In the second experimental session the same ten stimulus values were used but on each occasion the stimulus was prefaced by a 2 sec. anchor terminating 1 sec. before the onset of the stimulus to be judged. The anchor was not attenuated and the instructions for the experiment were modified by telling Ss to ignore the first or anchor stimulus and to make judgements only about the second stimulus. All responses were recorded by Ss on pro-forma record sheets.

Results

Mean scale values for each stimulus have been determined for both conditions (i.e. with and without the anchor); these are presented in Table IX: 1. Mean response uncertainty per trial, for both conditions, has been calculated from the group data and these are presented in Table IX: 2. It is clear that the effects of the anchor have been negligible on both measures.

TABLE IX: 1

MEAN CATEGORY SCALE VALUES FOR AUDITORY STIMULI DIFFERING IN LOUDNESS WITH AND WITHOUT AN ANCHOR

	Stimulus intensity (d.b. attenuation)									
	35	32.5	30	27.5	25	22.5	20	17.5	15	12.5
without anchor	1.2	1.5	1.9	2.6	2.9	3.6	4.1	4.8	5.3	6.6
with anchor	1.2	1.7	2.0	2.4	3.0	3.6	3.8	4.8	5.2	6.5

TABLE IX: 2

MEAN RESPONSE UNCERTAINTY PER TRIAL IN BITS FOR CATEGORY RATINGS OF AUDITORY STIMULI DIFFERING IN LOUDNESS WITH AND WITHOUT AN ANCHOR

	Stimulus intensity (d.b. attenuation)									
	35	32.5	30	27.5	25	22.5	20	17.5	15	12.5
without anchor	.64	1.17	1.30	1.54	1.65	1.87	1.99	1.91	1.78	1.23
with anchor	.64	1.21	1.68	1.38	1.64	1.89	1.86	1.90	1.78	1.30

Discussion

The results of this experiment indicate that the presentation of an anchor in these circumstances has had no effect on judgement. This cannot be taken as disconfirming the adaptation level theory since the weighting of the anchor is, in terms of this theory, a matter of empirical determination; in this case it must be accorded a weighting of zero. Since the anchor was 35 d.b. different from the softest stimulus used, this is a surprising result as impressionistically one might have felt that the anchor was bound to have an effect. It can only be concluded that anchor effects in category rating tasks are rather less general than might be supposed.

Since it had not been possible to demonstrate the effects of anchoring in an auditory task, the following experiment involving judgement of lifted weights was set up; anchor effects can be reliably produced in such tasks.

Lifted Weights Experiment

Method

Twelve people associated with the Psychology Department served as Ss for the experiment; they were naive with respect to the purpose of the experiment. Each S completed the task under three conditions, each on a separate occasion. The three conditions were without anchor, with heavy anchor and with light anchor; two Ss completed the experiment in each of the six possible orders of conditions.

The stimuli consisted of a standard set of laboratory weights encased in uniform black bakelite cases, there were eight stimuli ranging from 50 to 64 grms. in 2 grm. steps. The heavy anchor was 121 grms. and the light anchor 16 grms.; the anchors were identical, except for their weight, with the stimuli. During the course of the experiment Ss made 10 judgements about each of the eight stimuli; stimuli were presented in blocks of 10 trials and each stimulus occurred once in random order in each block.

During the experiment S's hands were screened from his view. Standard instructions (Appendix D) were presented to S on a card and read out aloud by E before the commencement of each session.

Results

For each S the following measures were computed from the raw data, mean category value for each stimulus, mean response uncertainty per trial for each stimulus, and mean stimulus uncertainty per trial for each response. The group mean of each of these measures, together with their associated standard errors, are tabulated in Tables IX: 3, IX: 4 and IX: 5; the same data are graphically presented in Figs. IX: 1, IX: 2 and IX: 3. Separate analyses of variance for each of these measures have been carried out and summaries of these appear in Tables IX: 6, IX: 7 and IX: 8.

TABLE IX: 3

MEAN CATEGORY SCALE VALUES AND ASSOCIATED STANDARD ERRORS FOR LIFTED WEIGHTS WITHOUT ANCHOR AND WITH HEAVY AND LIGHT ANCHOR

		Stimulus (gms.)							
		50	52	54	56	58	60	62	64
no anchor	$\overline{X}$	3.4	3.4	3.9	4.4	4.9	5.4	5.8	6.0
	SEM	.23	.22	.21	.15	.19	.20	.13	.18
heavy anchor	$\overline{X}$	2.3	2.5	2.9	3.4	3.6	4.1	4.3	4.6
	SEM	.093	.098	.15	.14	.18	.15	.15	.18
	$\overline{X}$	3.8	4.1	4.5	5.1	5.2	5.8	5.9	6.2
	SEM	.19	.19	.17	.15	.13	.17	.11	.12

TABLE IX: 4

MEAN RESPONSE UNCERTAINTY PER TRIAL IN BITS AND ASSOCIATED STANDARD ERRORS FOR CATEGORY RATINGS OF LIFTED WEIGHTS WITHOUT ANCHOR AND WITH HEAVY AND LIGHT ANCHOR

		Stimulus (gms.)							
		50	52	54	56	58	60	62	64
no anchor	$\overline{X}$	1.79	1.84	1.87	1.95	1.95	1.50	1.68	1.56
	SEM	.084	.13	.093	.088	.094	.13	.11	.15
heavy anchor	$\overline{X}$	1.67	1.72	1.95	2.00	2.04	2.03	1.94	1.93
	SEM	.11	.079	.11	.053	.11	.12	.12	.12
light anchor	$\overline{X}$	1.90	1.92	2.09	1.85	1.94	1.49	1.66	1.29
	SEM	.11	.11	.065	.12	.070	.12	.094	.17

TABLE IX: 5

MEAN STIMULUS UNCERTAINTY PER TRIAL IN BITS AND ASSOCIATED STANDARD ERRORS FOR CATEGORY RATINGS OF LIFTED WEIGHTS WITHOUT ANCHOR AND WITH HEAVY AND LIGHT ANCHOR

		Response						
		1	2	3	4	5	6	7
no anchor	$\overline{X}$	1.23	.89	1.81	2.41	2.41	2.33	1.88
	SEM	.13	.10	.16	.20	.20	.20	.16
heavy anchor	$\overline{X}$	1.88	2.35	2.67	2.63	2.27	1.46	.93
	SEM	.16	.20	.22	.22	.19	.14	.096
light anchor	$\overline{X}$	.57	1.06	1.98	2.27	2.45	2.57	2.20
	SEM	.076	.12	.17	.19	.21	.22	.19

TABLE IX: 6

SUMMARY OF ANALYSIS OF VARIANCE OF MEAN CATEGORY RATINGS OF LIFTED WEIGHTS

Source	d.f.	S.S.	M.S.	F	P
Subjects (S)	11	4,270.9			
Groups (G)	5	2,649.2	529.8	1.96	n.s.
Indiv. Dif. (ID)	6	1,621.7	270.3		
Stimuli (St)	7	21,212.5	3,030.	134	.001
Conditions (C)	2	13,591.9	6,796.	40.7	.001
S x St	77	2,208.7			
G x St	35	1,258.2	35.95	1.59	n.s.
ID x St	42	950.5	22.63		
S x C	22	3,965.9			
G x C	10	1,960.5	196.0	1.17	n.s.
ID x C	12	2,005.4	167.1		
St x C	14	216.8	15.49	<1	n.s.
S x St x C	154	3,080.0			
G x St x C	70	1,496.2	21.37	1.13	n.s.
ID x St x C	84	1,583.8	18.85		
Total	287	48,546.7			

TABLE IX: 7

SUMMARY OF ANALYSIS OF VARIANCE MEAN RESPONSE UNCERTAINTIES OF LIFTED WEIGHTS IN CATEGORY RATING TASK

Source	d.f.	S.S.	M.S.	F	p
Subjects (S)	11	5.6898			
Groups (G)	5	1.1150	.2230	<1	n.s.
Indiv.Dif. (ID)	6	4.5748	.7625		
Stimuli (St)	7	4.9009	.7001	6.39	.001
Conditions (C)	2	1.2602	.6301	2.47	n.s.
S x St	77	9.7249			
G x St	35	5.1216	.1463	1.33	n.s.
ID x St	42	4.6033	.1096		
S x C	22	5.3435			
G x C	10	2.2886	.2289	<1	n.s.
ID x C	12	3.0549	.2546		
St x C	14	5.1222	.3659	2.53	.01
S x St x C	154	20.5761			
G x St x C	70	8.4086	.1201	<1	n.s.
ID x St x C	84	12.1675	.1449		
Total	287	52.6176			

TABLE IX: 8

SUMMARY OF ANALYSIS OF VARIANCE OF MEAN STIMULUS UNCERTAINTIES OF RESPONSES FOR CATEGORY RATINGS OF LIFTED WEIGHTS

Source	d.f.	S.S.	M.S.	F	p
Subjects (S)	11	8.6685			
Groups (G)	5	1.9466	.3893	<1	n.s.
Indiv. Dif. (ID)	6	6.7219	1.120		
Responses (R)	6	48.4734	8.079	21.4	.001
Conditions (C)	2	1.5626	.7813	2.35	n.s.
S x R	66	23.4798			
G x R	30	11.3295	.3777	1.00	n.s.
ID x R	36	12.1503	.3775		
S x C	22	6.4035			
G x C	10	2.4142	.2414	<1	n.s.
ID x C	12	3.9893	.3324		
R x C	12	48.7433	4.062	20.7	.001
S x R x C	132	40.9726			
G x R x C	60	26.8353	.4473	2.28	.01
ID x R x C	72	14.1373	.1964		
Total	251	178.3037			

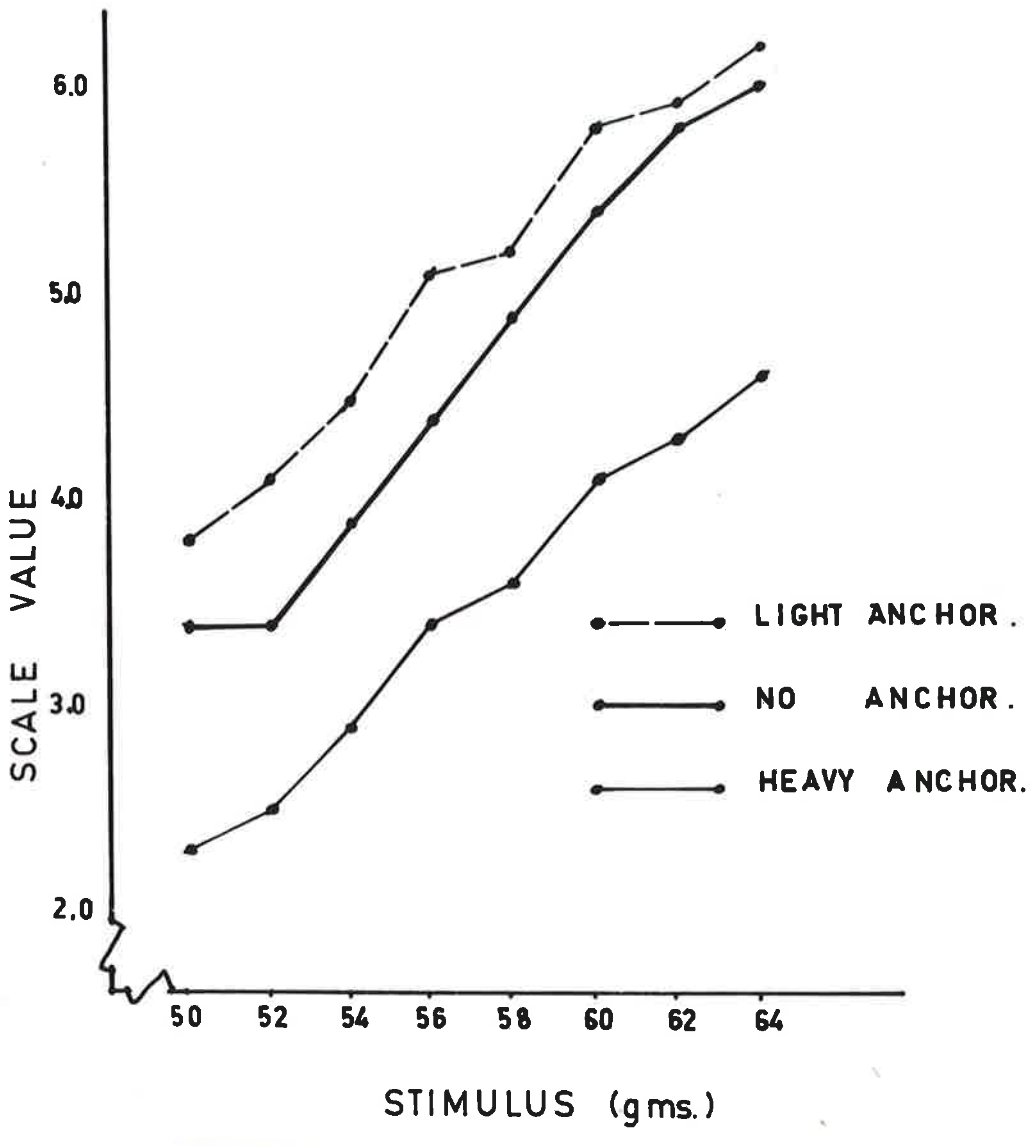

FIG. IX:1 RELATIONSHIP BETWEEN STIMULUS VALUES AND CATEGORY SCALE VALUES, WITH AND WITHOUT ANCHORS

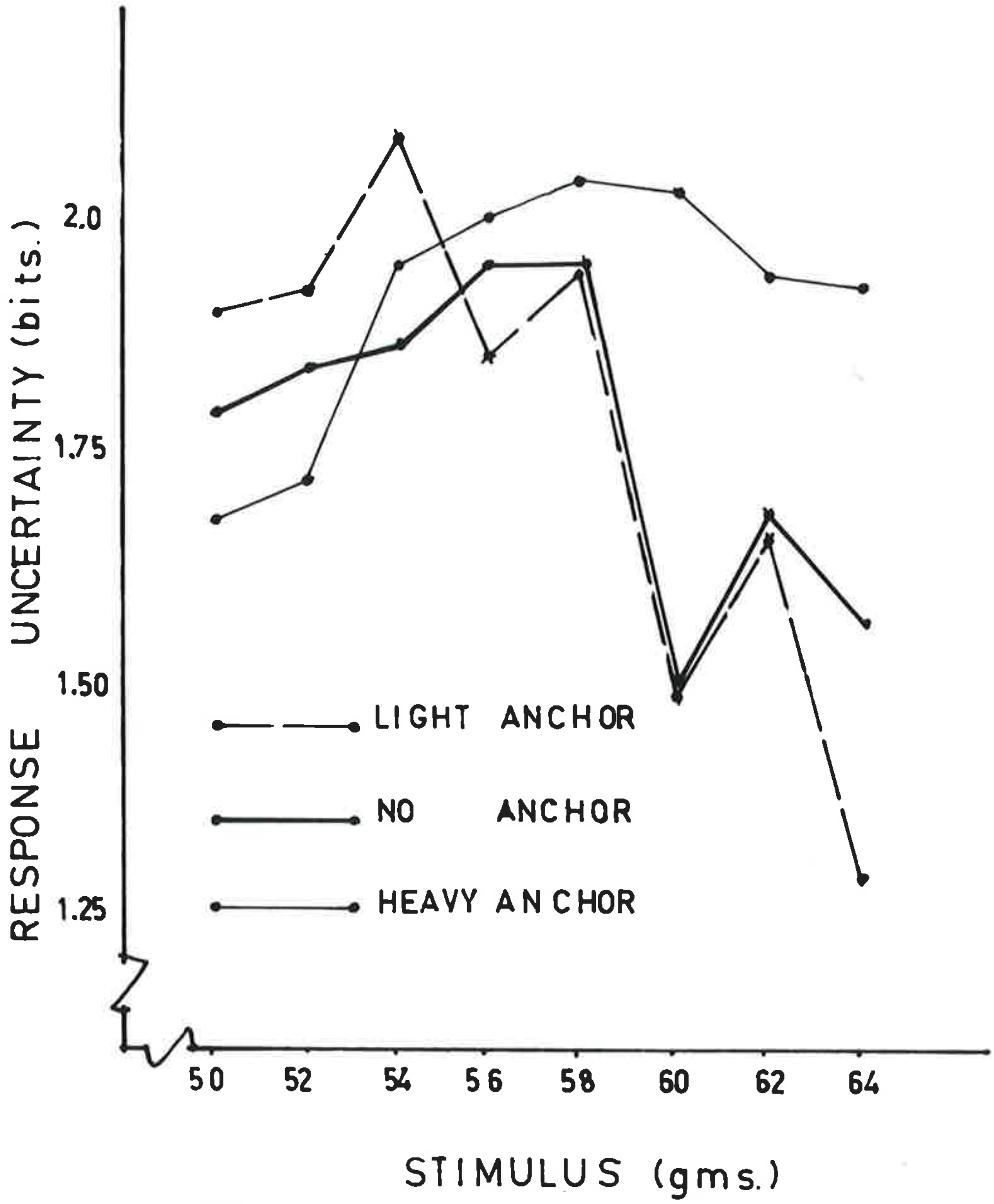

FIG. IX:2 RELATIONSHIP BETWEEN MEAN RESPONSE UNCERTAINTY PER TRIAL AND STIMULUS VALUE, WITH AND WITHOUT ANCHORS

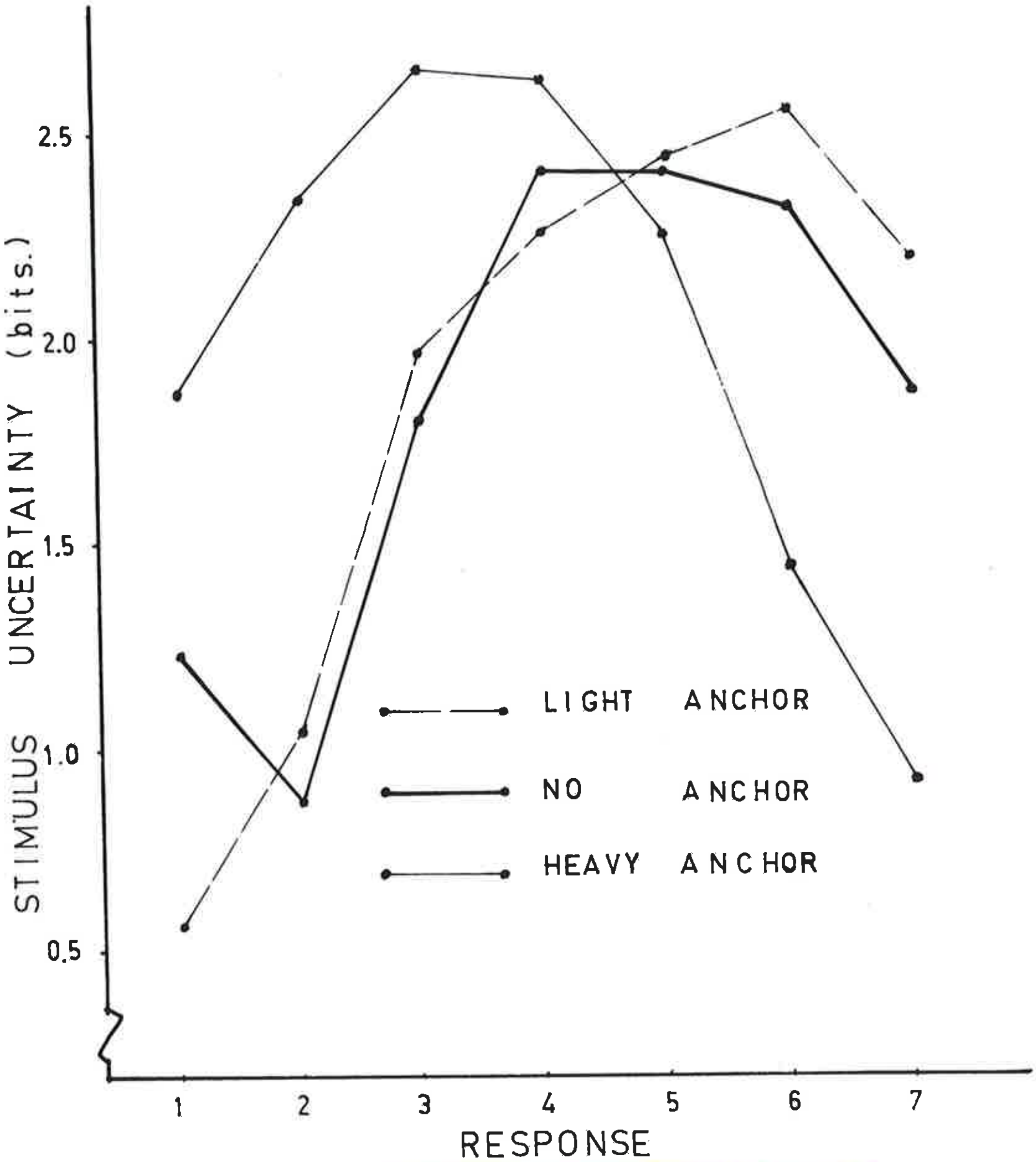

FIG. IX:3 RELATIONSHIP BETWEEN MEAN STIMULUS UNCERTAINTY PER TRIAL AND RESPONSE VALUE, WITH AND WITHOUT ANCHORS

It may be seen that the anchors have had the expected effect on mean scale values (Fig. IX: 1). The function for a light anchor lies above and that for a heavy anchor below, the function obtained without any anchor. This same effect is reflected in the analysis of variance (Table IX: 3) when the Conditions variable is shown to be highly significant ($p < .001$).

The effects of the anchors on response uncertainty are clearly shown in Fig. IX: 2. It is apparent that a heavy anchor gives rise to a relative increase in response uncertainty for stimuli in the top portion of the range and a relative decrease for stimuli in the bottom portion. Similarly a light anchor produces increased response uncertainty for the bottom of the range and a decrease at the top of the range. This interpretation is borne out by the significant interaction of Stimuli x Conditions ($p < .01$) shown in Table IX: 7.

A feature of Fig. IX: 2 is the apparent irregularity of two of the functions associated with the 60 grm. stimulus. The reduced response uncertainties associated with this stimulus suggest that it may have been differentiated from the remaining stimuli on the basis of some cues other than weight. A very close inspection of the stimuli could not confirm this hypothesis but it, nevertheless, remains as the most likely explanation of this aspect of the results.

The manipulation of the anchor variable has also had an effect on the stimulus uncertainty measures. In the analysis of variance (Table IX: 8), the interaction of Responses x Conditions is shown to be significant at the .001 level; reference to Fig. IX: 3 shows that with a heavy anchor there is relatively less uncertainty associated with the large responses while with a light anchor there is relatively less uncertainty associated with the small responses.

Discussion

The results of this experiment show that the use of anchor stimuli has quite marked effects on the relationship between response uncertainty and stimulus magnitude. Since response uncertainty and stimulus uncertainty are not independent measures, there has also been a corresponding change in the pattern of stimulus uncertainties but it will be argued here that this is only a secondary and logical consequence of the manipulation of the pattern of response uncertainties by the use of anchor stimuli.

These results suggest quite strongly that one of the effects of anchor stimuli is, as was initially suggested, to prevent or hinder the differentiation of the end of the stimulus array nearest to the anchor stimulus. This probably comes about because the anchor stimulus, rather than the end stimulus of the array, now serves as one of the reference points upon which judgements are based.

Another result of the use of anchor stimuli which had not been foreseen is that they produce increased differentiation of relevant stimuli at the opposite end of the stimulus array. This is of some importance in so far as increased differentiation of stimuli means a reduced spread of judgements and a consequent lessening of the importance of the truncation of the response distribution. If there is less variance of responses there will be a lessened tendency for the mean of responses to stimuli at the end of the range to be displaced towards the centre. The overall results of both of these effects, that is reduced differentiation of stimuli near the anchor and increased differentiation of stimuli at the end of the stimulus array furthest from the anchor, will be the same, namely an increase in the mean of responses with small anchors and a decrease with large anchors.

There is a suggestion that the effects produced on the mean of responses by decreased stimulus differentiation is rather greater than those produced by increased differentiation; thus it may be seen (Fig.IX: 1) that the scale value - stimulus value functions obtained with the use of anchor stimuli do not lie parallel to the function obtained without an anchor, but appear to diverge at that end of the scale nearest to the anchor.

Summary

Two experiments designed to examine the effects of anchor stimuli on category judgements are described and analysed. In one experiment in which judgements were made of auditory loudness the anchors had no effect. In the other experiment in which judgements were made of lifted weights it was shown that anchors hinder the differentiation of stimuli in that portion of the stimulus range nearest the anchor, and enhance differentiation of stimuli at the other end of the stimulus range. It is suggested that the effects of anchors on central tendency of judgements is a secondary consequence of this effect.

CHAPTER X

PSYCHOPHYSICAL HYSTERESIS

The phenomenon of psychophysical hysteresis is observed when Ss are required to make judgements of stimuli within a stimulus range which is defined on each trial by the two end stimuli of that range. It may be found that there is a reliable difference between judgements of the same stimulus when it is presented on trials in which all three stimuli are arranged in ascending order of stimulus magnitude and when it is presented on trials in which all three stimuli are arranged in descending order of stimulus magnitude. The difference takes the form of a relative underestimation of the stimulus when it is presented in ascending order. Stevens (1957) has claimed that the occurrence of this phenomenon is one of the four defining characteristics of prothetic stimulus continua and that it does not occur with metathetic stimulus continua.

One of the conclusions to be drawn from the work reported in previous chapters is that measures of central tendency of performance in sensory discrimination tasks may be influenced in consistent and characteristic ways by the properties, particularly the skew of the dispersion of judgements. Since psychophysical hysteresis does not appear to have, as yet, been adequately explained, the question is raised as to whether or not the phenomenon might not reflect some feature of the distribution of judgements other than central tendency. The following experiment was set up to investigate this possibility.

Method

Thirty female students fulfilling a Psychology I course requirement served as _Ss_. The stimuli consisted of six cylindrical plastic pill bottles containing a solidified mixture of lead shot and paraffin wax; the stimuli weighed 35, 61, 77, 113, 128 and 150 gms. The values of the weights were chosen so that no simple numerical ratio obtained between their magnitudes.

Each trial consisted of the presentation of three weights, 35 gms., 150 gms. and one of the other four weights in either ascending or descending order of magnitude; there were therefore eight different kinds of trials and the experiment consisted of seven repetitions of these eight trials. Each type of trial recurred once in random order in each of seven blocks of trials.

_S_ was seated at a table opposite _E_ and placed her preferred hand face down on the table where it was obscured from her view by a horizontal screen about twelve inches above the table top. The weight was always placed between Ss thumb and forefinger and after each weight was lifted it was replaced by E. Responses were obtained by having S manipulate a cursor on a horizontal scale attached above the screen. The scale consisted of 50 1cm squares alternately coloured red and blue and was labelled "heavy" at the right end and "light" at the left end. At the commencement of the experiment S was handed a card on which the instructions were printed (Appendix E), and these instructions were read to S. The instructions requested S to report on the second weight presented on each trial by shifting the cursor to an appropriate square on the scale and pointed out that the magnitude of the heaviest and the lightest weights on each trial were represented by the two ends of the scale. At the commencement of each trial the cursor was shifted to a scale position determined at random. Two practice trials were administered prior to the commencement of the 56 trials of the experiment proper.

Results

Scale values of 1 to 50 were assigned to each square on the scale and mean scale values for each of the four middle weights in each order of presentation were determined. These, together with their associated standard errors, are presented in Table X: 1; it may be seen that stimuli presented in ascending

TABLE X: 1

MEAN SCALE VALUES FOR JUDGEMENTS OF WEIGHTS ACCORDING TO ORDER OF PRESENTATION TOGETHER WITH ASSOCIATED STANDARD ERRORS

		Weight (gms.)			
		61	77	113	128
Descending	$\bar{X}$ Scale Value	16.0	24.2	38.7	42.2
	S.E.M.	.88	.92	.78	.50
Ascending	$\bar{X}$ Scale Value	13.3	20.2	35.1	39.5
	S.E.M.	.73	.85	.78	.77

order are consistently underestimated in comparison with those presented in descending order and, therefore, the hysteresis phenomenon has been unequivocally demonstrated.

Response uncertainty associated with each stimulus in each order of presentation was determined for each S: the means of these values are presented in Table X: 2. Analysis of variance of these data (Table X: 3) confirms that impression gained by inspection that there are no significant effects on this measure which are attributable to order of presentation.

TABLE X: 2

MEAN RESPONSE UNCERTAINTY IN BITS FOR JUDGEMENTS OF WEIGHTS ACCORDING TO ORDER OF PRESENTATION

	Weight (gms.)			
	61	77	113	128
Descending	2.53	2.51	2.43	2.30
Ascending	2.43	2.44	2.43	2.26

TABLE X: 3

SUMMARY OF ANALYSIS OF VARIANCE OF RESPONSE UNCERTAINTY IN LIFTED WEIGHTS TASK

Source	d.f.	S.S.	M.S.	F	p
Subjects (S)	29	4.6591	.1607		
Stimuli (St)	3	1.5929	.5310	3.72	.05
Orders (O)	1	.1676	.1676	1.72	n.s.
S x St	87	12.4219	.1428	1.63	n.s.
S x O	29	2.8177	.09716	1.11	n.s.
St x O	3	.0805	.02683	<1	n.s.
S x St x O	87	7.6322	.08773		
Total	239	29.3719			

Discussion

The results of this experiment provide no support for the suggestion that the hysteresis phenomenon might be due in some way to differences in the dispersion as opposed to central tendency of judgements associated with the two orders of presentation. The experimental conditions have permitted an unequivocal demonstration of hysteresis but this has not been accompanied by even a suggestion of any effect on the dispersion of judgements related to order of presentation.

Summary

A lifted weights experiment utilising 30 Ss is described, the results of which demonstrate a marked psychophysical hysteresis effect. A further analysis of the data in terms of the response uncertainty associated with the various stimuli in both ascending and descending trials was undertaken. No reliable effects associated with order of presentation could be demonstrated. This experiment, therefore, provides no support for the view that the hysteresis phenomenon might primarily reflect differences in the dispersion rather than central tendency of judgements.

CHAPTER XI

RE-ANALYSIS OF TEMPORAL DIFFERENCE ESTIMATION DATA

A fairly general feature of the results of the experiments reported using the methods of magnitude estimation and category rating has been that the stimuli used in such experiments become differentiated according to their position on the stimulus continuum, and that in general there is least response uncertainty about the end stimuli of the range and progressively more uncertainty about those stimuli towards the centre of the range. The general form of the function linking response uncertainty and position of stimulus on the stimulus continuum is that of an inverted U.

An implication of the different amounts of response uncertainty associated with different stimuli is the asymmetry of the distribution of errors of judgement about those stimuli. Suppose, for example, we have three stimuli A, B and C, such that the response uncertainty of $A > B > C$; this means that when B is judged or discriminated it will be confused with A more often than with C, or in other words that the distribution of judgements about B will be skewed in the direction of A. When the relationship between response uncertainty of stimuli and position on the stimulus continuum is of the inverted U shaped kind, it is clear that this effect will manifest itself as what has been called the central tendency effect.

Although it seems reasonable that some degree of differentiation of stimuli might be achieved in an experiment employing a fairly wide range of stimuli, the range of stimuli employed in methods such as the method of constant stimulus differences is usually so small, covering as a rule only a few J.N.D.s that at first sight it might seem unlikely that any differentiation within such a small range would occur. Nevertheless the possible occurrence of stimulus differentiation within such a small stimulus range, in experiments of this kind, seems to provide a potential explanation for the observed central tendency effect.

The data collected in the experiment on temporal difference estimation (Chapter IV) were of a kind, it will be recalled, to permit determination of response uncertainties for each of the V stimulus values used and accordingly they have been re-analysed to throw light on this question. Since in this experiment S was not permitted to make a judgement of "no difference", the data from St-St trials have not been re-analysed as this restriction would undoubtedly lead to spuriously high values of response uncertainty associated with St, and this measure would in no way be comparable with the response uncertainty values obtained for each of the V stimuli.

Response uncertainty values have been determined for each V stimulus in both the St-V and V-St orders of presentation for each S at each ISI. Since each V stimulus was presented eight times under each condition, it can be seen that the maximum response uncertainty value is 3 bits. The response uncertainty values have been subject to analysis of variance and the results of this analysis are summarised in Table XI: 1. It can be seen that there are four main effects. Subjects, ISIs, Orders and Stimuli. The Subjects variable is further broken down into Groups and Individual Differences components; Groups, it will be recalled, are constituted on the basis of the sequence in which Ss completed the four experimental sessions. The Stimuli variable has also been broken down into Halves and Individual Stimuli components; the Halves variable refers to whether the stimuli were above or below the value of St and the Individual Stimuli variable refers to the differences between stimuli within the two semi ranges.

The variable Individual stimuli and the interaction of Orders x Halves are significant at the .001 level. Three sources of variance are significant at the .05 level, Groups x ISIs, ISIs x Orders, and Groups x ISIs x Orders x Halves. The manner of operation of the first two significant sources of variance may be seen by reference to Table XI: 2. It may be seen that the relationship between stimulus value and response uncertainty is of the, now familiar, inverted U shape form (Fig. XI: 1). The Orders x Halves interaction reflects the fact that there is apparently more response uncertainty about the top stimulus semi range on trials in the St-V order and

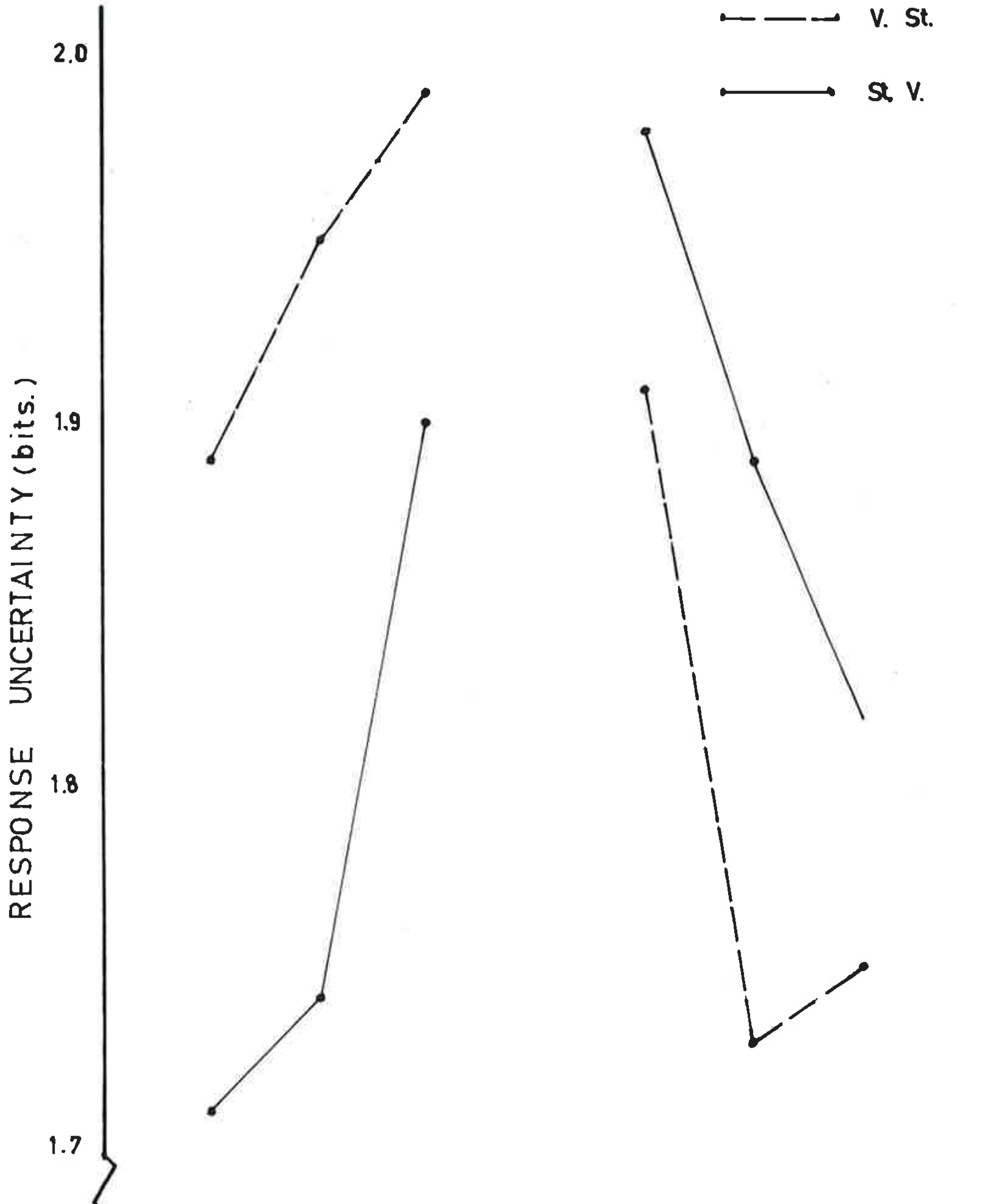

FIG. XI:1 RELATIONSHIP BETWEEN MEAN RESPONSE UNCERTAINTY PER TRIAL, VARIABLE STIMULUS VALUE, AND ORDER OF PRESENTATION (TEMPORAL DIFFERENCE ESTIMATION TASK)

TABLE XI: 1

SUMMARY OF ANALYSIS OF VARIANCE OF ESTIMATES OF MEAN RESPONSE UNCERTAINTY PER TRIAL IN TEMPORAL DIFFERENCE ESTIMATION TASK

Source	d.f.	S.S.	M.S.	F	p
Subjects (S)	23	248.9810			
Groups (G)	3	49.0010	16.33	1.63	n.s.
Indiv. Dif. (ID)	20	199.9800	9.999		
ISIs	3	1.8205	.6068	1.21	n.s.
Orders (O)	1	.2890	.2890	2.73	n.s.
Stimuli (St)	5	5.0420			
Halves (H)	1	.0649	.0649	1	n.s.
Ind. stim. (IS)	4	4.9771	1.244	7.40	.001
S x ISI	69	40.5682			
G x ISI	9	10.4922	1.166	2.33	.05
ID x ISI	60	30.0760	.5013		
S x O	23	2.4383			
G x O	3	.3184	.1061	1.00	n.s.
ID x O	20	2.1199	.1060		
S x St	115	17.8046			
G x St	15	1.1653			
G x H	3	.1079	.03597	<1	n.s.
G x IS	12	1.0574	.08812	<1	n.s.
ID x St	100	16.6393			
ID x H	20	3.2031	.1602		
ID x IS	80	13.4362	.1680		
ISI x O	3	1.2722	.4241	3.16	.05

TABLE XI: 1 (Continued)

Source	d.f.	S.S.	M.S.	F	p
ISI x St	15	2.0657			
ISI x H	3	.1503	.05010	<1	n.s.
ISI x IS	12	1.9154	.1596	1.30	n.s.
O x St	5	5.5706			
O x H	1	4.9370	4.937	28.9	.001
O x IS	4	.6336	.1584	1.17	n.s.
S x ISI x O	69	9.2501			
G x ISI x O	9	1.1833	.1315	<1	n.s.
ID x ISI x O	60	8.0668	.1344		
S x ISI x St	345	40.5718			
G x ISI x St	45	3.2613			
G x ISI x H	9	.9220	.1024	<1	n.s.
G x ISI x IS	36	2.3393	.06498	<1	n.s.
ID x ISI x St	300	37.3105			
ID x ISI x H	60	7.9613	.1327		
ID x ISI x IS	240	29.3492	.1223		
S x O x St	115	16.1486			
G x O x St	15	1.8847			
G x O x H	3	.2358	.07860	<1	n.s.
G x O x IS	12	1.6489	.1374	1.01	n.s.
ID x O x St	100	14.2639			
ID x O x H	20	3.4130	.1707		
ID x O x IS	80	10.8509	.1356		
ISI x O x St	15	2.0665			
ISI x O x H	3	.6397	.2132	1.82	n.s.
ISI x O x IS	12	1.4268	.1189	<1	n.s.

TABLE XI: 1 (<u>Continued</u>)

Source	d.f.	S.S.	M.S.	F	p
S x ISI x O x St	345	43.6302			
G x ISI x O x St	45	6.0710			
G x ISI x O x H	9	2.2638	.2515	2.15	.05
G x ISI x O x IS	36	3.8072	.1058	<1	n.s.
ID x ISI x O x St	300	37.5592			
ID x ISI x O x H	60	7.0235	.1171		
ID x ISIxO x IS	240	30.5357	.1272		
Total	1151	437.5193			

TABLE XI: 2

MEAN RESPONSE UNCERTAINTY PER TRIAL IN BITS IN TEMPORAL DIFFERENCE ESTIMATION TASK ACCORDING TO VALUE OF STIMULUS, SEMI-RANGE AND ORDER OF PRESENTATION

Order of presentation	Stimulus (secs.)							
	.6	.7	.8	Bottom semi-range	1.0	1.1	1.2	Top semi-range
St - V	1.71	1.74	1.90	1.78	1.98	1.89	1.82	1.90
V - St	1.89	1.95	1.99	1.94	1.91	1.73	1.75	1.80
Combined	1.80	1.84	1.94	1.86	1.94	1.81	1.78	1.85

about the bottom semi range in the V-St order. Since the analysis contains so many individual sources of variance no great weight should be placed on sources which achieve significance at only the .05 level.

Although it is not possible to interpret the quadruple interaction (Table XI: 3) with any degree

TABLE XI: 3

MEAN RESPONSE UNCERTAINTY PER TRIAL IN BITS IN TEMPORAL DIFFERENCE ESTIMATION TASK ACCORDING TO STIMULUS SEMI-RANGE, ORDER OF PRESENTATION AND ORDER OF EXPERIMENTAL SESSION

Order of presentation	Semi range	Order of experimental session			
		1	2	3	4
St - V	bottom	1.78	1.85	1.77	1.73
	top	1.93	1.94	1.95	1.76
V - St	bottom	1.86	2.01	2.05	1.86
	top	1.83	1.89	1.75	1.72

of precision and it is of marginal statistical significance, this finding appears to be consistent with the finding in the original analyses of these results (Chapter IV) that continued experimentation has an effect on the constant error. The combination of Groups x ISIs implicates the involvement of order of experimental sessions and it is clear that inequalities in the number of "longer" or "shorter" judgements must result from the interaction of Orders x Halves.

Discussion

The results of this analysis have strikingly confirmed that differential response uncertainty values are associated with different values of stimuli within the small range employed in this experiment. Furthermore the nature of the relationship between these two variables is the now familiar inverted U. This can only mean that the effects of individual stimuli in this situation are mediated by some form of internalised schematic representation of the whole set of stimuli employed. The effects of individual stimuli are not explicable except without reference to their position within the set of all stimuli employed in the experiment, and this appears to be independent of the size of the stimulus range.

This is, undoubtedly, a finding with far reaching implications for the whole area of sensory measurement and one which, since it has not previously been demonstrated, has not been fully appreciated.

A second relationship which has been revealed by this analysis, that is the effects of the Orders x Halves interaction seems to throw some new light on the understanding of constant errors. In the St-V order of presentation there is most response uncertainty about stimuli in the top half of the range, whereas in the V-St order there is most response uncertainty about stimuli in the bottom half of the range. This means, in effect, that stimuli falling in the middle part of the range are relatively more likely to be confused with stimuli at the top end of the range when the trials are administered in the St-V order and with stimuli at the bottom end of the range when the trials are administered in the V-St order. This would, of course, lead to a preponderance of "longer" responses over the course of the experiment and such a preponderance is conventionally spoken of as a negative constant error.

On the basis of this analysis it would appear that constant errors do not reflect any intrinsic bias of the discriminatory mechanism but rather that they are a reflection of the asymmetrical distribution of errors of judgement. It would further appear that the occurrence of constant errors is an artifact of the use of measures of central tendency of performance which are either not appropriate to conditions where errors are distributed asymmetrically, or else which conceal that fact. This is not to say that constant errors constitute a pseudo-problem - they do not; they are a manifestation of a very real phenomenon - the differential precision of judgement under different conditions. They are not, however, a reflection of differences in central tendency of judgement under different conditions.

It seems quite clear that the highly significant Orders x Halves effect must be responsible for that aspect of performance which has previously been called the constant error but it is not altogether clear as to why such an effect should be observed. The following explanation is tentatively suggested but it is acknowledged that it must be subject to independent empirical confirmation.

It has previously been suggested that whenever stimuli arranged on a single stimulus dimension are presented, a number of times, some form of internalised schematic representation of the stimulus range is built up and, in general, those stimuli at both ends of the range are most clearly differentiated whereas there is progressively less differentiation of those stimuli towards the centre of the range. It can be expected that evidence of such a relationship will be uncovered in all experiments of this type but it can also be expected that under certain circumstances this relationship might be obscured by properties of the response system which is being used as a basis for inferring the properties of the internalised schematic representation or, in other words, for externalising the schema.

In this experiment the properties of the schema are being inferred on the basis of a comparative judgement situation. In comparative judgement situations it seems to be a well established principle that the error of judgement is proportional to relative size of the comparison to be made and that as the relative size of the difference between the two stimuli to be compared increases so does the error or uncertainty of that judgement. In the case of St-V trials, therefore, we might expect on this basis that there would be more uncertainty about the outcome of trials in which the largest differences are being compared. This patently does not occur in this experiment and it must be concluded, therefore, that this effect is obscured by a more robust effect, that is the gradient of differentiation of individual stimuli within the range. The fact that these two principles apparently oppose each other in this situation means that the curve of differentiation (i.e. response uncertainty plotted against stimulus value) obtained in this experiment most certainly underestimates the relative difference between stimuli with respect to this variable. In considering the operation of this factor in St-V trials it is important to see that the two semi ranges of stimuli are identical with respect to their relative difference from the St; thus both .6 sec. and 1.2 sec. compared with the St of .9 sec. produce a relative difference of .33. For this reason both semi ranges are symmetrical from this point of view and this consideration can not be advanced as an explanation for the asymmetrical response uncertainties associated with the two semi ranges.

The larger response uncertainty associated with the top semi range in the St-V order seems, therefore, to reflect some genuine property of the underlying schema. It would seem plausible to account for this by the relatively smaller difference between adjacent stimuli in the top semi range giving rise to greater confusion of identity or uncertainty.

In the case of trials in the V-St order it does seem that the obtained asymmetry can be attributed to a response factor rather than to the properties of the underlying schema. In V-St trials an identical stimulus is compared with one of any six V stimuli which serve as the basis for comparison; .9 compared with .6 sec. gives a relative difference of .5 whereas .9 sec. compared with 1.2 sec. gives a relative difference of .25. It can be seen, therefore, that the size of the relative difference to be estimated decreases as we ascend the stimulus range and this factor would seem to provide an adequate reason for the asymmetries observed in the V-St order when there is more response uncertainty in the bottom semi range.

Summary

The data from the temporal difference estimation task (Chapter IV) have been re-analysed in terms of estimated response uncertainties per trial. It is shown that there is a inverted U shaped relationship between stimulus value and response uncertainty and this appears to provide an explanation for the central tendency of judgement. An additional finding is made concerning the effect of order of stimulus presentation which, it is argued, provides an explanation for constant errors.

CHAPTER XII

AUDITORY INTENSITY DIFFERENCE ESTIMATION

The re-analysis of the data from the temporal difference estimation task has provided evidence that performance in this situation is mediated by an internalised representation of the stimulus array which is best differentiated with respect to the terminal stimuli of the array and less well differentiated with respect to the middle stimuli. It will be recalled, however, that no "equal" judgements were permitted in this experiment and because of this it was not possible to obtain a picture of the degree to which St became differentiated from the other stimuli in the array. Since St is presented on each trial and therefore six times more frequently than any of the V stimuli (if six V stimuli are employed), it might be expected that the St stimulus would become rather better differentiated than the other stimuli of the array. If this expectation were fulfilled the usual inverted U shaped relationship between position of stimulus in the stimulus array and response uncertainty would be complicated by a dip in the peak of the curve associated with St. The aim of the following experiment was to provide the conditions for this result to be observed. Rather than utilise a temporal difference estimation task again it was decided to utilise an auditory intensity difference estimation task so that incidental light might be thrown on any differences between judgements of auditory duration and auditory intensity.

Method

Four separate stimulus schedules were pre-recorded on tape using a 1,000 ~ tone. There was one schedule for each of the ISIs 1, 2, 4 & 6 seconds. Each schedule consisted of 104 trials arranged in eight consecutive blocks of thirteen trials. Within each block of trials there was one St-St trial, six St-V trials and six V-St trials arranged in a different random order for each block; the duration of each stimulus was one second. The St had an intensity of 80 d.b. (s.p.l.) and the V stimuli were spaced symmetrically about St at intervals of 1.5 d.b. Control of stimulus intensity was achieved by the use of an accurate attenuator stepped in .5 d.b. steps over a range of 10 d.b. which was built in the workshops of the Psychology Department.

Thirty two Psychology I students fulfilling a course requirement acted as Ss. They were tested individually in sessions lasting about half an hour and spaced at least one day apart; a short rest pause was introduced half way through the experiment which lasted about 30 minutes. The Ss were divided into four groups, each of which completed the experimental sessions in a different order.

At the commencement of the session the recorded instructions (Appendix F) were played to S through the head phones, at the same time S could read these instructions on a printed card. Five practice trials which covered the whole stimulus range were given at the completion of the instructions.

The task which was required of S was similar to that of the previous difference estimation task (Chapter IV) but with some essential differences. The scale consisted of 49 1 cm. squares, the centremost of which was coloured black, while the remainder were alternatively brown and orange; S was permitted to make judgements of "no difference", that is to let the cursor remain in the black square, but was instructed as to the actual proportions of trials in which there would be no difference between the two stimuli (i.e. 1:13). The ends of the scale were labelled "softer" and "louder".

The data from each S at each session were subsequently transposed onto a separate matrix for each kind of trial (i.e. St-V, V-St, and St-St).

Results

Contingent uncertainty estimates were determined for St-V, and V-St trials and these have been subject to a three way analysis of variance. The summary of this analysis may be seen in Table XII: 1.

TABLE XII: 1

SUMMARY OF ANALYSIS OF VARIANCE OF CONTINGENT UNCERTAINTY IN AUDITORY INTENSITY DIFFERENCE DETECTION TASK

Source	d.f.	S.S.	M.S.	F	p
Subjects (S)	31	4.77338			
Groups (G)	3	.35876	.1196	<1	n.s.
Indiv. Dif. (ID)	28	4.41462	.1577		
ISIs	3	.45159	.1505	5.71	.01
Orders (O)	1	1.89682	1.897	50.4	.001
S x ISI	93	2.40782			
G x ISI	9	.19499	.02167	<1	n.s.
ID x ISI	84	2.21283	.02634		
S x O	31	1.13832			
G x O	3	.08459	.02820	<1	n.s.
ID x O	28	1.05373	.03763		
ISI x O	3	.11438	.03813	1.97	n.s.
S x ISI x O	93	1.77134			
G x ISI x O	9	.14517	.01613	<1	n.s.
ID x ISI x O	84	1.62617	.01936		
Total	254	12.55365			

The Orders variable is significant at the .001 level. This arises from the usual superiority of performance on St-V trials; on this occasion a mean contingent uncertainty of 1.91 bits per trial for St-V trials as against 1.74 bits for V-St trials. The ISI variable is significant at the .01 level and its action is illustrated in Table XII: 2. The results suggest a relatively rapid deterioration of performance over the interval between 1 and 2 seconds but a much slower rate of decline thereafter.

TABLE XII: 2

MEAN CONTINGENT UNCERTAINTY PER TRIAL IN BITS AT VARIOUS ISIs

ISI (secs.)	1	2	4	6
$\bar{X}$ contingent uncertainty per trial	1.89	1.81	1.82	1.78

Response uncertainty estimates for St-V and V-St trials have also been subject to analysis of variance with four main effects; Subjects, ISIs, Orders and Stimuli. A sub classification of the Subjects variable into Groups and Individual stimuli has been made. A summary of this analysis is contained in Table XII: 3.

TABLE XII: 3

SUMMARY OF ANALYSIS OF VARIANCE OF RESPONSE UNCERTAINTY IN AUDITORY INTENSITY DIFFERENCE DETECTION TASK

Source	d.f.	S.S.	M.S.	F	p
Subjects (S)	31	69.32313			
Groups (G)	3	3.49416	1.165	<1	n.s.
Indiv. Dif.(ID)	28	65.82897	2.351		
ISIs	3	3.47373	1.158	5.32	.01
Orders (O)	1	.46499	.4650	2.28	n.s.
Stimuli (St)	5	2.80277			
Halves (H)	1	.33138	.3314	1.70	n.s.
Ind. Stim. (IS)	4	2.47139	.6178	4.24	.01
S x ISI	93	20.53627			
G x ISI	9	2.25521	.2506	1.15	n.s.
ID x ISI	84	18.28106	.2176		
S x O	31	7.18884			
G x O	3	1.48409	.4947	2.43	n.s.
ID x O	28	5.70475	.2037		
S x St	155	23.22185			
G x St	15	1.43063			
G x H	3	.08846	.02949	<1	n.s.
G x IS	12	1.34217	.1118	<1	n.s.
ID x St	140	21.79122			
ID x H	28	5.45641	.1949		
ID x IS	112	16.33481	.1458		
ISI x O	3	.26838	.08946	<1	n.s.

TABLE XII: 3 (Continued)

Source	d.f.	S.S.	M.S.	F	p
ISI x St	15	2.76547			
ISI x H	3	.03768	.01256	<1	n.s.
ISI x IS	12	2.72779	.2273	2.09	.05
O x St	5	5.89685			
O x H	1	2.60969	2.610	11.5	.01
O x IS	4	3.28716	.8218	7.40	.001
S x ISI x O	93	10.16570			
G x ISI x O	9	.57951	.06439	<1	n.s.
ID x ISI x O	84	9.58619	.1141		
S x ISI x St	465	48.88316			
G x ISI x St	45	4.06778			
G x ISI x H	9	.97079	.1079	1.09	n.s.
G x ISI x IS	36	3.09699	.08603	<1	n.s.
ID x ISI x St	420	44.81538			
ID x ISI x H	84	8.30653	.09889		
ID x ISI x IS	336	36.50885	.1087		
S x O x St	155	20.70719			
G x O x St	15	1.89172			
G x O x H	3	.24733	.08244	<1	n.s.
G x O x IS	12	1.64439	.1370		
ID x O x St	140	18.81547			
ID x O x H	28	6.37715	.2278		
ID x O x IS	112	12.43832	.1111		
ISI x O x St	15	3.07151			
ISI x O x H	3	.39062	.1302	1.33	n.s.
ISI x O x IS	12	2.68089	.2234	2.00	.05

TABLE XII: 3 (Continued)

Source	d.f.	S.S.	M.S.	F	p
S x ISI x O x St	465	51.34604			
G x ISI x O x St	45	5.56032			
G x ISI x O x H	9	1.16067	.1290	1.32	n.s.
G x ISI x O x IS	36	4.39965	.1222	1.09	n.s.
ID x ISI x O x St	420	45.78572			
ID x ISI x O x H	84	8.19413	.09755		
ID x ISI x O x IS	336	37.59159	.1119		
Total	1,535	270.11588			

It can be seen that the ISI variable is significant at the .01 level, reference to Table XII: 4 shows that there appears to be a general trend, as might be expected, for response uncertainty to increase with lengthening of ISI although there is some irregularity in this trend associated with the 4 second ISI for which no obvious explanation is at hand.

TABLE XII: 4

MEAN RESPONSE UNCERTAINTY PER TRIAL
IN BITS AT VARIOUS ISIs

ISI (Secs.)	1	2	4	6
$\bar{X}$ response uncertainty per trial	2.19	2.24	2.16	2.29

Two sources of variance are significant at the .05 level (ISI x IS and ISI x O x IS) and no interpretation of these will be attempted. The remaining significant sources of variance are Individual stimuli (.01), Orders x Halves (.01) and Orders x Individual stimuli (.001). The operation of these variables may be clarified by reference to Table XII: 5.

TABLE XII: 5

MEAN RESPONSE UNCERTAINTY PER TRIAL IN BITS ASSOCIATED WITH INDIVIDUAL STIMULI IN BOTH ORDERS OF PRESENTATION

	Stimulus (d.b. of attenuation from St)							
Order	-45	-3.0	-1.5	$\overline{X}$ Bottom semi-range	+1.5	+3.0	+4.5	$\overline{X}$ Top semi-range
St-V	2.11	2.18	2.15	2.14	2.36	2.30	2.11	2.26
V-St	2.28	2.30	2.21	2.26	2.17	2.24	2.21	2.21
$\overline{X}$	2.19	2.24	2.18	2.20	2.26	2.27	2.16	2.23

Part of this data has also been represented graphically in Fig. XII: 1 in which the mean response uncertainty for St-St trials (2.01 bits) is also represented. It is clear that, as had been predicted, the usual inverted U shaped relationship between response uncertainty and position of the stimulus in the stimulus array has been complicated by a markedly lower value of response uncertainty associated with St; certain other features of these results will be returned to subsequently.

The data from St-St trials have been classified according to whether the second stimulus was judged to be either "louder" or "softer". These data have also been subject to analysis of variance (Table XII: 6).

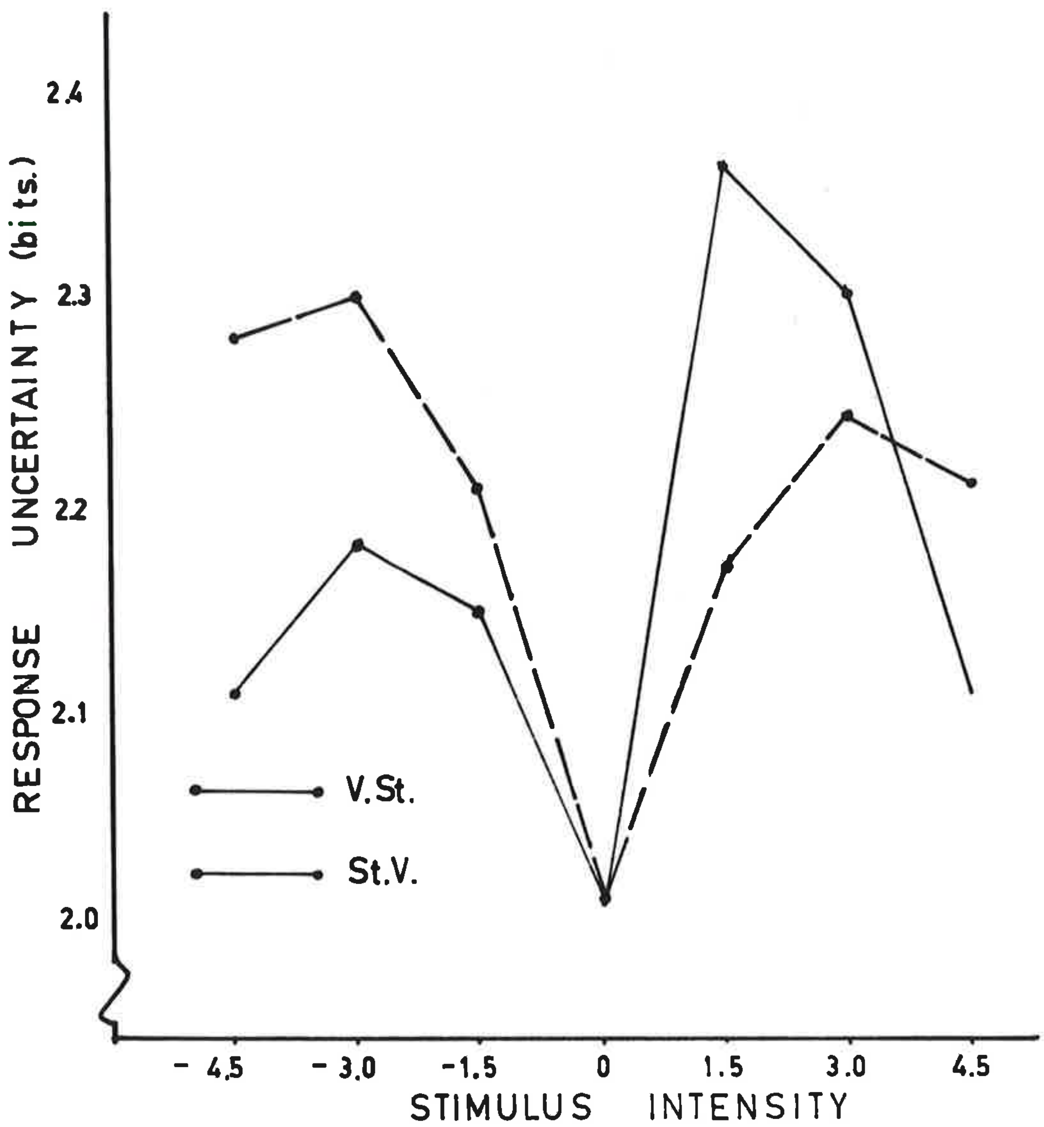

FIG. XII:1 RELATIONSHIP BETWEEN MEAN RESPONSE UNCERTAINTY PER TRIAL, VARIABLE STIMULUS VALUE, AND ORDER OF PRESENTATION (AUDITORY INTENSITY DIFFERENCE ESTIMATION TASK)

TABLE XII: 6

SUMMARY OF ANALYSIS OF VARIANCE OF NUMBERS OF "LOUDER" AND "SOFTER" JUDGEMENTS ON St-St TRIALS

Source	d.f.	S.S.	M.S.	F	p
Subjects (S)	31	101.6523			
Groups (G)	3	8.6680	2.889	<1	n.s.
Indiv. Dif.(ID)	28	92.9843	3.321		
Responses (R)	1	98.7539	98.75	12.0	.01
ISIs	3	10.6992	3.566	3.88	.05
S x R	31	251.3711			
G x R	3	20.1992	6.733	<1	n.s.
ID x R	28	231.1719	8.256		
S x ISI	93	87.1758			
G x ISI	9	9.9726	1.108	1.21	n.s.
ID x ISI	84	77.2032	.9191		
R x ISI	3	58.2305	19.41	6.10	.01
S x R x ISI	93	337.1445			
G x R x ISI	9	69.8789	7.764	2.44	.05
ID x R x ISI	84	267.2656	3.182		
Total	255	945.0273			

The Responses variable is significant at the .01 level and reflects an overall tendency to make more "louder" responses or a negative constant error. The ISIs variable is significant at the .05 level and results from a tendency for more "louder" and "softer" and hence incorrect responses to be made as ISI increases. The interaction Responses x ISIs is significant at the .01 level and appears to result from a rather more pronounced negative constant error at the 6 second ISI than at other intervals. All of these three effects are illustrated in Table XII: 7, while Table XII: 8 illustrates the mode of action of the significant (.05) Groups x Responses x ISIs interaction.

TABLE XII: 7

MEAN NUMBER OF "LOUDER" AND "SOFTER" RESPONSES ON St-St TRIALS ACCORDING TO INTER-STIMULUS INTERVAL

	ISI (secs.)				
	1	2	4	6	
$\bar{X}$ "louder"	3.1	2.9	2.9	4.4	3.3
$\bar{X}$ "softer"	1.8	2.6	2.3	1.6	2.1
$\bar{X}$	2.5	2.7	2.6	3.0	2.7

TABLE XII: 8

MEAN NUMBER OF "LOUDER" AND "SOFTER" RESPONSES ON St-St TRIALS ACCORDING TO ORDER OF EXPERIMENTAL SESSION

	Order of session			
	1	2	3	4
$\bar{X}$ "louder"	4.3	3.3	3.2	2.6
$\bar{X}$ "softer"	1.7	1.8	2.2	2.7

In this table responses are arranged according to order of session since it is on this basis that the Groups were differentiated; it can be seen that the constant error appears to decline in a regular fashion with increased experimentation.

Discussion

The findings of this experiment with respect to the effect of ISI on contingent uncertainty, largely confirm the picture which has previously emerged with respect to auditory intensity information, that is a decline as ISI increases. The finding concerning the nature of this decline seems to be consistent with the view that, in common with other memory processes, the rate of decline decreases over time.

The complex relationships between response uncertainty, order of presentation and stimulus value which are shown in Fig. XII: 1 seem to be quite consistent with the interpretation suggested in connection with the analysis of the data from the temporal difference detection task (Chapter XI). This is that there is a basic internalised schematic representation of the stimulus array which is rather better differentiated at the bottom end of the stimulus array than at the top because here the individual stimuli are situated at greater relative distances to the end stimulus than at the top end of the stimulus array. This information about the schema is only externalised in the context of a comparative judgement situation and the picture which emerges is to some extent determined by the general principles of comparative judgement and, in particular, by the fact that the variance or uncertainty associated with judgements of differences is a direct function of the size of the difference.

The relatively small uncertainty values associated with St-St judgements must, to some extent, reflect the fact that the size of the difference being judged is zero and consequently the variance associated with those judgements will be minimal. In addition it must also reflect a relatively better differentiation of St within the internalised schema as a consequence of its more frequent presentation. Since St is appreciably better differentiated within the schema which mediates performance, it is to be expected that performance on these trials in which St is used as the basis for comparative judgements (i.e. St-V) will be superior to performance on trials in which a less well differentiated stimulus is used as the basis for comparison (i.e. V-St). It is this fact which seems to underly the very robust order effects observed in experiments of this kind.

In the St-V situation the differences between St and V associated with each of the V stimuli are not symmetrical for each of the stimulus semi-ranges because the stimuli are evenly spaced on a d.b. scale. This means that the relative differences between stimuli in the top semi-range and St are greater than those between stimuli in the bottom semi-range and St. This fact, combined with the underlying asymmetry of the stimulus schema, appears to account for the very marked asymmetry observed in this experiment.

In the V-St situation the first stimulus presented (i.e. V) serves as a basis for comparison; the size of St relative to V is of course much greater at the bottom end of the stimulus range than at the top and it appears to be this fact which superimposed upon the structure of the stimulus schema which gives rise to the greater response uncertainty in the bottom stimulus semi-range.

It has not been possible to demonstrate in this experiment any effects of prolonged experimentation on response uncertainty for St-V and V-St trials. It will be recalled that the Groups variable did not, by itself or in interaction with any other variable, act as a significant source of variance in the analysis of these results (Table XII: 3). If Table XII: 8 is referred to, however, it may be seen that prolonged experimentation has had an effect on the relative numbers of "louder" and "softer" responses or the constant error. By the fourth session the constant error appears to have disappeared. Table XII: 7 also indicates some changes in the constant error associated with ISI. It would appear, therefore, that the picture revealed by a response uncertainty analysis of this experiment while being very informative in some respects, does not permit the definition of some of the more subtle aspects of performance in this situation.

As in previous experiments Ss completing this task were asked how they went about remembering the stimulus material. Only three of the thirty two Ss reported using any sort of active approach, all other Ss relied upon a passive auditory image of the first stimulus. Of the three Ss, two reported quite interesting techniques of coding. One S reported coding the information contained on the first stimulus in terms of the imagined apparent distance of the sound source; this is of some interest in view of Warren's (1958) contention that distance is the physical correlate of loudness. The other S reported clenching his jaw after the first stimulus with a tension proportional to its intensity. This technique, which in effect consists of coding by posture, is reminiscent of the coding techniques employed by some sub-human Ss in the delayed reaction task.

Summary

An experiment employing 32 Ss in an auditory intensity difference estimation task is described; one variable investigated was that of interstimulus interval. The results show a regular decline in the information available about the first stimulus for intervals of up to 6 seconds. A negative constant error diminishing with prolonged experimentation was observed. The finding concerning the relationship between the response uncertainty associated with individual members of the stimulus array employed in the experiment was interpreted as being consistent with previous findings concerning the structure of the internalised schema of the stimulus array which has been proposed as mediating performance in situations of this kind, but it is pointed out that certain features of the results appear to be unique to a comparative judgement situation.

CHAPTER XIII

CHOICE REACTION TIME

A general finding arising from the experiments previously described would seem to be that sensory performance with respect to the individual stimuli of a unidimensional stimulus array is not wholly determined by the absolute properties of the stimulus but is to some extent dependent upon the position of the stimulus within the stimulus array. It would appear necessary to postulate that performance is mediated by some form of internalised representation of the stimulus array which possesses the property of being most clearly or adequately differentiated at the limits of the array and progressively less well differentiated towards the middle of the array.

There is a formal similarity between the conventional choice reaction time (RT) situation and most sensory discrimination tasks; in the former case the stimuli, for example a row of lights, and the responses, for example a row of keys, can be thought of as individual members of arrays differentiated with respect to the dimension of space. In line with previous findings it might be expected that differential levels of efficiency of performance might be found in a situation of this kind associated with the different positions of stimuli and responses within their respective arrays. In this situation efficiency of performance would be reflected in speed of reaction whereas in discrimination tasks it is reflected in consistency of performance.

This expectation might be maintained as long as the choice RT situation were structured in such a way that performance was of necessity mediated by such internalised structures. It seems clear, however, that it would be possible to structure the situation in a way that would require less and less reliance upon the mediational process; this could be done by making performance in the task less and less dependent upon the necessity of identifying individual stimuli within the stimulus array and individual responses within the response array. The conventional way in which this has been achieved is by manipulation of what has been called S-R compatability (Fitts & Seeger, 1953) and perhaps the most extreme example of this would be a situation in which stimuli were provided by vibrators under the fingers and the appropriate response was pressing a key with the stimulated finger (Leonard 1959).

ship between frequency of repetition of individual stimuli and RT to these stimuli.

The following experiment was therefore devised in an attempt to determine whether a relationship could be demonstrated between RT and position of stimulus in the stimulus array and position of the response in the response array when these two latter variables were independently manipulated.

Method

The stimulus display for the experiment consisted of 10 red bezel lights spaced $1\frac{1}{2}$ inches apart and arranged in a horizontal row. The response keyboard was 5 inches from the stimulus display with each response key immediately below the corresponding bezel of the stimulus display; the response keys were $\frac{3}{4}$ inch wide and $2\frac{1}{2}$ inches long. Placed about 5 inches immediately in front of the centre of the response keyboard was a conventional telegraphic key which served as the home key. A small warning light was placed 5 inches above the centre of the stimulus display. Below the stimulus lights and above the response keys there was provision for inserting an identifying number;

these were prepared with a "Dymo" machine and were $\frac{3}{8}$ in. high.

At the commencement of each trial S placed his right hand on the home key, the warning light flashed and after a random interval controlled by E (which varied from about 0.5 - 2.0 sec.) a stimulus light came on, this was extinguished by S pressing the appropriate key with his right hand. Both RT and movement time were recorded by E who was also able to determine when an incorrect response had been made.

The apparatus permitted the manipulation of stimulus-response relationships and during the ten experimental sessions of this experiment a different set of relationships was employed for each session. These relationships were arranged at random but with the provision that over the whole ten sessions each stimulus would be paired once with each response.

Two male students who had not previously participated in a RT experiment were paid for their services as Ss. Subject C completed two preliminary sessions before the commencement of the experiment proper and Subject G completed one; during these sessions the appropriate key for each light was that immediately below it. Each experimental session consisted of 100 trials arranged in ten blocks of ten; each S-R combination for that session occurred once in random order in each block; only the data from the last seven blocks was considered in the analysis.

Subject C completed the experiment with response factors constant and stimulus factors averaged out; this was achieved by instructing S that the keys always had the numerical value of 1 - 10 from left to right, beneath each stimulus light was placed a number which represented the number of the key which for that session, when pressed, would extinguish it. Subject G completed the experiment with stimulus factors constant and response factors averaged out; in his case he was instructed that the lights always had the numerical value of 1 - 10 from left to right and above each response key was placed a number which represented the number of the light which would be extinguished when that key was pressed. There was an interval of at least 24 hours between experimental sessions each of which lasted about 20-30 minutes.

Results

The RTs of the last seventy trials of each experimental session were utilised in the analysis; the data from trials in which Ss made correct and incorrect responses were treated independently. RTs from correct trials were converted to reciprocals and mean reciprocal RT for each stimulus-response combination for each session was determined. The overall mean reciprocal RT and standard deviation of the individual means for each experimental session were determined thus enabling the results from each S-R combination for each session to be expressed as a 50-10 T score. This manipulation has the effect of eliminating the between sessions variance. The complete matrix of T scores for each S is shown in Tables XIII: 1 & 2.

These matrices have been subjected to analysis of variance and the form of the relationship between speed of response and position of stimuli and responses within the stimulus and response arrays has been examined by the use of orthogonal polynomials (Hays 1965). Summaries of these analyses of variance may be found in Tables XIII: 3 & 4. It can be seen that in the case of Subject C the quadratic component of the relationship between response speed and both stimulus and response position is significant at the .001 level. In the case of Subject G the quadratic component of the relationship between response speed and stimulus position is also significant at the .001 level. The comprehension of these relationships is assisted by referral to Figures XIII: 1 & 2.

In Figure XIII: 1 it may be seen that for Subject C (response factors constant) there is a general tendency for faster responses to those stimuli near the middle of the stimulus array; this undoubtedly reflects the effects of eye fixation and faster reactions to stimuli in central than in peripheral vision. For Subject G (stimulus factors constant) there is a dramatic reversal of the relationship between response speed and stimulus position with the fastest responses occurring to the outside stimuli of the array and the slower to the middle; this is the relationship predicted on the basis of the considerations previously

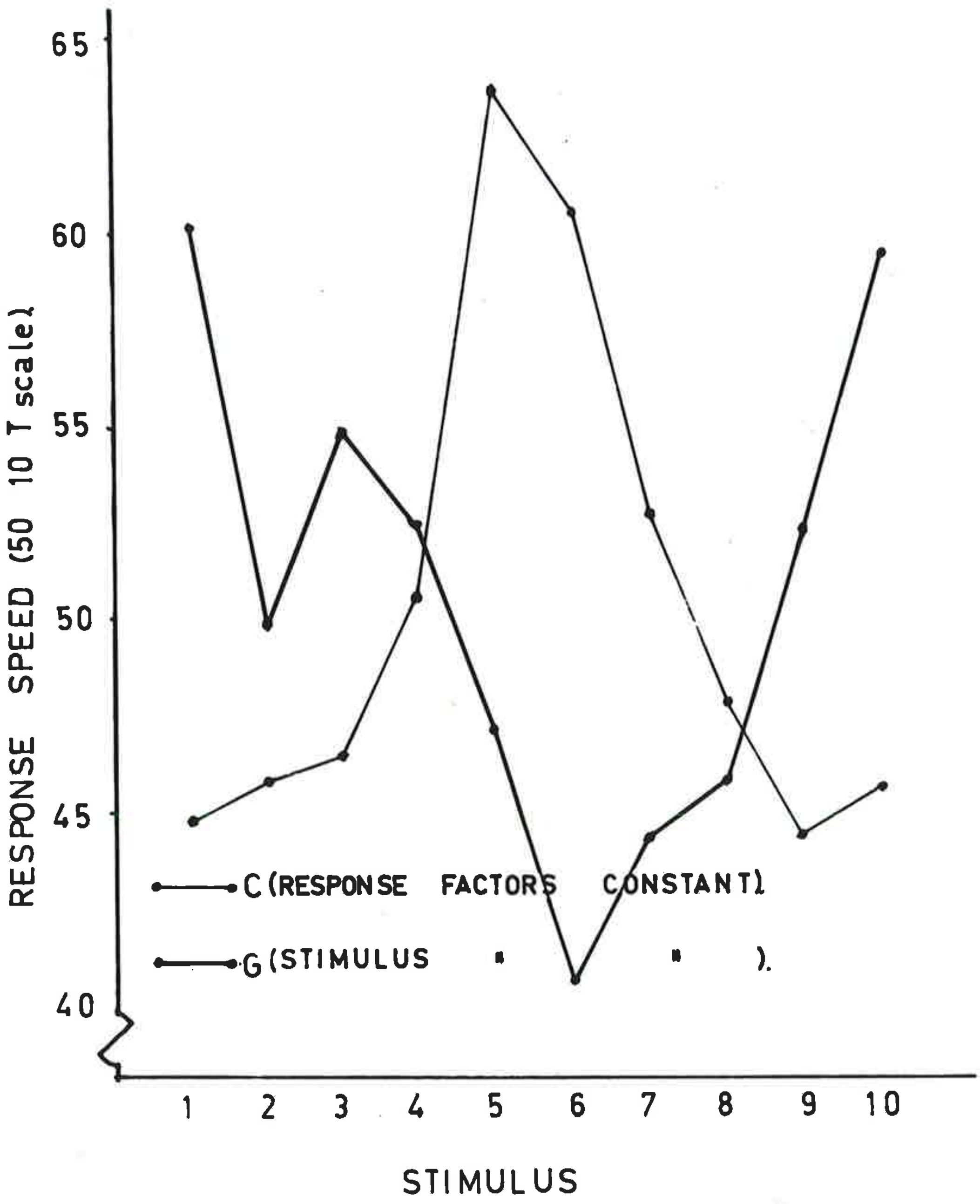

FIG. XIII:1 RELATIONSHIP BETWEEN RESPONSE SPEED AND STIMULUS POSITION IN CHOICE RT TASK

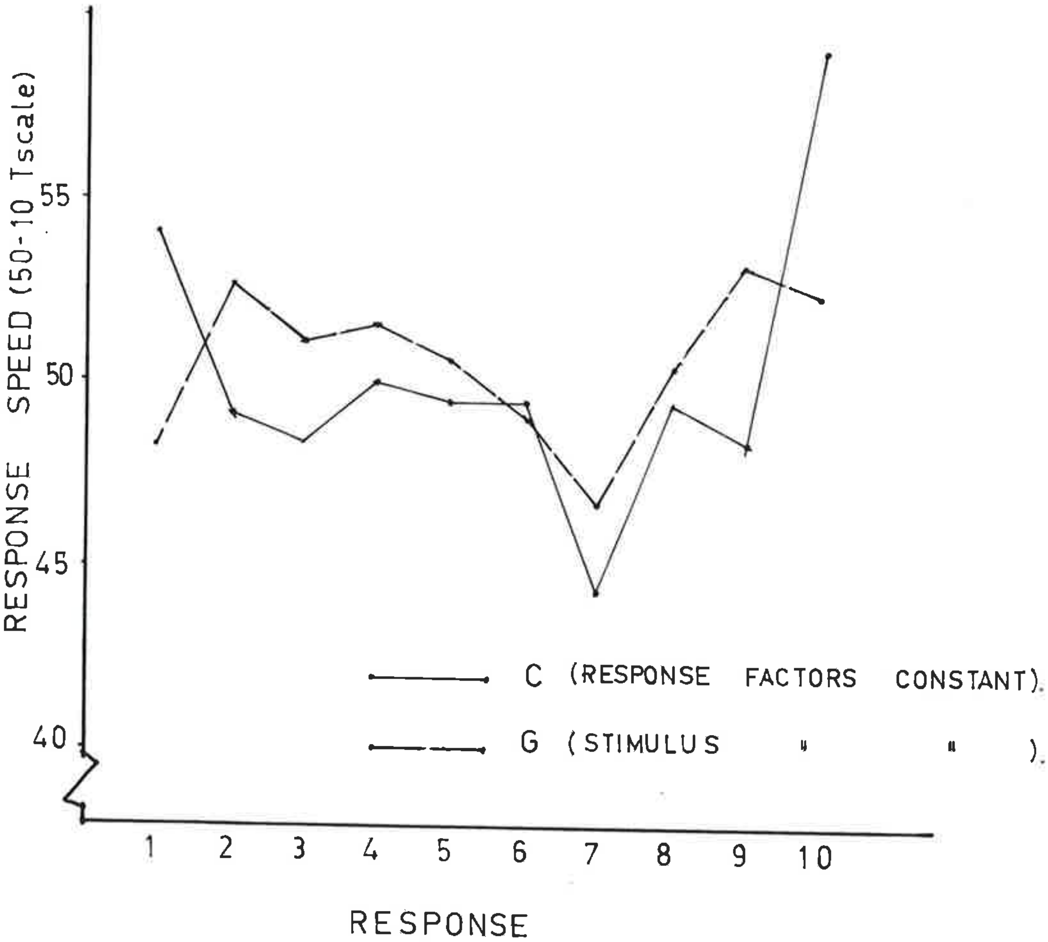

FIG. XIII:2 RELATIONSHIP BETWEEN RESPONSE SPEED AND RESPONSE POSITION IN CHOICE RT TASK

TABLE XIII: 1

STIMULUS - RESPONSE MATRIX OF T SCORES OF SPEED OF RESPONSE FOR SUBJECT C (RESPONSE FACTORS CONSTANT)

Stim.	Responses 1	2	3	4	5	6	7	8	9	10	
1	53.8	46.9	44.2	37.9	42.0	36.6	40.7	47.6	39.7	59.9	449.3
2	46.3	45.9	53.1	50.4	41.0	34.9	45.7	44.8	44.5	50.9	457.5
3	53.4	52.2	50.8	43.5	39.6	46.6	42.4	44.7	44.9	47.7	465.8
4	60.3	44.6	49.6	50.5	51.1	45.0	42.7	56.3	44.9	59.6	504.6
5	53.6	60.2	50.8	68.6	74.5	62.5	57.4	61.2	74.3	71.6	634.7
6	61.7	50.7	56.8	75.0	73.2	65.4	59.2	38.2	54.0	70.2	604.4
7	61.1	49.7	52.4	49.3	49.2	76.5	46.5	44.7	45.7	51.8	526.9
8	51.2	38.2	47.6	43.7	43.8	50.4	36.5	53.6	50.5	61.2	476.7
9	46.4	43.7	41.6	44.9	41.4	36.6	39.7	60.0	41.8	47.8	443.9
10	52.4	59.7	39.1	35.8	40.1	40.1	33.0	44.1	43.4	69.0	456.7
	540.2	491.8	486.0	499.6	495.9	494.6	443.8	495.2	483.7	589.7	5020.5

TABLE XIII: 2

STIMULUS - RESPONSE MATRIX OF T SCORES OF SPEED OF RESPONSE FOR SUBJECT G (STIMULUS FACTORS CONSTANT)

	Responses										
Stim.	1	2	3	4	5	6	7	8	9	10	
1	70.5	54.5	73.3	58.7	48.7	54.6	48.1	52.3	67.8	72.2	600.7
2	30.2	63.6	59.7	57.6	42.3	44.6	46.2	46.0	48.4	58.8	497.4
3	56.9	60.0	52.9	49.5	51.7	47.3	55.4	59.9	55.9	59.3	548.8
4	49.3	59.0	49.8	61.0	50.3	44.1	41.6	53.0	74.1	41.4	523.6
5	39.5	50.3	40.1	51.9	71.9	52.6	39.5	36.8	38.3	48.8	469.7
6	38.0	35.4	35.2	42.9	39.6	35.0	44.4	46.8	50.9	36.8	405.0
7	52.8	48.6	44.5	38.3	46.4	48.9	33.7	50.1	39.0	40.6	442.9
8	42.7	42.7	44.3	53.4	41.8	42.3	49.6	47.5	46.6	46.9	457.8
9	49.4	50.1	56.4	49.3	54.5	56.6	53.3	53.3	48.7	51.1	522.7
10	53.9	62.4	55.0	52.9	59.7	65.2	56.2	58.2	62.3	67.9	593.7
	483.2	526.6	511.2	515.5	506.9	491.2	468.0	503.9	532.0	523.8	5062.3

TABLE XIII: 3

SUMMARY OF ANALYSIS OF VARIANCE OF T SCORES OF SPEED OF REACTION FOR SUBJECT C (RESPONSE FACTORS CONSTANT)

Source	d.f.	S.S.	M.S.	F	p
Stimuli	9	4,085.7565	454.0	8.05	.001
Linear	1	1.1837	1.184	<1	n.s.
Quadratic	1	2,332.2888	2,332.	41.4	.001
Other	7	1,752.2840	250.3	4.44	.001
Responses	9	1,337.6645	148.6	2.64	.05
Linear	1	21.4573	21.96	<1	n.s.
Quadratic	1	693.8250	693.8	12.3	.001
Other	7	622.3822	88.91	1.58	n.s.
Error	81	4,566.4665	56.38		
Total	99	9,989.8875			

TABLE XIII: 4

SUMMARY OF ANALYSIS OF VARIANCE OF T SCORES OF
SPEED OF REACTION FOR SUBJECT G
(STIMULUS FACTORS CONSTANT)

Source	d.f.	S.S.	M.S.	F	p
Stimuli	9	3,697.6841	410.9	7.22	.001
Linear	1	127.1258	127.1	2.23	n.s.
Quadratic	1	2,459.1840	2,459.	43.2	.001
Other	7	1,111.3743	158.8	2.79	n.s.
Responses	9	372.2061	41.36	<1	
Linear	1	13.1734	13.17	<1	
Quadratic	1	30.6678	30.67	<1	
Other	7	328.3649	46.91	<1	
Error	81	4,609.9069	56.91		
Total	99	8,679.7971			

discussed. In Figure XIII: 2 it may be seen that for Subject C (response factors constant) there is a general tendency for faster responses to be made with keys at the outside of the response array and for slower responses to occur near the middle. For subject G no general trend is in evidence at all; these aspects of the results again confirm the predictions.

The information concerning the errors made by each S is shown in Tables XIII: 5 & 6.

TABLE XIII: 5

STIMULUS-RESPONSE MATRIX OF ERRORS FOR SUBJECT C (RESPONSE FACTORS CONSTANT)

Responses

Stim.	1	2	3	4	5	6	7	8	9	10	
1					1		1				2
2					1						1
3											
4								2			2
5						1					1
6				1							1
7											
8						1					1
9						1					1
10				2		2					4
				3	2	5	1	2			13

TABLE XIII: 6

STIMULUS-RESPONSE MATRIX OF ERRORS FOR SUBJECT G (STIMULUS FACTORS CONSTANT)

Responses

Stim.	1	2	3	4	5	6	7	8	9	10	
1											
2										1	1
3				1							1
4	1							1			2
5			1			1		2	2		6
6			1	2							3
7		1	1			1					3
8					1	1			1	2	5
9											
10											
	1	1	3	3	1	3		3	3	3	21

It can be seen that in the case of subject C (response factors constant) errors tend to be associated with responses in the middle of the response array but are more evenly distributed throughout the stimulus array. In the case of subject G this relationship is reversed. It would appear therefore that relatively more errors are made under the conditions which produce the slowest response speeds and that fast response speeds are in no way purchased at the price of increased error rates.

Discussion

The results of this experiment are in general a striking confirmation of the original hypothesis since the specific hypotheses concerning the occurrence of a U shaped relationship between speed of response and position in the stimulus and response arrays when each of these factors has been held constant, have been confirmed at a very high level of significance. An incidental but unpredicted finding concerns the apparent difference in the importance of stimulus and response factors. It would appear that the postulated relationship is much more marked in the case of stimuli than in the case of responses. This generalisation can, of course, only be accepted in a tentative fashion since in this experiment the experimental manipulations are confounded with subjects, but at least in the case of this sample, manipulation of stimulus factors accounts for appreciably more variance than manipulation of response factors.

In view of the small sample size the question of the generality of the main findings might be raised. This question might be met by saying that the postulated properties of the internalised structures which are held to mediate performance in this situation are, as has been demonstrated in previous experiments, markedly uniform. They seem to represent one of the most stable of psychological invariants. In this experiment the conditions have been manipulated in two independent ways to allow the possibility of revealing the same properties in a new situation, and in both cases they have been revealed in a particularly robust fashion. When we are dealing with a phenomenon of such a basic kind, whose existence has been independently verified in a wide range of other situations, it would seem that one is on relatively safe ground in generalising about the occurrence of the phenomenon when it has been demonstrated in a compelling fashion in a very small sample.

Summary

A choice reaction time experiment is described utilising two _S_s. One _S_ completed the experiment with factors associated with position of stimuli in the stimulus array averaged out and factors associated with position of the response in the response array held constant; for the other _S_ the experimental manipulations were reversed. It was shown that when both stimulus and response factors are independently held

constant there is a U shaped relationship between speed of response and position of stimulus or response in their respective arrays. This confirmed predictions arising from an analysis of this situation in which it was postulated that performance in this situation, in common with performance in other sensory discrimination tasks is in some way mediated by internalised representations of the stimulus and response arrays. The results appear to provide an explanation of the common finding of a logarithmic relationship between RT and number of alternative stimuli.

CHAPTER XIV

DISCUSSION AND CONCLUSIONS

The starting point of this study was an interest in the topic of short term storage of non-verbal stimulus material and the view was expressed that an investigation of the psychophysical time error, as well as being of some intrinsic interest, might incidentally throw light on this topic. It would appear that the results of the experiments reported here do have considerable implications for an understanding of non-verbal short term memory and the psychophysical time error as well as a number of other related topics although it must be stated that many of the findings are only suggestive and much additional empirical work will be required to fill in the gaps. The aim of this final chapter will be to summarise and interpret the main findings of these experiments, to attempt to integrate them with other current views and to explore some of their implications.

The major finding of these experiments has been that in situations involving the use of an array or set of stimuli arranged on a single dimension, S appears to build up some form of internalised representation, schema or model of the stimulus array which seems to mediate performance in this situation. This model appears to have highly invariant properties in that the stimuli most adequately differentiated within the model are the extreme or end stimuli of the array, there is progressively less differentiation of stimuli as they approach the centre of the range. The relationship between position of the stimulus within the stimulus range or set and the amount of differentiation is not symmetrical; stimuli in the top semi-range are rather less well differentiated than stimuli in the bottom semi-range. It is suggested that this asymmetry reflects the differences in the relative distance of the stimuli in the two semi-ranges from the end stimulus of the semi-range. That is the end or extreme stimuli of the range appear to play a critical role as reference points and the extent to which the remaining stimuli are differentiated decreases as their relative distance from the reference stimulus increases.

Evidence for the existence of schema or models of this kind has come in this study from the results of sensory discrimination and choice RT experiments, however there would seem to be little doubt that models of this kind mediate performance over a wide range of other situations. The serial position effect which occurs within the context of serial rote learning seems to reflect the operation of such a schema or model in that situation. This interpretation of the serial position effect is in accord with the types of interpretation which have recently been advanced by workers such as Ebenholz (1965), Jensen (1962), and Murdock (1960): Murdock has also pointed to certain presumed similarities between rote learning and sensory discrimination tasks.

The discovery that performance in simple situations of this kind is mediated by such schema or models must be regarded as a substantiation of Bartlett's (1932) views concerning the role of schema in memory and pereptual processes and are consistent with the views concerning perception recently put forward by Garner (1966). These views seem to be most cogently summarised in the following quotation;

> "How the single stimulus is perceived is a function not so much of what it is, but rather a function of what the total set and particular subset are. The properties of the total set and the subset are also the perceived properties of the single stimulus, so we cannot understand the knowing of the single stimulus without understanding the properties of the sets within which it is contained."

The whole weight of evidence from these experiments shows quite strongly that the consistency or clarity with which a stimulus is perceived is a function of its position within the stimulus array or set and that the process of perception or discrimination must consist of relating the stimulus input in some way to the schema or model. The finding (Chapter V) that comparative judgements of temporal duration are rather less accurate with a 1 sec. ISI than with a 2 sec. ISI suggests that the process of relating the stimulus input to the schema or model or, to use Piaget's term, assimilation, is one which is extended in time and if interfered with or prevented results in reduced perceptual accuracy. Although the finding mentioned seems to be consistent with this view it is much better substantiated by the large number of experiments concerning aktualgenese or microgenesis of perception (e.g. Smith, 1957).

There are occasions on which verbal distinctions serve to obscure fundamental similarities between situations. This appears to be the case in the distinction which is maintained between perception experiments and short term memory experiments. In general such experiments employ similar tasks and differ only with respect to the restrictions which are placed on the time at which S reports on the stimulus, immediately in the case of perceptual experiments and after some delay in the case of memory experiments. To point out that the verbal distinction between perceptual and memory tasks is not based on a sound logical distinction is by no means novel (e.g. Bartlett 1932), but what has happened in this study is to provide some empirical evidence concerning the fundamental unity of the two processes. The schema or model which is inferred on the basis of delayed reports of stimuli has the same properties as that which is inferred on the basis of immediate reports. That is although the information which is available about the properties of a stimulus (ignoring for the moment the property of temporal duration) diminishes over time the relative amount of information in the individual stimuli of the array compared with each other appears to remain constant. It would therefore appear that loss of stimulus information in storage is dependent upon the initial assimilation of the stimulus to the model or schema.

In the case of judgements of temporal duration the situation seems to be rather different. The initial perception of the stimulus appears to be mediated in the usual way by the model but the evidence suggests that immediately following perception the stimulus information is consciously recoded into another form which is likely to vary quite considerably from S to S. In this form the stimulus information seems to be relatively immune from deterioration in storage. The evidence from these studies suggests that storage of auditory intensity information in this way is rather exceptional.

Auditory intensity information seems to be lost over time but in common with most other memory processes the rate of loss diminishes. These findings are consistent with a decay or disintegration theory of memory although there is no suggestion that the process of loss of information in storage could not be speeded up by interfering stimuli. The relative role of these two factors remains to be empirically determined.

If the implications of these experiments regarding the fundamental importance of the mediating role of models or schema in performance of this kind is acknowledged it would seem to follow that the properties of such models ought to be systematically explored. The work already done contains some suggestions for future procedures and some information about the properties of the models.

The use of uncertainty measures as a means of quantifying the properties of these models or schema seems to have been quite successful and clearly should be continued with. It has the particular advantage of making no assumptions what so ever about the underlying metric of S's response system and for that reason avoids the continuing controversy on this point.

Since the properties of the model are inferred and not directly observable, a valid picture of it can only be built up by use of the system of methodological triangulation called by Garner, Hake, & Eriksen (1956) converging operations. This means that the same stimulus conditions must be studied by utilising a variety of response systems and the regularities observed. To some extent this has been done in this series of experiments but by no means sufficiently to allow a full picture to emerge.

It is clear that the results of some experiments are affected in characteristic ways by the properties of the response system which is being utilised to externalise the model or schema. This is particularly so of the methods which employ comparative judgements and some of the features of the results of experiments of this type appear to have considerable intrinsic interest and to throw some light on some of the traditional problems of psychophysics. This point will subsequently be returned to.

One of the implications of these experiments must be that all of our commerce with the environment around us is mediated by models of this kind and in these experiments we have been concerned to impose a degree of control and regularity on the environment so that stable schema or models could be built up and their properties examined; we have not been primarily concerned to study the process of the building up of these models. It is clear, nevertheless, that under ordinary circumstances when the individual is subject to a continuous flux of stimulation that these models are not static but are continually changing as a result of incoming stimuli. The results from the magnitude estimation experiments (Chapter VII) show that these changes take place very rapidly and it seems that the ease with which the model is changed is by no means unrelated to its fundamental structure. The model can be thought of as primarily representing a store of information about the range of stimuli rather than about the individual members of the stimulus array; stimuli lying outside of the range currently represented in the model bring about changes in the model to an extent which is not matched by stimuli within the range. There would seem to be rather obvious advantages in storing information about the world in this way in that it permits the easy identification of stimuli outside of the range to which the organism is currently adapted by the use of relatively little stored information.

The results of these experiments have shown the importance of the extreme stimuli of the stimulus array in determining the structure of the model, when other factors are held constant, but the results of the auditory intensity difference estimation task (Chapter XII) strongly suggest that stimuli which are repeated more frequently than the other stimuli in the stimulus array also have the effect of bringing about changes in the basic structure of the model. The change takes the form of a greater differentiation of the model of the stimulus array at the point corresponding to the repeated stimulus. A similar change in structure can apparently be achieved by investing a stimulus with a particular significance, for example by means of instructions as in the magnitude estimation task.

The findings of these experiments seem to be of some relevance in understanding the phenomenon of the habituation of the arousal reaction. It has been pointed out by Sokolov (1960) that this process must be mediated by some store of information concerning past patterns of stimulation and he has referred to this store as a "neuronal model". It seems clear that there is some identity between Sokolov's concept of a "neuronal model" and the concept of a model or schema which has been outlined in this discussion. It appears that stimulus inputs which can be assimilated, in the Piagetian sense, to the existing model do not elicit the arousal response. On the other hand stimulus inputs which can not be assimilated to the model and therefore require its restructuring or accommodation do appear to elicit the arousal response. It is known that the greater the regularity in the pattern of past stimulus input the easier it is to elicit the arousal response by slightly discrepant stimuli; this suggests that under stable conditions a much more highly differentiated model is built up thus permitting more accurate recognition of mismatches with the model; under conditions of stimulus flux the model is relatively poorly differentiated and mismatches are not so adequately recognised. The facts of spontaneous recovery of the arousal response to a previously habituated stimulus suggest that the model is continuously disintegrating and maintains a stable structure only under conditions of regular and continuous stimulus input. The disinhibition of a previously habituated stimulus following a highly discrepant stimulus input seems to suggest that the discrepant stimulus has brought about a restructuring of the model.

Some systematic differences in the ease with which different types of Ss habituate to stimuli (Lynn 1966) suggest that there may be reliable differences in the way in which the model is built up. It is reported, for instance, that both seniles and schizophrenics habituate poorly and inferentially must be regarded as having difficulty in building up adequate models. Evidence suggests that the fundamental difficulty in the case of schizophrenics is that the models which they build up are relatively unstable in that their structure appears to be determined to a disproportionate extent by the most recent stimulus inputs (John 1967). In the case of seniles it is tempting to think of their difficulty as being a general one in building up or establishing models. This is undoubtedly speculative but the foregoing discussion suggests that the apparent short term memory deficit of seniles must eventually be related to some characteristics of the models which mediate this performance.

The findings from these experiments appear to have some relevance for the controversy concerning the nature of perceptual learning. The major parties to this dispute, the Gibsons (1955) and Postman (1955) have favoured what have been called "differentiation" and "enrichment" views respectively. The Gibsons' position is that the essential basis of perceptual learning is the ability to make distinctions between stimuli and attributes which could not previously be differentiated. Postman has favoured the view that the basis of perceptual learning is for the same stimulus to elicit a wider range of responses than previously. The experimental evidence accrued in these studies is not of a kind to throw any light on the type of processes which Postman postulates but it does seem to provide quite a lot of support for a learning process of the type postulated by the Gibsons. That is the simple repetition of stimuli does appear to lead to changes in the extent to which they can be differentiated from other stimuli and this process involves, and is mediated by, a change in the properties of the model. These changes do not seem to involve reinforcement of any kind and appear to be unrelated to the process of associative learning.

The results of this series of experiments have been interpreted as supporting the view that performance in sensory discrimination tasks is mediated by the properties of an internalised model or schema of the stimulus array and it has been argued that there is a certain uniformity about the properties or structure of these models which reflects itself in certain characteristic aspects of behaviour. The discussion has been limited to a consideration of unidimensional models or schema since the evidence which we have bears on models of this type. It is probably best to regard these unidimensional models as a rather special case for it is clear that in most complex tasks the models which are built up and utilised are multi-dimensional. The results which have been obtained within the field of sensory discrimination do suggest that more complex problems associated with perception, pattern recognition, problem solving and concept formation may be amenable to investigation by a similar approach which aims to map out and explore the structure of the multi-dimensional models which presumably mediate performance in these situations.

In this series of experiments on sensory discrimination the traditional problem of psychophysics, the scaling problem, has been virtually ignored. What has been aimed at is the making of a functional analysis of S's behaviour in sensory discrimination tasks. To some extent this has been achieved and a picture has been built up which suggests that there is an underlying similarity between all sensory discrimination tasks and situations. This interpretation imposes somewhat more order on the situation than exists at present when a number of alternative formulations vie for consideration. The basic notion is that performance in sensory discrimination tasks is mediated by the model or schema which S builds up of the stimulus situation and which has the basic properties outlined previously. It is the properties of this model in conjunction with the constraints imposed upon S's behaviour by E which appear to account for the characteristic uniformities and differences between the various psychophysical methods.

The major difference between the category rating method and the magnitude estimation method seems to be the restrictions which are placed on the response system that S is allowed to use in the category rating situation. In this situation the two end stimuli of the range are defined for S and he is told that he must use a limited response scale of, say, from "one" to "seven" to encompass this stimulus range. Although there is only one stimulus range it would seem that S approaches the task as one involving two semi-ranges, each judged with respect to a different reference stimulus; S is therefore confronted with the problem of dividing up the response scale between the two stimulus semi-ranges and it would seem that this is done by allocating equal response scale distances to each stimulus semi-range. This results in what are in effect two independent scales, one for each stimulus semi-range, with the result that in the top stimulus semi-range unit distances on the stimulus scale must be represented by smaller distances on the response scale than is the case for the bottom stimulus semi-range. A division of the response scale in this way appears to account for the fact that the mid-point of the response scale corresponds to the point on the stimulus scale which is at the same relative distance from the two end points of the stimulus scale. Such a point corresponds to the log mean of the two end stimuli and has been called by Helson (1964) the adaptation level.

In the magnitude estimation task the sole restriction placed on the response system is that the initial reference stimulus is given a specific response, say, "100". Although this is the initial reference point it seems clear that the S quickly differentiates out the two extreme stimuli of the stimulus range and subsequently uses these as reference points. In differentiating out these points S assigns to them scale values thereby defining the response scale but in this situation since no restrictions are placed on S, the two halves of the response scale have consistent properties based probably, as Warren (1958) has suggested, on S's knowledge of the physical correlate of the stimulus dimension.

It is this restriction on the response system in the category rating task which appears to be the essential difference between the two situations and to account for the fact that when category scale values are plotted against ratio scale values the resulting curve is concave downwards. This relationship merely reflects that the top part of the category rating scale is compressed relative to the bottom half while this is not so in the case of ratio scales.

An additional consideration determining the form of category rating scales is that since restrictions are placed on the responses which may be used, the distribution of responses to stimuli at the ends of the array will be truncated. Scale values of stimuli at the bottom of the array tend, consequently, to be elevated while scale values of stimuli at the top end of the array tend to be correspondingly depressed. Since no such restrictions operate in magnitude estimation tasks, this consideration is not applicable.

The interpretation of category rating tasks which is being advanced here leads to a number of predictions which are consistent with those derived from adaptation level theory, for example that the mid-point of the response scale should correspond with the log mean of the stimulus range, but it is very much at variance with the view implied by adaptation level theory that the adaptation level in some way serves as a reference point against which all other stimuli are assessed.

It is possible to extend this interpretation of category rating tasks to gain an understanding of the role of anchor stimuli. The experimental evidence suggests quite strongly that these stimuli produce their effects by hindering the development of the model or schema of the stimulus array at the end which is closest to the anchor stimulus and facilitating the differentiation of stimuli at the other end of the stimulus array. Since these restrictions imposed by E result in a truncated distribution of responses, there will be a relative displacement of the scale values of the stimuli which are poorly differentiated towards the middle of the response scale. In the case of the stimuli which are rather better differentiated than they are when no anchor is used, their mean scale value will suffer less displacement towards the centre of the scale than is usually the case. A combination of both of these factors seems to be responsible for the usual anchor effects of a displacement of the mean scale values of the stimuli away from the direction of the anchor.

Attention has recently been directed by Ross & DiLollo (1966) towards a consistent feature of the psychophysical functions obtained with magnitude estimation methods; that is the occurrence of two discontinuities which appear in these functions above and below the mid-points. The magnitude estimation task is structured for S by giving him an initial reference stimulus and instructing him to assign to it a particular magnitude. This stimulus appears initially to act as a basis for judgements but is rather quickly displaced by the two end stimuli of the stimulus array which are soon differentiated out by S and then serve as reference points. The distribution of estimates of judgements of individual stimuli is not symmetrical but is always skewed away from the reference point which is being used; this is a corollary of the fact that the further stimuli are situated from the reference point the more uncertainty there is about them. A consequence of the skewed distribution of judgements is that the mean and median are inappropriate measures of central tendency as they incorporate a systematic bias. Since, according to this analysis, the function linking stimulus value and magnitude estimate is really a composite of three functions associated with three different reference points, the original one and the two end ones, and since the magnitude estimates (based usually on the median) incorporate a systematic bias, the function should exhibit two discontinuities where the direction of the systematic bias changes because of a shift to a different reference point.

These views of sensory discrimination also permit a more adequate understanding of the method of constant stimulus differences. Performance in this situation is determined by a combination of the properties of the model with the particular characteristics of the response system used. The fact that there is more uncertainty about stimuli in the centre of the stimulus array than those at the periphery means that individual stimuli are more likely to be confused with stimuli near the centre of the stimulus array than those near the periphery. Such a situation would give rise to what has been called the central tendency of judgement.

What has been called the order effect, that is, that judgements in the St-V order are more accurate and consistent than judgements in the V-St order, appears to reflect the fact that over the course of the experiment St becomes better differentiated than the V stimuli since it is presented much more frequently. In the St-V trials, St serves as a basis for the comparative judgement and these are consequently more consistent than judgements in the V-St order where the V stimuli, which are not so well differentiated as St, serve as the basis for comparison.

When comparative judgements are made in the St-V order and the V stimuli are placed symmetrically about the St, the same relative differences from the St are maintained by the V stimuli in both stimulus semi-ranges. Under these conditions the relationship between position in the stimulus array and the uncertainty associated with the comparative judgement of each of the V stimuli in the stimulus array will have the same general form as is found with other types of judgements, that is an asymmetrical inverted U. Because of the asymmetry of the relationship the distribution of comparative judgements will also be asymmetrical or skewed towards the right. This will mean that the mean or median value of the judgements when used as an indication of central tendency will involve a systematic upward bias.

When judgements are made in the V-St order the relative size of the differences being judged is greater for stimuli in the bottom stimulus semi-range than for stimuli in the top and hence the judgements of these stimuli will be accompanied by more uncertainty. This means that the asymmetry of the relationship between response uncertainty and position in the stimulus array is opposite to that observed in the St-V order and that the bias involved in the use of the mean as a measure of central tendency will be downwards. Since comparisons of the V stimuli relative to St are systematically biased upward and comparisons of St relative to V are systematically biased downward this gives rise to a situation in which it appears that the subjective magnitude of St, or the PSE is less than the objective value of St, or that there is a negative constant error. The constant error in the method of constant stimulus differences therefore appears not to have anything to do with time <u>per se</u> but is a reflection of the pattern of response uncertainty or the variable error. To the extent that the response uncertainty can be manipulated by lengthening ISI or increasing practice, so might we expect this to either increase or decrease the constant error.

Another form of the constant error which has consistently been observed in perceptual experiments is what has been called the error of the standard. The error of the standard reflects the fact that the objective St in these experiments is consistently reported as being bigger than the subjective St, the size of which is inferred from the results of the experiment. The logical identity of these two errors seems to have been overlooked because one is usually spoken of as an underestimate and the other as an overestimate; in the first case we are concerned to determine the magnitude of the subjective St which is found to be smaller than that of the true St and is, therefore, said to be underestimated while in the second case we are concerned to determine the subjective size of the real St. This is usually found to be greater than the PSE or subjective St and is therefore said to be overestimated.

A third type of constant error has very frequently been found in studies of size constancy when the apparent size of St exceeds its true size (Wohlwill 1963). In both of these additional situations it does not seem at all unlikely that the basic cause of the observed constant errors is similar to the one which has been advanced to account for its occurrence in the method of constant stimulus differences.

Two of the topics which have been discussed, namely the time error and the relationship between category scales and ratio scales, are of some relevance to an assessment of Stevens' views on sensory measurement since he has asserted (Stevens 1957) that the occurrence of the time error and of the bow shaped relationship between category scale values and ratio scale values are two of the defining characteristics of prothetic as opposed to metathetic stimulus continua. In this discussion explanations have been advanced to account for these two phenomena which do not involve the necessity of invoking the distinction between prothetic and metathetic stimulus continua. This may be taken as providing some further weight to Warren & Warren's (1963) contention that the functional criteria for distinguishing between the two types of continua are without adequate support. It should also be said however that an attempt to obtain evidence for a particular explanation of the phenomenon of psychophysical hysteresis, the occurrence of which is yet another of Stevens' defining criteria, was not successful.

One of the implications of this work on sensory measurement is that it adds to our understanding of the factors, other than sensory acuity, which influence performance in sensory discrimination tasks. Since the mediating schema or model is so important in determining performance it must be expected that variables associated with the building up and maintenance of these models will be important determinants of performance. It would seem to follow that signal detection type methods which involve only two stimulus values, signal and signal plus noise and consequently the very simplest type of model, must provide the best situations for a study of acuity uncontaminated by other factors. The properties of the schema also seem to provide an explanation for the observation (Swets, Shipley, McKey & Green 1964) that in signal detection tasks performance under conditions of multiple detection where a number of signal intensities are used is relatively poor.

The interpretation of the absolute judgement situation which has been advanced suggests that a major limitation on performance in this situation must be imposed by S's ability to build up and maintain the mediating schema or model. It is this ability which appears to underly the relatively invariant limits of performance in situations of this kind, of between two and three bits of information per absolute judgement (Miller 1956).

In common with other tasks which involve an array of stimuli located on a single dimension it has been shown that choice RT performance too, appears to be mediated by a model or schema with properties the same as those previously outlined. It must follow from the operation of such a mechanism that each additional stimulus which is added to the stimulus array will lead to an increase in the overall mean response uncertainty and hence RT, but the size of this increase will diminish for each additional stimulus which is added to the stimulus array. This argument also applies to the response array and it is suggested that it forms the basis of the observed logarithmic relation between RT and number of alternative stimuli in the array.

It would seem to follow that this relationship could be expected to be most pronounced when the choice RT situation was structured so as to ensure that performance required identification of the stimulus in the stimulus array and identification of the response in the response array. To the extent that S could minimise the necessity to identify both stimulus and response in carrying out the task, the strength of the relationship might be expected to be reduced. An indication of the strength of this relationship is given by the slope of the function linking RT and number of stimulus alternatives. One way of minimising the necessity to make separate identification of stimulus and response would be to manipulate the spatial and physical arrangements between stimuli and responses. The ultimate in this manipulation was probably achieved in an experiment in which the individual stimuli were vibrators under the fingers to be used to press the appropriate response key (Leonard 1959). A further way of reducing the necessity for reliance on the postulated mediating processes would be to establish strong direct associational links between stimulus and response by prolonged practice; evidence has shown (Mowbray & Rhoades 1959) that under these conditions the slope of the function is zero and that the relationship between RT and number of stimulus alternatives disappears. A manipulation which would increase the necessity to rely upon the mediating schema would be to break down the spatial equivalence between the stimulus and response arrays and to arrange the individual stimuli or responses on a continuum defined in numerical rather than spatial terms; experiments of this kind have had the effect of increasing the slope of the function (e.g. Morin & Grant 1955).

It would therefore appear that this interpretation of the choice RT task not only accounts for the major findings about performance in this situation but successfully integrates this task within the wider context of sensory discrimination.

APPENDIX A

Instructions for Temporal Difference Estimation Task.

The aim of this experiment is to determine how well you can discriminate short intervals of time. On each trial you will hear two sounds of varying duration separated by a short interval. Your task is to compare the length of the second sound with the first. You are to make the comparison by means of this scale and cursor. The middle position of the cursor always corresponds to the length of the first sound; on each trial you are to shift the cursor to the square which you feel best expresses the length of the second sound as compared with the first. You shift the cursor to the right if you feel the second sound was longer than the first; you shift the cursor to the left if you feel that the second sound was shorter than the first. On each trial you must shift the cursor to a square which you feel best expresses the relationship between the length of the two sounds.

This task requires your undivided attention. If at any time you feel that your concentration is lapsing and that you require a short break please indicate.

We will now have a few preliminary trials so that you can get some idea of the nature of the task and the range of stimuli used.

APPENDIX B

Instructions for Temporal Difference Detection Task.

The aim of this experiment is to determine how well you can discriminate short intervals of time. On each trial you will hear two sounds of varying duration separated by a short interval. Your task is to compare the length of the second sound with the first. You may make judgements of "shorter", "longer" or "equal". It will be necessary to make your judgements quite quickly at the end of each trial as there is only a small interval between trials. Whether the second stimulus is longer, shorter or equal to the first on any one trial is determined purely at random: however, there are equal proportions of each kind of trial. That is, on one third of the occasions the second stimulus is shorter than the first, on one third it is longer, and on one third it is equal.

We will now have a few preliminary trials to acquaint you with the situation. This task requires your undivided attention. If at any time you feel that your concentration is lapsing and that you require a short break please indicate.

APPENDIX C

Instructions for Auditory Intensity Difference Detection Task.

The aim of this experiment is to determine how well you can discriminate small differences in loudness. On each trial you will hear two sounds separated by a short interval. Here is an example. "Now." --

Your task is to compare the loudness of the second sound with the first. You may make judgements of "louder", "softer", or "equal". As soon as you have made your judgement enter it in the appropriate square of the record sheet using an L for "louder", an S for "softer" and a - for "equal".

From time to time a voice will announce the number of the next trial. This will enable you to check that you are completing the record sheet correctly.

Whether the second sound is "louder", "softer", or "equal" to the first on any one trial is determined purely at random; however, there are equal proportions of each kind of trial. That is, on one third of the occasions the second stimulus is "louder" than the first, on one third it is "softer", and on one third it is "equal".

Here are a few practice trials. Do not record your response to these. "Now" --
"Now" --
"Now" --
"Now" --
"Now" --

We will now commence the experiment proper; remember, record your response "louder", "softer", or "equal after each trial. "Start."

APPENDIX D

Instructions for Category Rating of Lifted Weights.

(a) Without anchor.

"The aim of this experiment is to determine how well you are able to make judgements of weight. On each trial you will be presented with one weight and you are to report how heavy it is. In reporting on each weight you may use any number from one to seven inclusive, one for the lightest weights and seven for the heaviest. On each trial use that number which you think is most appropriate.

Here is the heaviest weight of the series.
Here is the lightest weight of the series."

(b) With anchor.

"The aim of this experiment is to determine how well you are able to make judgements of weight. On each trial you will be presented with two weights and you are to report how heavy the second weight is. The first weight will be the same on each trial but the second weight will vary from trial to trial. In reporting on each weight you may use any number from one to seven inclusive, one for the lightest weights and seven for the heaviest. On each trial use that number which you think is most appropriate.

Here is the heaviest weight of the series.
Here is the lightest weight of the series."

APPENDIX E

Instructions for Hysteresis Experiment.

The aim of this experiment is to determine how well you are able to make judgements of weight. On each trial I shall give you three weights in succession, either in increasing order of heaviness or decreasing order of heaviness. Your task is to make a judgement of the weight which was presented second in comparison to the other two; that is, the first and the third weights. On each trial the heavy and light weight will be the same although they may be presented either first or last in any particular trial; only the second or middle weight will vary.

The heaviness of the two end weights is represented by the two ends of this scale, the lightest weight at the left end of the scale and the heaviest at the right end of the scale. On each trial you must shift the cursor to that square which you feel best represents the heaviness of the second or middle weight.

APPENDIX F

Instructions for Auditory Intensity Difference Detection Task.

The aim of this experiment is to determine how well you can discriminate small differences in loudness of sounds. On each trial you will hear two sounds separated by a short interval. Your task is to compare the loudness of the second sound with the first. You are to make the comparison by means of this scale and cursor. The middle position of the cursor, that is where it is now, always corresponds to the loudness of the first sound; on each trial you are to shift the cursor to the square which you feel best expresses the loudness of the second sound as compared with the first. If you feel that the two sounds were of equal loudness let the cursor remain in its present position but the two sounds will be of equal loudness on the average, only once in every thirteen trials. On the remaining trials there will be an equal number of occasions when the second sound will be louder or softer than the first. If you feel that the second sound was louder than the first, shift the cursor to the right, if you feel that the second sound was softer than the first, shift the cursor to the left. On each trial you must shift the cursor to a square which you feel best expresses the relationship between the loudness of the two sounds.

APPENDIX F (Continued)

In effect you must translate your judgement of loudness into spatial terms. You may choose whatever distance on the scale you think is most appropriate to express a particular difference in loudness but experience with this task has shown that performance is better if judgements are well spaced out and a large portion of the scale is used.

We will have a few preliminary trials so that you can get some idea of the nature of the task and the range of stimuli used. After each trial is completed please return the cursor to the middle position.

This task requires your undivided attention. If at any time you feel that your concentration is lapsing and that you require a short break, please indicate.

REFERENCES

Axelrod, S. & Eisdorfer, C. Auditory time-error and context effects in the aged. in Tibbits, C. & Donahue, W. (eds.) Social and Psychological Aspects of Aging. New York: Columbia Univ. Press, 1962

Bachem, A. "Time factors in relative and absolute pitch determination." J. Acoustical Soc. of America, 1954, 26, 751-753.

Bartlett, F. C. Remembering: A Study in Experimental and Social Psychology. Cambridge: C.U.P., 1932.

Bartlett, R. J. Measurement in Psychology. Advancement of Sci., 1939, 1-20.

Berlyne, D. E. Conflict, Arousal, and Curiosity. New York: McGraw-Hill, 1960.

Birch, H. G., Belmont, I. & Karp, E. "The prolongation of inhibition in brain-damaged patients." Cortex. 1965a, 1, 397-409.

Birch, H. G., Belmont, I. & Karp, E. "Social differences in auditory perception." Percept. & Mot. Skills, 1965 b, 20, 861-870.

Bruner, J. S. "On perceptual readiness." Psychol. Rev., 1957, 65, 123-152.

Buckner, D. N. & McGrath, J. J. (eds.) Vigilance: A Symposium. New York: McGraw-Hill, 1963.

Dawes, R. M. "The logic of S-R matrices." Psychol. Rev., 1963, 70, 365-368.

Doughty, J. M. "The effect of psychophysical method and context on pitch and loudness functions." J. exp. Psychol., 1949, 39, 729-745.

Doughty, J. M. "The role of repetition rate and inter-stimulus interval in context effects. J. exp. Psychol., 1952, 43, 156-161.

Ebenholz, S. M. "Positional cues as mediators in discrimination learning." J. exp. Psychol., 1965, 70, 176-181.

Fechner, G. Elements of Psychophysics. New York: Holt, Rinehart & Winder, 1966. (First published 1860.)

Fernberger, S. W. "On absolute and relative judgements in lifted weight experiments." Amer. J. Psychol., 1931, 43, 560-578.

Fitts, P. M. & Seeger, C. M. "S-R compatibility: spatial characteristics of stimulus and response codes." J. exp. Psychol., 1953, 46, 199-210.

Garner, W. R. Uncertainty and Structure as Psychological Concepts. New York: Wiley, 1962.

Garner, W. R. "To perceive is to know." Amer. Psychologist, 1966, 21, 11-19.

Garner, W. R., Hake, H. W. & Eriksen, C. W. "Operationism and the concept of perception." _Psychol. Rev._, 1956, 63, 149-159.

Geertsma, R. H. "Time order errors in comparative judgements of hurtfulness." _J. exp. Psychol._, 1958, 55, 284-288.

Gibson, Eleanor J. "Improvement in perceptual judgements as a function of controlled practice or training." _Psychol. Bull._, 1953, 50, 401-431.

Gibson, J. J. & Gibson, Eleanor J. "Perceptual learning: Differentiation or enrichment?" _Psychol. Rev._, 1955, 62, 32-41.

Guilford, J. P. _Psychometric Methods_. 2nd Ed. New York: McGraw-Hill, 1954.

Guilford, J. P. & Park, D. G. "The effect of interpolated weights upon comparative judgements." _Amer. J. Psychol._, 1931, 43, 589-599.

Gundy, R. F. Auditory detection of an unspecified signal. in Swets, J. A. (ed.) _Signal Detection and Recognition by Human Observers_. New York: John Wiley & Sons, 1964.

Harris, J. D. "The effect of inter-stimulus interval or intensity discrimination for white noise." _Amer. J. Psychol._, 1949, 62, 202-214.

Harris, J. D. "The decline of pitch discrimination with time." _J. exp. Psychol._, 1952, 43, 96-99.

Hays, W. L. Statistics for Psychologists. New York: Holt, Rinehart & Winston, 1963.

Helson, H. Adaptation-level theory. New York: Harper & Row, 1964.

Hollingworth, H. L. "The central tendency of judgement." J. philos. psychol. & Sci. Meth., 1910, 7, 461-469. (Not sighted.)

Inomata, S. "Comparison of time-error phenomena in different sense-modalities." Jap. Psychol. Res., 1964, 6, 10-20.

Jensen, A. R. "Temporal and spatial effects of serial position." Amer. J. Psychol., 1962, 75, 390-400.

John, I. D. "Sequential effects of stimulus characteristics in a serial reaction time task." Aust. J. Psychol., 1967, 19, 35-40.

Johnson, D. M. The Psychology of Thought and Judgement. New York: Harper & Brothers, 1955.

Karlin, L. "The time error in the comparison of visual size." Amer. J. Psychol., 1953, 66, 564-573.

King, H. E. "The retention of sensory experience: I Intensity." J. of Psychol., 1963a, 56, 283-290.

King, H. E. "The retention of sensory experience: II Frequency." J. of Psychol., 1963b, 56, 291-298.

King, H. E. "The retention of sensory experience: III Duration." J. of Psychol., 1963c, 56, 299-306.

King, H. E. "The retention of sensory experience: IV Short delay versus long delay intervals. J. of Psychol., 1965, 60, 103-115.

King, H. E. "The retention of sensory experience: V Variation of the standard stimuli." J. of Psychol., 1966a, 62, 15-22.

King, H. E. "The retention of sensory experience: VI Stimulus repetition and interference effects." J. of Psychol., 1966b, 64, 59-61.

Koester, T. "The time error and sensitivity in pitch and loudness discrimination as a function of time interval and stimulus level." Arch. Psychol., 1945. Whole No. 297.

Koester, T. & Schoenfeld, W. N. "The effect of context upon judgements of pitch differences." J. exp. Psychol., 1946, 36, 417-430.

Koffka, K. Principles of Gestalt Psychology. London: Routledge and Kegan Paul, 1935.

Kohler, W. "Zur Theorie des Sukzessivvergleichs und der Zeitfehler." Psychol. Forsch., 1923, 4, 115-175. (Not sighted.)

Leonard, J. A. "Tactual choice reactions." Quart. J. exp. Psychol., 1959, 11, 76-83.

Lynn, R. Attention, Arousal and the Orientation Reaction. Oxford: Pergamon, 1966.

Marchetti, P. V. "Time errors in judgements of visual extents." J. exp. Psychol., 1942, 30, 257-261.

McClelland, D. "Factors influencing the time error in judgements of visual extent." J. exp. Psychol., 1943, 33, 81-95.

McGavren, Musetta. "Memory of brief auditory durations in comparison discriminations." Psychol. Rec., 1965, 15, 249-260.

Michels, W. C. & Helson, H. "A quantitative theory of time-order effects." Amer. J. Psychol., 1954, 67, 327-334.

Miller, G. A. "The magical number seven, plus or minus two." Psychol. Rev., 1956, 63, 81-97.

Morikiyo, Y. "Time order error in successive comparison of tones: An examination by adaptation level theory." Jap. J. Psychol., 1959, 30, 198-207.

Morin, R. E. & Grant, D. A. "Learning and performance on a key-pressing task as a function of the degree of spatial stimulus-response correspondence." J. exp. Psychol., 1955, 49, 39-47.

Mowbray, G. H. & Rhoades, M. V. "On the reduction of choice reaction times with practice." Quart. J. exp. Psychol., 1959, 11, 16-23.

Murdock, B. B. Jr. "The distinctiveness of stimuli." Psychol. Rev., 1960, 67, 16-31.

Nakajima, S. "Time errors in successive comparison of tonal durations." Jap. J. Psychol., 1958, 29, 18-27.

Needham, J. G. "The time-error as a function of continued experimentation." Amer. J. Psychol., 1934, 46, 558-567.

Needham, J. G. "The effect of the time interval upon the time-error at different intensive levels." J. exp. Psychol., 1935, 18, 530-543.

Osgood, C. E. Method and Theory in Experimental Psychology. New York: O.U.P., 1953.

Parducci, A. "Category judgements: A range-frequency model." Psychol. Rev., 1965, 72, 407-418.

Peak, Helen. "Time order error in successive judgements and in reflexes. I Inhibition of the judgement and the reflex." J. exp. Psychol., 1939, 25, 535-565.

Peterson, L. R. Immediate memory: Data and theory. in Cofer, C. N. & Musgrave, B. S. (eds.) Verbal Behaviour and Learning: Problems and Processes. New York: McGraw-Hill, 1963.

Posner, M. I. "Immediate memory in sequential tasks." Psychol. Bull., 1963, 60, 333-349.

Postman, L. "The time-error in auditory perception." Amer. J. Psychol., 1946, 59, 193-219.

Postman, L. "Association theory and perceptual learning." Psychol. Rev., 1955, 62, 438-446.

Ross, Helen E. "Constant errors in weight judgements as a function of the size of the differential threshold." Brit. J. Psychol., 1964, 55, 133-141.

Ross, J. & DiLollo, V. Paper delivered at seminar on perception. Monash University, 1966.

Small, A. M. Jr., & Campbell, R. A. "Temporal differential sensitivity for auditory stimuli." Amer. J. Psychol., 1962, 75, 401-410.

Smith, G. "Visual perception: An event over time." *Psychol. Rev.*, 1957, 64, 306-313.

Sokolov, E. N. Neuronal models and the orienting reflex. in Brazier, M. A. B. (ed.) *The Central Nervous System and Behaviour*. Josiah Macy Jr. Foundation. New York: 1960.

Stevens, S. S. "On the psychophysical law." *Psychol. Rev.*, 1957, 64, 153-181.

Stevens, S. S. The psychophysics of sensory function. in Rosenblith, W. A. (ed.) *Sensory Communication*. New York: John Wiley, 1961.

Stevens, S. S. & Galanter, E. H. "Ratio scales and category scales for a dozen perceptual continua." *J. exp. Psychol.*, 1957, 54, 377-411.

Swets, J. A., Shipley, E. F., McKey, M. J. & Green, D. M. Multiple observations of signals in noise. in Swets, J. A. (ed.) *Signal Detection and Recognition in Human Observers*. New York: Wiley, 1964.

Swets, J. A., Tanner, W. P. Jr. & Birdsall, T. G. "Decision processes in perception." *Psychol. Rev.*, 1961, 68, 301-340.

Tresselt, M. E. "Time-errors in successive comparison of tonal pitch." *Amer. J. Psychol*. 1948, 61, 335-342.

Warren, R. M. "A basis for judgements of sensory intensity." *Amer. J. Psychol.*, 1958, 71, 675-687.

Warren, R. M. & Warren, Roslyn P. A critique of S. S. Stevens "New Psychophysics". Percept. Mot. Skills, 1963, 16, 797-810.

Watson, W. A. "Contrast, assimilation and the effect of central tendency." Amer. J. Psychol., 1957, 70, 560-568.

Weinstein, S. "Time error in weight judgements after brain injury." J. comp. physiol. Psychol., 1955a, 48, 203-207.

Weinstein, S. "Time error in tactile size judgements after penetrating brain injury." J. comp. physiol. Psychol., 1955b, 48, 322-323.

Wever, E. G. & Zener, K. E. "The method of absolute judgement in psychophysics." Psychol. Rev., 1928, 35, 466-493.

Wohlwill, J. F. The development of "Overconstancy" in space perception. in Lipsitt, L. P. & Spiker, C. C. (eds.) Advances in Child Development and Behaviour. Vol. I. New York: Academic Press, 1963.

Woodrow, H. "Weight discrimination with a varying standard." Amer. J. Psychol., 1933, 45, 391-416.

Woodrow, H. "The temporal indifference interval determined by the method of mean error." J. exp. Psychol., 1934, 17, 167-188.

Woodrow, H. "The effect of practice upon time-order errors in the comparison of temporal intervals." Psychol. Rev., 1935, 42, 127-152.

Woodrow, H. & Stott, L. H. "The effect of practice on positive time-order errors." *J. exp. Psychol.*, 1936, 19, 694-705.

Woodworth, R. S. & Schlosberg, H. *Experimental Psychology*. 2nd ed. London: Methuen, 1955.

ERIKSEN, C.W. & HAKE, H.W. Absolute judgements as a function of stimulus range and number of stimulus and response categories. *J. exp. Psychol.* 1955, 49, 323-332.

GARNER, W.R. An informational analysis of absolute judgements of loudness. *J. exp. Psychol.* 1953, 46, 323-380.