INDIVIDUAL DIFFERENCES

IN

THE REPRODUCTION OF TEMPORAL INTERVALS

A thesis presented to the Department of Psychology of the University of Cape Town in partial fulfilment of the requirements for the degree of Ph.D.

by

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INDIVIDUAL DIFFERENCES IN THE REPRODUCTION OF TEMPORAL INTERVALS

SUMMARY

1. MAIN AIMS

(i) To determine the reliability of the reproduction of short time intervals by the method of linear arm movement* under conditions of free movement (in which the distance and speed of the linear movement was left to the subject's own preference) and controlled movement (in which the distance, and, indirectly, the speed of linear movement was experimentally varied) (Chapter 4).

(ii) To investigate relations among time judgements by different methods of reproduction and by verbal estimation (Chapter 5).

(iii) To investigate motor time-space relations under conditions of free movement (Chapter 6) and controlled linear arm movement (Chapter 7).

(iv) To investigate the effects of short periods of delay on the reproduction of short time intervals (Chapter 8).

(v) To investigate the relationship between individual differences in extraversion (measured by the Maudsley Personality Inventory) and individual differences in the reproduction of short time intervals by both free and controlled linear arm movement (Chapter 9).

(vi) To investigate the relationship between individual differences in measures of unstructured motor speed, measures of secondary functioning, and reproduction of short time intervals by free linear arm movements (Chapter 10).

(vii) To investigate the relationship between individual differences in Taylor Manifest Anxiety score and individual differences in the reproduction of short time intervals by both free and controlled linear arm movement (Chapter 11).

(viii) To investigate the relationship between individual differences in time imagery (measured by the Metaphor Preference Scale) and individual differences in the reproduction of short time intervals by both free and controlled linear arm movements (Chapter 12).

(ix) To investigate the relationship between individual differences in n Achievement and individual differences in the reproduction of short time intervals by free linear arm movements (Chapter 12).

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* I wish to record my gratitude to Professor K. Danziger for suggesting the method of reproduction of time by linear arm movements.

2. METHOD

2.1 Experiments to Measure Time Judgement (Chapter 3)

Apparatus.

(i) The time interval to be judged was an auditory stimulus, timed by a Hunter Decade Interval Timer, presented to the subject through a pair of earphones.

(ii) The apparatus for measuring the reproduction of time by free movement consisted of a handle, suspended by a cord which passed over pulleys, which could be moved horizontally across a frame 42 inches wide. The duration of the movement was recorded by an electric stop clock. The distance could also be read by means of a measuring tape visible to the experimenter only.

(iii) The apparatus for measuring the reproduction of time by controlled movement consisted of a handle through which passed a metal rod. The handle could be moved horizontally across a frame of variable width (from 5 inches to 60 inches). The duration of the movement was recorded by an electric stop clock.

(iv) A key was connected in series with an electric stop clock so that time intervals could be reproduced by depression of the key for the judged duration of the interval.

Procedure.

Experiment 1.

In the first session of Experiment 1, 43 subjects twice reproduced, by free linear arm movement, signals ranging from 0.9 sec. to 6.1 sec. immediately after hearing each signal.

In the second session of Experiment 1, separated from the first by a median period of one month, 31 of the original subjects twice reproduced the same range of signals in the same way.

Experiment 2/ ...

Experiment 2

In the first session of Experiment 2, 77 subjects reproduced, by free linear arm movements, signals ranging from 1 to 16 seconds (a) immediately after hearing the signals, and (b) after delays of up to 60 seconds. Subjects made verbal estimates of each time signal after reproducing it. Forty-three subjects also reproduced the time signals for a third time by pressing a key.

In the second session, separated from the first by a median period of one month, 56 of the original subjects twice reproduced the same range of signals by free linear arm movement immediately after hearing each signal, and also made a verbal estimate of each signal immediately after reproducing it. Thirty-two of these subjects had reproduced the time signals by key-pressing in the first session and were asked to do so again.

Experiment 3

There were four sessions, spaced as close to a month apart as possible.

In the first session, 40 subjects reproduced 8 seconds (a) by linear arm movements of experimentally controlled distance up to 60 inches; (b) by linear movements of preferred distance; and (c) by gripping the handle without moving it. Each subject verbally estimated the time signal as well.

In the second session, these subjects repeated what they had done in the first session.

In the third and fourth sessions, the procedure was kept the same as in the first, but the signal length was changed to 16 seconds.

2.2 Measures of Personality, Temperament and Time Imagery

Extraversion (Chapter 9)

Fifty-four subjects of Experiment 2 were asked to fill in the short form of the Maudsley Personality Inventory

immediately /...

immediately after they had completed their time reproduction trials in the second session. All the subjects of Experiment 3 were asked to fill in both the short and the long forms of the Maudsley Personality Inventory, immediately after testing sessions, but on different days.

Secondary Functioning. (Chapter 10)

Subjects of Experiment 2 who returned for the second session were given a number of tests of tempo related to primary-secondary functioning and unstructured motor speed. These tests were: preferred and maximum tapping speed, speed of making crosses on squared paper, and speed of handwriting.

Manifest Anxiety (Chapter 11)

Thirty-eight subjects of Experiment 2, and all subjects of Experiment 3, filled in the Taylor Manifest Anxiety Scale.

Time Imagery (Chapter 12)

Forty of the subjects of Experiment 2 and the 40 subjects of Experiment 3 filled in the Metaphor Preference Scale of Knapp and Garbutt.

n Achievement (Chapter 12)

Forty of the subjects of Experiment 2 wrote imaginative stories in response to three pictures which were scored for n Achievement by two post-graduate research students, not connected with the experimental study of individual differences in time judgement.

3. TREATMENT OF RESULTS

(i) Reliability

Inter-session reliability coefficients were calculated, using the first and second session scores of the 32 subjects who attended both sessions in Experiment 1, and of the 56 subjects who attended both sessions in Experiment 2.

(ii) Relations Among Different Methods of Time Judgement

The relationship between verbal estimates of time and reproduction of time by free linear arm movement was calculated

by / ......

by correlating the free movement reproduction scores and the verbal estimates of the 77 subjects who attended the first session of Experiment 2.

The relationships among stationary grip, free, and controlled movement reproductions of time intervals were investigated by correlating time judgements by these methods of the 40 subjects who attended the first and third sessions of Experiment 3. The relations among different methods were also studied by correlating inter-session changes in performance. It was argued that time judgements by different methods might be functionally related, even though raw scores might show little relationship. This functional relationship might be revealed by covariance of changes in judgement.

(iii) Motor Time-Space Relations

The relations among distance moved, speed of movement, and time of movement under conditions of free and controlled linear arm movement were studied with the data from the first session of Experiment 2 and the first and third sessions of Experiment 3.

(iv) The Effects of Short Delay on the Reproduction of Time.

The effects of short periods of delay on the reproduction of time intervals were investigated, using the delayed reproduction data obtained in the first session of Experiment 2. Both inter- and intra-individual comparisons were made.

(v) Extraversion and Time Judgement

The relationship between extraversion and time judgement was investigated with the time judgements of the 54 subjects of Experiment 2 who completed the Maudsley Personality Inventory,

(vi) Secondary Functioning and Time Judgement

The relationships between unstructured motor speed, secondary functioning, and time judgement were investigated by correlating the results of speed tests and time judgements obtained in Experiment 2 (54 subjects).

(vii) Manifest / ...

(vii) Manifest Anxiety and Time Judgement

The relationship between Manifest Anxiety and time judgement was investigated, using the time judgements of the 38 subjects of Experiment 2 who filled in the Manifest Anxiety Scale, and of the 40 subjects of Experiment 3, who all filled in the Manifest Anxiety Scale.

(viii) Time Imagery and Time Judgement

The relationship between time imagery and time judgement was studied, using the time judgements of the 40 subjects of Experiment 2 who filled in the Metaphor Preference Scale, and of the 40 subjects of Experiment 3, who all filled in the Metaphor Preference Scale.

(ix) n Achievement and Time Judgement

The relationship between n Achievement and time judgement was studied, using the time judgements of the 40 subjects of Experiment 2 who were tested for n Achievement.

4. MAIN CONCLUSIONS

(i) Reliability

(a) The method of reproduction of time signals by either free or controlled linear movement is more reliable than the method of reproduction by key-pressing, and is of the same order of reliability as verbal estimation of time (average reliability coefficient +.71). The level of reliability is suitable for detecting individual differences.

(ii) Relations of Different Methods of Time Judgement

(a) Methods of reproduction of time by key-pressing and by linear movement are not more closely related to each other than they are to verbal estimates. The commonly accepted idea that the classification of methods of time judgement into verbal estimates, reproductions and productions is psychologically significant does not seem to be true. This is a logical, not a psychological division of methods.

(b) / ....

(b) For all methods of time judgement, the relationship between time judged and length of signal may be satisfactorily fitted to Stevens' (1957) power law,

sensation = kS^n (where k is a constant; S is the stimulus; and n is the log. sensation ratio/log stimulus ratio).

Different k values have to be substituted in the equation, but the power n is almost identical for all methods.

(c) For all methods, error bears a linear relation to the length of signal reproduced, within the range observed. All the lines have different slopes and require the substitution of different values.

(iii) Motor Time-Space Relationships.

Free Linear Movement

(a) Time reproduced by free linear movement, and speed of free linear movement, are not significantly related. This is found when either raw scores (average correlation, regardless of direction, -.18), or intra-subject changes in scores (average correlation +.03) are correlated.

(b) Time reproduced and distance of free linear movement in reproducing time are significantly correlated. This applies both to raw scores and to changes in scores (average correlations are +.39 and +.46, respectively). This means that subjects who move further tend to move for a longer time (the alternative is that they might move faster and keep duration constant) and that, when a subject increases his distance of movement, he increases the time taken for the movement (the alternative is that he might increase his speed sufficiently to compensate).

(c) Speed and distance of linear movement are positively related to each other, as might be expected. The alternative is that a subject might move faster, but for a shorter time, and so keep the distance constant. The positive correlation between distance and speed of movement is found among both raw scores (average correlation +.78) and intra-individual changes in scores (average correlation +.71).

(d) /.....

(d) The correlation between distance of free linear arm movement and verbal estimate of the length of signal is greater than that between time reproduced by free linear arm movement and verbal estimate of the length of the signal (average coefficients are +.51 and +.33, respectively). This leads to the conclusion that time estimate and distance of movement are more closely associated than time estimate and duration of movement. Jaensch's (1905) conclusion that estimates of the spatial extent of a limb movement are partly determined by the time taken for that movement may be true in the reverse as well: estimates of the duration of a movement are partly determined by the spatial extent of that movement.

Controlled Linear Movement Reproduction

(a) When the distance of the linear arm movement by which the subject reproduces time signals is experimentally varied, no significant differences in time judgements occur. This means that the subject can reproduce the same time interval by movements of varying speed and distance.

(b) All linear movement reproductions, whether free- or controlled-distance, differ significantly from key-pressing reproductions, but free- and controlled-distance linear movement reproductions do not differ from each other. This suggests that the method of linear movement requires a different adaptive timing system from key-pressing.

(iv) The Effect of Delay on Time Judgement.

(a) Where the time interval to be judged is presented in the form of a continuous auditory signal, delay has no effect on time judgement. This may be understood in terms of Broadbent's (1957) model: where the information stored is within the capacity of a recurrent system, no delay effects may be expected as long as the system is kept active.

(v) Extraversion and Time Judgement.

(a) Eysenck's conclusion that level of time judgement is negatively related to extraversion is contradicted by positive (though

statistically / ......

statistically insignificant) correlations between reproduction by controlled linear movement and extraversion. The results show that time judgements cannot be thought of as distinct from the method used to obtain them. On the whole, the results do not favour his Typological Postulate.

(b) Extraverts tend to be less variable in their performance than introverts. The correlation between extraversion and variability in speed of free linear movement is statistically significant ($-.43$; $p < .01$). All other correlations between extraversion and variability scores are negative, though not statistically significant.

(c) There is no difference between extraverts and introverts in the speed of linear arm movement, nor in the distance moved. Both of these were expected of extraverts (rather tentatively) on the basis of the finding that extraverts tend to be rather more expansive than introverts in graphic expression (Wallach and Gahm, 1960).

(d) Extraverts are more accurate than introverts in their reproduction of time signals by both free- and controlled-distance linear arm movement. In Experiment 2 the correlations between extraversion and error are -.48 at 8 second signal and -.50 at 16 second signal (both significant at less than 1%). In Experiment 3 the correlations between extraversion and error are -.12 at 8 second signal and -.47 at 16 second signal. The latter correlation is significant at less than 1%.

(vi) Secondary Functioning and Time Judgement.

(a) The view that secondary functioning is related to extraversion and to reproduction of time by linear movement is supported by the direction of the correlations. But none of the correlations is statistically significant.

(vii) Manifest Anxiety and Time Judgement.

(a) There is no relationship between Manifest Anxiety and Time Judgement by any of the methods in the experiments described.

(b) Manifest /...

(b) Manifest Anxiety seems to be positively related to variability of response. All correlations between Manifest Anxiety and measures of variability are positive, and two of them are statistically significant. These are: (a) between Manifest Anxiety and variability in speed of free linear movement ($r = +.39$; $p < .05$); and (b) between Manifest Anxiety and variability in verbal estimate of 16 seconds ($r = +.33$; $p < .05$).

(viii) <u>Metaphor Preference and Time Judgement.</u>

(a) Metaphor Preference is not related to time judgement by any of the methods described.

(b) The relationship between a preference for swift, directional metaphors and speed of linear arm movement approaches statistical significance ($r = +.27$) and may indicate that there is a general expressive preference guiding imagery and gesture.

(ix) <u>n Achievement and Time Judgement.</u>

(a) n Achievement is not related to the judgement of time by any of the methods described.

(b) n Achievement is significantly related to speed of free linear arm movement in reproducing time signals. This confirms Aronson's (1958) discovery that n Achievement is related to spatial extension and mobility in graphic expression.

(c) n Achievement is significantly related to variability in speed of movement. This may be expected in terms of the prediction that oscillation of response is positively related to strength of motive.

CHAPTER I

INTRODUCTION

1.1 The Experience of Time

1.1.1 Change and the Idea of Change

When one reads through the major books that have been written on the psychology of time in the last seventy years - those of Sturt (1925) and of Fraisse (1957), one becomes very much aware how much they owe the spirit of their approach to William James. This is not to say that William James was the first psychologist to consider the problem of the awareness of time, or that he was a major experimenter in this field, but that, in Chapter XV of The Principles of Psychology, he made condensed and penetrating statements of problems and solutions to problems in a language which has seldom been matched by any other writer on the subject.

One of the problems which James had to consider - as had others before him - was the source of the awareness of time. One may take as a starting point his statement that "we have no sense for empty time", (James, 1950, vol. i, p.619). "Awareness of change is thus the condition on which our perception of time's flow depends ..." But are these changes directly responsible for the idea of time? This is the view which was apparently held by Helmholtz, who believed that the perception of time is the only case "in which our perception can correspond with outer reality", since "events, like our perception of them, take place in time, so that the time-relations of the latter can furnish a true copy of those of the former".(ibid., 628). But, James points out, this view of the idea of time overlooks the fact that there is a great difference "between the mind's own changes being successive, and knowing their succession ... A succession of feelings, in and of itself, is not a feeling of succession" (ibid., 628). The idea of time is not a direct product of the changes in sensations or perceptions or sensations. We are returned to the problem of the way in which these changes are acted upon by the mind to form the idea of time.

1.1. 2 /...

1.1. 2 A Receptor for Time

The view has been held (by E. Mach) that time is directly perceived by a sense distinct from the other major senses. Mach (quoted by Fraisse, 1963, p.p. 80 - 81) took the expression "Time-sense", then current, literally. "It is probable that this feeling is connected with that organic consumption which is necessarily linked with the production of consciousness, and that the time which we feel is probably due to the work of attention ... The fatigue of the organ of consciousness, as long as we wake, continually increases, and the work of attention augments as continually. Those impressions which are conjoined with a greater amount of work appear to us as later" (quoted by James, ibid., p. 635). Mach attempted to find a special receptor for time, and surmised that there might be an accommodation mechanism in the ear which would act as one. This receptor, he thought, would enable us to perceive the temporal position of stimuli, just as the accommodation of the eye enables us to perceive spatial positions. Attention would, by causing fatigue in this receptor, assist us in temporal location.

The choice of the ear as the structure in which there might be a special time receptor was not capricious. The ear is particularly adapted to detect temporal succession, as Fraisse (1963, p. 83) points out. When one compares the various senses, one notes that they display various degrees of temporal inertia. It is impossible, for example, to present exactly demarcated time intervals to the sense of smell or the sense of taste. Nor can we detect a rapid succession of different stimuli with these receptors. Vision is also unsuitable for the detection of patterns of rapidly succeeding stimuli of different intensities or colours. The tactile and the auditory modalities have the lowest temporal inertia, but the auditory modality is obviously the more important. It has greater cortical representation and greater association value, and it can detect stimuli in a greater spatial area. "Hearing only locates stimuli very vaguely in space, but it locates them with admirable precision in time. It is par excellence the sense which appreciates time, succession, rhythm and tempo" (Guyau, quoted by Fraisse, 1963, p. 83).

But time /...

But time is a property of perceptions in all modalities, though there are differences in organisation. It has been shown that the visual, auditory and tactile seconds differ in length (Goldstone and others, 1959; Lhamon and others, 1962); and that visual and auditory time signals cannot be matched with accuracy (Fraisse, 1963). The time properties of perception in each modality depend on the organisation of perception in that modality. As Pavlov stated (quoted by Dmitriev and Kochigina, 1959), there is no special cortical analyser for time. The power to analyse time is found in all cortical analysers.

1.1. 3 Time as an Attribute.

A solution which has often been proposed is that time is an attribute, rather than a sensation with a special receptor. Wundt formulated a doctrine of attributes, putting forward the view that the two essential attributes of sensation are quality and intensity. Titchener extended the list to five: quality, intensity, protensity (duration), extensity, and attensity (clearness). But the atomistic view that perceptions were organised out of sensations suffered at the hands of many psychologists, especially of the gestalt school, and the doctrine of attributes underwent a corresponding eclipse. If perceptions are not built of sensations, then they cannot be built of the attributes of sensations. A further logical objection to the doctrine of attributes is that they do not have the independence which they ought to have. One example is that loudness (intensity) of a sound is not independent of pitch (quality). The same relations of different dimensions may also be shown in the perception of colour.

But it is clear that the mind must have the power to abstract time from experience, from all perceptions. It also seems clear that time is not directly perceived through the agency of any particular receptor. Therefore, though we may not wish to resuscitate the doctrine of attributes in its original form, we must conclude that time is an attribute of all perceptions, though it may not be a pure attribute independent of all other dimensions. Piéron (1951) has remarked: "For the psycho-physiological organism there are in fact several times as there are several spaces, and their intellectual unification, which is mainly a social achievement, makes one forget this fundamental heterogeneity".

1.1. 4 The Specious Present.

We have still not dealt with the way in which the idea of time may come into existence. It has been shown that a succession of mental events is not enough to give rise to the idea of time. James (ibid., p.629), points out that "if events A and B are to be represented as occurring in succession they must be simultaneously represented; if we are to think of them as one after the other, we must think of them both at once". This idea was developed still further. "The cause of the intuition which we have cannot be the duration of our brain-processes or of our mental changes. That duration is rather the object of the intuition which, being realised at every moment of such duration, must be due to a permanently present cause. This cause - probably the simultaneous presence of brain-processes of different phase - fluctuates, and hence a certain range of variation in the amount of the intuition, and in its subdivisibility, accrues".

If we are to attribute the intuition of time to the "simultaneous presence of brain processes of different phase", then it is important to know how long these brain processes are likely to persist. James emphasises that they are asymptotic; that there is no moment at which the process suddenly ceases to exist. On the basis of experiments by Wundt and others, James concluded that the maximum direct intuition of duration covers about 12 seconds, and we may take this to correspond to the supra-liminal duration of the brain-processes. This interval of time which is directly perceived has been variously named the conscious present, the specious present, the sensible present, the psychic present, the mentally present, and the actually present (Fraisse, 1963, p. 85). Fraisse prefers to call it "the perceived present". It was this period, directly and wholly grasped, that James believed was the datum for the idea of time. "The original paragon and prototype of all conceived times is the specious present, the short duration of which we are immediately and incessantly sensible". (ibid., p. 631). Longer time intervals are conceived as multiples of the specious present; shorter time intervals are conceived as fractions of the specious present.

Since / .....

Since a succession of present events (as in Helmholtz' theory) would merely form an eternal present, theorists examining the question of the cause of our awareness of time have had to rely on one or other form of the specious present. But most have made it rather shorter than James did. Boring (1936) has used the indifference interval as the unit of perceived time, which means that he places it at less than one second. Fraisse (1963), also believes that the perceived present is shorter than James had it. His evidence is drawn from several kinds of observation. Firstly, there is the limit of successive organisation. If the interval between sounds is greater than about 2 seconds, the impression of rhythm is no longer possible. Secondly, there is the number of successive elements which can be clearly perceived as a unit. This varies with the kind of element and the rate of presentation, but the maximum appears to be 5 or 6 elements separated by a maximum of 0.63 seconds. That is, less than four seconds.

Fraisse (1963) rejects James' view that the present consists of different evenly fading processes. The present is not composed merely of the last elements presented. It should rather be thought of as a discontinuous process. The subject perceives, successively, groups of elements. Each successive grouping has a certain span - the span of apprehension - consisting of a certain limited number of units, but it is related to the remembered past. While writing a certain sentence, to take an example, one may be aware of a certain number of limited elements composing that sentence, but this does not mean that it is unrelated to what has preceded it. That sentence, that present, exists in the context of the past. This is rather reminiscent of the Heymans-Wiersma theory that each mental event has a primary and a secondary effect. The duration of the primary effect may be taken to correspond to the conscious present, but the secondary effect gives continuity. It is important to realise that the perceived present is not inelastic. It "depends on the possibilities for the organisation of successive elements into one unit" (Fraisse, 1963, p.88). When the organisation of the elements is complete, the present may be a sentence, but when the organisation is difficult, the present may contract to a single phrase or a word. In the same way, in listening to music, a phrase occupying several seconds may be easily grasped; but a sudden change will focus attention on a brief moment in the music. This may be the surprising entry of an instrument, or the abrupt interruption of percussion. This extension and contraction of the listener's direct experience of time is a vital technique in music and in peetry. At one moment the listener is carried along on an even stream; at the next he is poised, held at a single narrow point of time.

But the way in which we apprehend the present remains as much of a problem as ever. Fraisse relates the alternations in time to alternations in perception, as in inspecting reversible figures. These alternations occur at about 5 - 10 seconds. The analogy is interesting, but, he admits, the cause of these alternations is not known. Therefore, even if the two processes are related, we know as little about their causation as before.

Our conclusion is that the idea of time is the result of an unknown relation between the mind and the perceived present. Phenomenal time depends on the span and flow of this perceived present, but social time is a construct based upon it.

The next question we shall consider is the major conclusions which may be drawn about the relationship between judged time and the time signal presented.

1.2 The Judgement of Time.

Two themes dominated the older studies of the judgement of time, The first was the exact determination of the indifference interval and the second was the application of the Weber-Fechner law to time judgements.

The indifference interval of Vierordt is that interval which is judged with the minimum error. Below this interval, time signals are over-estimated. Above this interval, time signals are underestimated. These are average trends, but there may be vast individual differences which go completely contrary to this rule. The indifference interval appears to average about 0.70 seconds (Fraisse, 1963) but there are considerable differences among authors. The indifference interval has been shown to vary with a large number of factors, such as the attitude of the subject and time order (Woodrow, 1951). This probably accounts for its occasional elusiveness and for the great differences in its determination. The explanation of the indifference point has been a matter of interest for many years. Wundt related it to the optimum association time - an explanation which has been further developed by Fraisse (1963). Fraisse comments: "Walking, heartbeats, movements effected at a spontaneous tempo, and perceptions all follow on at intervals of about 0.70 second, which we consider to be the optimum interval for the functioning of the nervous centres ... " (ibid., p. 128).

The other theme, that of application of the Weber-Fechner law, was developed by various authors without much success. Recently, Woodrow (1951) concluded that the results do not support the law.

In studies of time judgements since 1951, results have been found which follow a power law formulated by Stevens (1957).

$$\text{sensation} = kS^n$$

(k = a constant; S = the actual stimulus-length; n = log ratio of increase in sensation / log ratio of increase of stimulus).

The power law is held to cover judgements in a large number of fields, such as perceived intensity of sounds, weight, taste, pain, and luminosity. The law may be stated as: Equal stimulus ratios produce equal sensation ratios. In each case the stimulus ratio must be experimentally determined. But once found, it applies to a large range of lengths of signal and does not diminish, as the Weber-Fechner law would make it do.

If we examine the equation of the power law, we may see that the closer n is to unit in value, the more the curve of the relationship between judgement and stimulus will approximate a straight line. Values of 1.06 (Gregg, 1951); 1.1 (Stevens and Galanter, 1956); and 1.11 (Bjorkman and Holmkvist, 1960) have been obtained, for a range of signals from 0.4 to 7.0 seconds. Ross and Katchmar (1952) have obtained an exponent of 1.16 for a range from 5.38 to 60.12 seconds. For these ranges of signals, the relationship would be almost linear.

In Chapter 6 the application of the power law to data obtained by experiments with various methods of time judgement will be considered.

1.3 Time Judgements by Various Methods.

At this stage the various methods of conveying judgements of time will not be discussed in detail. That is left to the following chapter. Here, the methods and their relations to one another will merely be indicated. The main methods are the method of comparison, in which the subject merely reports whether a given signal is longer or shorter than a given standard; the method of reproduction, in which the subject is required to perform some action lasting as long as a given standard time signal; the method of verbal estimation, in which the subject makes clock time estimates of a given period; and the method of production, in which the subject is asked to perform some action lasting a given number of units of time.

These methods do not generally give results which are significantly correlated (Clausen, 1950; Kruup, 1961; Siegman, 1962; and Fraisse and others, 1962). Only the methods of verbal estimation and production may correlate significantly and negatively (Fraisse and others, 1962). Only the methods of verbal estimation and production may correlate significantly and negatively (Fraisse and others, 1962). The negative correlation indicates that a shorter production corresponds to an overestimation of time judgement.

A shortcoming of most methods of time judgement is that they show very low inter-session reliability (Kruup, 1961; Siegman, 1962), with the exception of the method of verbal estimation.

It is obvious that the methods measure rather different aspects of time judgement. The method of comparison does not require any activity from the subject beyond his attention and his verbal report that a given signal is longer, shorter, or equal to a given standard. But the method of reproduction requires an action of some kind, and the nature of that action must play some part in the subject's ability to equate its duration and that of the given standard signal. The action may interest the subject, may call for special skills which absorb his attention, or may be so simple that the subject pays attention almost exclusively to the duration of his response. The method of verbal estimation, unlike the two methods mentioned previously, tests the accuracy of a subject's knowledge of conventional time units. The same applies to the method of production, but there is the additional factor of the nature of the action by which he produces the given duration. This introduces the same problems as are found in the method of reproduction. There is no way of overcoming these difficulties. The judgement of time expressed by the subject is bound up with the method of expression.

The terminology best adapted to describing judgements of time has been studied by Bindra and Waksberg (1956). Consider the example of what we mean when we say that a subject is overestimating. When we are dealing with results obtained by the method of reproduction, this may mean either that the subject is overestimating the duration of the signal, or that he is overestimating the duration of his reproductive action. Presumably, if both the signal and the reproductive action are equally overestimated, the effects will cancel out. The most sensible usage, since we are referring our results to the standard, is to say that a subject is overestimating when the objective time reproduced by him is greater than the objective time of the signal. One may also say that the subject is over- or under-reproducing the given time signal.

When overestimation refers to the results obtained with the method of verbal estimation, it may mean that the subject experiences the signal as longer than it objectively is, and indicates this by making a high verbal estimate, or it may mean that the subject overestimates the length of time corresponding to the clock time units used (which would result in a low numerical estimate), or it may mean that the subject overestimates the number of clock time units which refer to a given time interval (which would result in a high numerical estimate). If we ignore the subject's private reference, then the term overestimation refers to the fact that a subject assigns a higher number of conventional time units to a given period than should be assigned to it. Ignoring the subject's private system of reference is, of course, unjustifiable if we wish to get at his experience of a particular time interval. For this reason, unless we ascertain what that system of reference is, verbal estimates are not useful in revealing individual differences in the experience of given time intervals.

The same ambiguity in the use of the term <u>overestimation</u> (and in the use of the term <u>underestimation</u>) applies to the methods of comparison and production.

In the present account, the first eight chapters will be found to deal very largely with the relationships of time judgements obtained by various methods. One method will be examined insspecial detail. This is the method of reproduction of time by means of linear horizontal movements of the arm.

In Chapters 2 and 3 the choice of a method for measuring time judgements, as well as individual differences in temperament and personality, and the details of that method will be described.

Reliability and distribution of scores obtained by various methods are examined in Chapter 4.

The relations among judgements obtained by different methods are discussed in Chapter 5. The possibility of detecting relations by correlating ratios of intrasubject changes in judgement is also dealt with.

Some of the relationships of space and time when the method of linear arm movement is used to judge time intervals are analysed in Chapters 6 and 7.

The effects of delay on time judgement, suggested by the findings of Frankenhaeuser, (1959), are studied in Chapter 8.

The last four chapters describe attempts to define consistent individual differences in time judgement.

1.4 <u>Individual Differences in Time Judgement</u>.

Studies of individual differences in time judgement are discussed in some detail in Chapters 9 - 12, and are only mentioned briefly here to give some idea of their scope.

Very few of the studies in this field rest on any systematic theoretical basis. For this reason, Eysenck's typological postulate (1957, p. 114) with its clear perceptual corollaries, is of particular interest. It is a prediction from his theory that extraverts under-reproduce a time signal as compared to introverts, since extraverts

generate / ...

generate a lower excitatory potential in response to a stimulus than introverts, but develop reactive inhibition more strongly and quickly. Eysenck (1959), and Claridge (1960), using hysterics (= extraverts) and dysthymics (= introverts) appear to have confirmed the predictions about time judgement from the postulate. Some criticisms of their use of neurotics as criterion groups will be detailed in Chapter 9. Lynn (1961), used normal university students tested according to the technique of positive feedback (whereby subjects start with the same stimulus in the first trial, but in subsequent trials they are asked to reproduce their reproduction of the previous signal).

The studies which follow were largely fact-finding studies, guided by more or less well-supported hypotheses, but they do not test any theory.

Orme (1962) has studied verbal judgements of longer periods of 20 and 30 minutes, and has found that hysterics and psychopaths make longer estimates than neurotic and psychotic depressives. He found no relationship between extraversion and time estimation in a normal sample. The difficulty in interpreting verbal estimates of time without determining the personal frame of reference of each subject has already been pointed out (1.3).

Dobson (1954) studied the problem of whether patients who are disoriented in time (by usual psychiatric criteria) also show distortion in their judgement of short durations; and he also investigated the hypothesis that greater anxiety would be associated with longer estimates of time. In his study, 16 normal, 16 neurotic, 16 time-oriented schizophrenics, and 8 time-disoriented schizophrenics were used as subjects. The subjects were asked to estimate a variety of filled and non-filled periods of time ranging from 17 seconds to 2 minutes under conditions of <u>set</u> (expecting to be asked to judge the time) and non-set (unprepared to estimate the time). He found that schizophrenic patients who are disoriented for time are not significantly different from time-oriented schizophrenics, neurotics, or normal subjects in their estimates of time, but they seem to show greater variation. Since the samples are so small this cannot be taken as established. If the neurotics are used

as the /.....

as the criterion group for anxiety, then the hypothesis that anxiety is related to longer time estimate does not hold. The neurotics were found to be more accurate and consistent than the other groups. Since the neurotics are not classified, it is important to note that Angyal (1948) found that obsessives tend to be more accurate in their perception of visual stimuli than other neurotics. Mental set was also found to affect judgement. Subjects set to make an estimate were more accurate and less variable.

Also using psychiatric patients, Lhamon and Goldstone (1956) have shown that schizophrenics judge a longer interval of time to be equal to one clock second than normals do. This is interpreted as an effect of the acceleration of the mental world of the patient, but this conclusion seems to be based on insufficient evidence. Since the same effect is found under conditions of sensory deprivation, it would be rash to attribute it to acceleration of the mental world.

Guertin and Rabin (1960), also investigating the verbal time judgements of schizophrenics, found they tended to be very variable. They conclude that there is a functional disability in their time judgements, but it may simply be that institutionalised patients become less accurate in their use of clock time.

Another study, unrelated to the previous studies discussed, has been made of the relationship between time perspective, time estimation, and impulse control (Siegman, 1961). The subjects used were 30 delinquents and 22 non-delinquent army inductees, who were selected in an effort to control the effects of institutionalisation. In both groups, a positive correlation between future time perspective (given by the average distance from the present of 10 future events named by the subject) and higher estimation of time wa s found. The author refers to the higher estimation of time as the speeding up of the subject's internal clock. Intervals of 5, 25, and 15 seconds were used. It is interesting to note that in the Lhamon and Goldstone study a low estimate of a given interval of time is referred to as a speeding up of the internal world of the patient (since more time passes before the subject feels that one clock second has elapsed), whereas in the Siegman study a high estimate of time is referred to as speeding up the internal clock. This demonstrates the need for an agreed terminology. Bindra and Waksberg (1956) have concluded that a verbal estimation which is larger than the standard indicates an internal clock which is faster than the external; a produced time which is larger than the standard indicates a slower internal clock; and a reproduced time which is larger than the standard indicates that the internal clock is faster than the external during reproduction only. Siegman also found significant negative correlations between motor impulse control (measured by how slowly the subject could trace a 2½ inch circle on onion skin paper) and time estimation.

A tendency to think of events as close to the present has been found to be associated with low estimate of time (Knapp and Green, 1959). Both are, in turn, associated with high n Achievement. This tendency to underestimate the time which separates past events from the present, and to underestimate the time taken by a moving point to reach a mark, is not incongruent with the Siegman finding that long future perspective is positively associated with high time estimate.

A study by Young and Sumner (1954) has shown that subjects tend to remain in the same rank order, whether their judgements of a given time interval are made immediately, after a delay of 15 days, or after a delay of 22 days. The intervals used were 30 seconds and 5 minutes in which the subject did arithmetic problems, and 30 seconds and 5 minutes in which the subjects attended passively. Another finding in this study is that reproductions on the 15th and the 22nd days tended to resemble each other more closely than they did immediate reproductions.

The most extensive study of individual differences in time judgement, in terms of length, is that of Loehlin (1959). Loehlin asked subjects to estimate sixteen 2 minute intervals spent in a variety of ways. Among the occupations in these periods were anagrams, arithmetic, repeated writing, pleasant thoughts, concentration on time, and counting the incidence of <u>the</u> in a prose paragraph. Other intervals were also estimated. Two short periods of 1 second and 4 seconds were estimated four times to the nearest 10th of a second. One 20 minute period was also estimated.

Short / .....

Short time intervals were compared, and a period filled with an accelerating pulse was compared to a period filled with a decelerating pulse. Subjects were also asked to fill in a questionnaire on attitudes to time. Fluency scores were computed for each subject from the number of 1's written by the subject in two minutes, the number of solutions of an easy anagram in two minutes, and the number of questionnaire items completed in two minutes. Analytic perception was measured by detection of figures in the Gottschaldt test and by the number of the's counted in the prose passage. Finally, MMPI's were completed voluntarily several months later by 70% of the subjects.

The data were correlated and factor analysed. Several factors were extracted. Factor 1.was found to be general to the 2 minute estimates, and appeared to reflect characteristic individual differences in the length of the time estimate of 2 minutes. Two determinants appeared to contribute to these individual differences. The first was personal differences in the conception of one minute, and the second was the degree of interest in the tasks. Bored subjects had higher estimates. Factor II had variance specific to short intervals and also reflected overestimation of empty intervals of time. Factor III appeared to be identical with factor I, but to reflect serial position. Factor IV reflected a tendency to estimate the second of two periods of a repeated activity as relatively long. There were positive loadings on the perceptual ability measures (Gottschaldt figure test and difficult anagrams). It is suggested that this factor is intellectual. Factor V loadings suggest an activity-passivity dimension. Subjects with high scores on this factor tended to write a large number of 1's and to overestimate periods spent passively. The MMPI differences were not all as expected. Passive subjects were, as expected, high of the Pt, Hy, and D scales but active subjects were not higher on the Pd and Es scales.

Questionnaire items which correlated with factor I seem to relate to differences in time perspective. Examples of such items are:-

> I have a poor memory for the past events of my life.
>
> Often, though the days go slowly, the weeks and months seem to fly by.

The future /.....

The future is too uncertain for a person to plan very far ahead.

Questionnaire items also correlated with Factor II, and seemed to reflect differences in the development of a sense of the conventional scale of time. Persons high on Factor II agreed with an item such as:-

A period of a few minutes often seems like hours to me.

Persons low on factor II agreed with items such as :-

My father isa rather dominant person.

I sometimes feel we would have been better off if clocks has never been invented.

The low S's say that they have an accurate idea of time, but the psychological distance of childhood, the dominant father, and the resentment of clocks lead Loehlin to suggest that this was achieved at some cost.

Subjects with high scores on factor V - those who seemed to be less subject to time illusions, also agreed with certain items in the questionnaire more often than with others. These items were:-

I have a pretty definite idea what I will be doing next summer.

I usually have a pretty accurate idea what time it is.

The high items reflect a feeling of control of time which seems to be consistent with the active-passive interpretation of this factor.

As was remarked at the beginning of the section, most of the studies of the individual differences in time judgement are fact-finding. Very few of them are guided by what one can regard as an articulate theory, and very few of them test crucial hypotheses. This is, unfortunately, an indication of the state of the subject.

PART I

METHODOLOGICAL PROBLEMS IN MEASURING TIME JUDGEMENT

There is no way of getting an absolute measure of the time experience of the individual. Each method yields different results. But not all methods are equally reliable, and if we wish to measure individual differences in time judgement it is essential to find a reliable method (Chapter 2).

The method of reproduction of time by linear arm movements is described (Chapter 3). The judgements of time intervals obtained by this method are more reliable than those obtained by other methods of reproduction, and are of the order of reliability associated with verbal estimates of time (Chapter 4).

Though different methods of time judgement yield different results, it seems likely that they all refer to the same core experience of time. Attempts were made to discover what relations exist between judgements conveyed by various methods by correlating the raw scores and by correlating intra-individual changes in scores from one session to the next (Chapter 5).

C H A P T E R   2

A METHOD FOR STUDYING TIME JUDGEMENTS

2.1. Introduction

A method which is at once sensitive and reliable is necessary for the investigation of time judgements.

Sensitivity may be of two kinds. Firstly, the method should be sensitive to small changes in the length of the interval to be judged. Secondly, the method should be sensitive to inter-subject differences in time judgement.

Reliability should not be achieved at the expense of inter-subject variation, particularly if we are interested in individual differences in time judgement. A test capable of wide inter-subject discrimination and low intra-subject variability is needed.

The role of the kind of time standard as it affects reliability and sensitivity will be discussed. If there is motivational engagement of the subject during the standard interval, and if there are changes in motivation, time judgement will be affected. There seems to be a delicate balance between awareness of time and the degree to which a task absorbs the motivation present. As Fraisse (1957, p 205) writes: "Satisfaction et non-conscience de la durée sont deux effects concomitants d'une activité exactement adèquate á la motivation présente." It may be that a slight disproportion between motivation and task is most favourable for accurate judgement. If the motivation is entirely absorbed by the task, or if there is disproportionately high or low motivation, judgement of time is likely to be inaccurate. Then, it will be shown that the sensory mode in which the interval is presented, the position of the interval in a series (anchor effects), the rate of stimulation, and the spatial properties of the time interval, affect judgement of duration and often affect reliability.

The role of the method of judgement will be discussed. In general, verbal estimates are more reliable than judgements obtained by other methods (e.g., Clausen, 1950), and they show wide inter-subject spread, but they tend to be stereotyped and crude. This is shown by the fact that judgements ending in 0 and 5 predominate (Weber, 1933). Different subjects change categories with different degrees of ease as the stimulus duration is altered, and there tend to be wide differences in the minuteness of the scale adopted by the subject in expressing his judgement. Klein's (1951) distinction between levellers and sharpeners is relevant in this context. But the greatest objection to the method of verbal estimation is that it tells us relatively little about the subject's perception of time, unless special methods of analysis are adopted. In order to deliver a verbal judgement of time the subject must translate a non-verbal activity (his immediate perception of the duration of the standard) into a symbol, the accuracy of which will vary greatly from individual to individual. The verbal judgement may not reflect the particular experience of time which the subject has; it may reflect largely the accuracy with which he has learnt in the past to apply symbols of time. Furthermore, the process of translating the non-verbal into a verbal activity may also involve individual differences. The only satisfactory way of using verbal estimates might be to separately establish a scale for each individual and to treat all experimental scores as quotients of the individual's private scale. In Chapter 7 the use of this method is shown. It might also be possible to train all subjects to estimate according to the same standard before commencing the experiment proper. Since these precautions are seldom taken, the method of verbal estimation seldom yields useful information about the perception of time. The method of production reverses the process of verbal estimation. Instead of being asked to give a verbal estimate of some non-verbal duration, the subject is given a verbal duration to reproduce by some non-verbal action. The subject is asked, for example, to engage in some action for 20 seconds.

Obviously,/..........

Obviously, we do not know whether the verbal instruction means the same thing to all the subjects; nor that all are equally able to translate the verbal instruction tnto a non-verbal action; nor that during this action the perception of time is in all cases identical. The problems are the same as in verbal estimation. Reproduction of time signals gives us the best information about non-verbal experience of time. The subject translates a non-verbal perception into a non-verbal reproduction. It is possible that in some cases there is symbolic intervention, but it is not deliberately introduced into the experiment as a complication. The method of reproduction, as might be expected, is more accurate (e.g., Clausen, 1950) than the other methods, but it is also less reliable (Clausen, 1950; Kruup, 1961; Siegman, 1962).

Each of these methods has some defect. The problem is to find a method of time judgement which discriminates between individuals, is sensitive to changes in signal length, is reliable, and does not introduce the complication of translation from asymbolic to symbolic process.

2.2. Methods of Presenting the Time Signal

Problems which confront us here are: (a) what are the effects on time judgement of various methods of presenting the interval; and (b) what kind of signal, under comparable conditions of judgement, is likely to enable the subject to be most consistent?

We have already mentioned that if the interval is presented in such a way that the subject is motivationally engaged, his judgement of the duration of that interval is likely to be affected. An ingenious experiment by Schonbach (1959) illuminates this problem. Schonbach tested the hypothesis that in a barrier situation, the greater the force acting on the subject to reach a goal (within unspecified limits) the greater will be his estimation of time spent in that situation. He also argued that the force acting on the subject would be an increasing function of the subject's need for the goal-object and of ideation relevant to the goal-object.

One/..................

One of the ways in which need was increased in a barrier situation was to deprive subjects of food. Ideation was increased by allowing the subjects to page through illustrated food books. Both of Schonbach's hypotheses were confirmed. Loehlin, in an extensive study of time judgements, found that (as might be expected) one of the factors determining the magnitude of the time judgement is interest-boredom. Interest in the task led to low time judgements, but boredom led to high estimates of the time taken by the activity. A terminal shock (Falk and Bindra, 1954), or movement towards a fall (Langer and others, 1961), both lead to a high estimation. In both these instances, attention is focussed on the time interval separating the subject from the unpleasant future.

A generalisation to be drawn from the work attempting to relate motivation to time judgement appears to be that an increase in motivation generally causes a rise in the time judgement where the attention of the subject is focussed on the time interval (as in the barrier situation of Schonbach, or as in a separation situation in a 1949 experiment by Filer and Meals in which the subjects showed greater tendency to over-estimate as they approached an attractive goal), and a decrease in time judgement when the subject is absorbed in the task (as in the task-completion tests of Hindle, 1950, or of Meade, 1959).

Where a continuous stimulus is presented for a certain duration as the time standard, the sensory modality in which it is presented seems to be important. Goldstone and others (1959) asked subjects to estimate when a given signal, presented in an ascending and a descending order of duration, was one second in length. No standard of comparison was given. They found that, on the average, a visual stimulus had to be longer than an auditory stimulus to be judged equal to a second. Lhamon and others (1962) have found that auditory stimuli are phenomenologically shorter than tactile stimuli. An auditory signal of 0.45 sec is judged to be a second, on the average, whereas a tactile signal lasting 0.35 sec is judged equal to a second. The null hypothesis is rejected at the 5% level. A direct intermodal comparison of perceived duration of successive stimuli shows that auditory stimuli are perceived as 20% longer than visual stimuli (Behar and Bevan, 1961).

It is/..................

It is interesting to note that the order, from the longest to the shortest, of the actual length of the signals which would be judged equal in duration is: visual, auditory, and tactile. A possible explanation of this order is that the sensory mode which is most prominent in a subject's task engagement in his environment is the mode in which signals seem subjectively shortest. It is a fair assumption that we are visually more than auditorily or tactually occupied with our environment. If we are forced to attend to a duration in a less prominent mode, it is almost as though we are in a barrier situation. An interesting check on this hypothesis would be to compare the time judgements in different sensory modes of musicians and painters, or of visualisers and verbalisers, to see whether the order is altered.

Another, rather expected finding, is that a stressful, noisy interval is judged longer than an equal, quiet period (Jerison, 1959). This may be partly a function of the rate of stimulation, which has been shown to affect time judgement (Frankenhauser, 1959). She varied the rate of stimulation by varying the rate of a metronome presented intermittently on tape. She found that an increase in the rate of the metronome led to an increase in the estimate of the duration of the interval. Her hypothesis, which tends to be confirmed by this finding, is that an increase in the rate of flow of mental events causes an objective second to seem longer. A problem is whether the sound of the metronome may not have a special significance in time judgements. Changes in intensity of stimulation did not affect judgement of duration, in Frankenhauser's experiments. But Oleron (1952) found, especially in the judgement of short intervals, that an increase in intensity of a sound made it subjectively longer. This effect was not so marked with longer intervals. The failure of changes in intensity to affect judgement of longer periods probably explains the fact that when intervals of 5 seconds to 15 seconds are presented, it makes no difference whether they are periods of continuous stimulation or periods demarcated by disparate stimuli.

But where/..................

But where the interval is an empty one, demarcated by terminal stimuli, variations in the length of the terminals are significant in determining the phenomenal length of the interval. Long initial sounds cause overestimation, probably as a consequence of the anchoring effect (Woodrow, 1928). Long terminal sounds do not have as great an effect.

Anchoring effects are important influences on time judgement. It has been shown that anchoring effects may be both heteromodal and homomodal (Behar and Bevan, 1961). Further, it has been shown that visual anchor effects are more easily obtained than auditory anchor effects (Goldstone and others, 1959). For this reason, an auditory stimulus appears to be preferable to visual stimulus where reliable time judgements are required.

The spatial properties of the stimulus are also an important influence on judgement of its duration - just as the temporal properties of a stimulus are an important determinant of judgements of spatial extension. Jaensch (1906, cited by Helson and King, 1931), found that judgement of the extent of an arm movement depended partly on the time taken to carry out the movement. The effect of time relations on space judgement has also been shown on the skin. The tau effect, as it is called, may be defind as follows: "If the time between the first and second stimuli is shorter (or longer) than that between the second and third stimuli, the distances undergo a corresponding change, for the first appears shorter (or longer) than the second" (Helson and King, 1931). When the interval is very short, a movement is felt. The tau effect is compared by the authors to the Muller-Lyer illusion, but in this case the space is enclosed in time as well as space. The reverse of the tau effect has been demonstrated. Suto (1955) has shown that the greater the distance between two stimulations on the forearm, the greater the estimation of the temporal interval between the stimuli. Suto believes that this effect is dependent on the visual experience of the subject, for two reasons. Firstly, subjects with their eyes closed tended to visualise the distance between the two stimuli; and, secondly, subjects who had been blind from infancy and did not visualise the distances, were not susceptible to the effect.

An attempt/................

An attempt to express the space-time relations of stimuli applied to the skin in exact mathematical terms has been made. It was found that a constant level at which the individual began to distinguish two cutaneous stimuli as distinct is a product of the time interval between the stimuli and an exponential function of the distance between the stimuli (Wieland, 1960). The minimum discriminable interval of time between two stimuli applied to the skin could be found by the formula:

$$\log T = a - bD$$

where T is time, D is distance, and a and b are constants.

Some evidence that an interval experienced as enclosed is likely to seem short has been produced by Abe (1933), who asked subjects to portray their experience of a time interval. Those subjects whose figures included prominent terminals apparently experienced the time interval as relatively short. Those subjects who experienced the time interval as long portrayed their experience in flowing, heterogeneous figures. Perhaps, as Helson and King suggested in their study of the tau effect, the terminals become more prominent when they are close together in time, and this prominence makes them seem closer together in space. And, in reverse, terminals which are closer in space may form more prominent boundaries to the time experience.

An extremely important experiment on the perceived relations between space and time properties of a field was conducted by Brown (1931 a,b). In his experiment the subject had to match the duration of a figure moving across a field and the duration of an empty interval bounded by two stimuli. The subject was presented with the empty interval and was asked to regulate the speed of the moving figure in such a way that the time it took to cross the field was equal to the time-interval of the standard. The reverse procedure was unfortunately not attempted as a check on his results, which were extremely interesting.

He found/..................

He found that the subject adjusted the speed of movement in such a way that the objective time taken by the figure to cross the field was longer than the time signal. Brown (1931 b) proposed the equation

$$\text{phenomenal velocity} = \frac{\text{phenomenal space}}{\text{phenomenal time}} .$$

It can be seen from this equation that phenomenal time decreases as phenomenal velocity increases. Therefore, anything which contributes to a rise in the subject's impression of velocity should also lead to a decrease in subjective time and an increase in the objective time allowed the figure to move across the field. Brown (1931 a) found that a large number of factors contribute to an increase in phenomenal speed. A decrease in distance between the subject and the field, a decrease in the homogeneity of the field surrounding the figure, a decrease in the width and length of the field across which the figure moves, a decrease in the size of the moving object, orienting the figure in the direction of its movement (e.g., an arrow pointing in the direction of movement), decreasing illumination, tilting from the horizontal, and fixation of the eyes on a stationary point are the major contributors to a rise in phenomenal speed and should, therefore, be associated with a fall in phenomenal time. Brown did not, unfortunately, undertake an extensive investigation of the effect of all these variables on time judgement. Nor did he ask subjects to reproduce the duration of moving stimuli by, say, key-pressing, to check whether the greater phenomenal time of the moving stimulus would be translated into a greater objective time reproduction when no movement was involved.

Brown held that changes in phenomenal time occur more frequently than changes in phenomenal space. It is interesting to note that in the very year in which he made this statement, Helson and King were reporting their discovery of a phenomenal change in space.

Abe (1935) appears to have been the first to demonstrate an effect which Cohen and others (1955) later called the kappa effect. In Abe's experiment the subject was faced with three light-flashes among which the spatial and the temporal intervals could be independently adjusted.

Abe found/................

Abe found that when the spatial intervals were equal, time judgement depended only on the actual length of time between the flashes. Unequal time intervals could be made to appear equal by adjusting the distances so that the shorter time interval was coupled with the longer distance. Abe also found that the above illusion was rather unstable, and could be destroyed by the subject's adopting a critical attitude. This effect discovered by Abe was rediscovered by Cohen, Hansel and Sylvester (1955), who presented a subject with a flash sequence ab and asked the subject to control the timing of a third flash, c, in such a way that the time interval ab = bc. The distance b and c could be varied so as to equal, be greater than, or less than the distance between a and b. They found that the greater the distance of bc relative to ab (within certain limits), the shorter the time interval before the subject switches once. This is, the subjective interval between two flashes further apart is extended, and the objective interval is correspondingly abbreviated. The authors maintain that the effect is produced by the everyday experience of intermittently seen objects moving along a path at a constant speed. It is established by experience that a greater distance covered takes a longer time. But when we turn to the vertical kappa effect also found by these authors, an appeal to experience does not appear to produce a satisfactory explanation. They found that the kappa effect is greater when the flashes are arranged in vertically descending order, than when the flashes are arranged in vertically ascending order. Now, an appeal to experience of falling and ascending bodies would result in reversing this. Since our experience of falling bodies is that they accelerate, and of ascending bodies is that they decelerate, a greater distance between the second two flashes than the first two should be subjectively compensated for on the descent but not on the ascent. And the finding that vertically descending kappa is greater than horizontal kappa is just as puzzling if we wish to appeal to experience, unless acceleration effects in falling are not part of our common experience. There seems to be no reason why they could not be. Apparently, the authors do not consider the greater descent kappa effect a contradiction to their explanation, since they do not discuss it.

After this/...........

After this fairly extensive review of the afferent or sensory effects on time judgement, we should consider the precautions, some of them rather obvious, to be taken in presenting a signal.

(a) Care must be taken to avoid anchor effects - or to keep them constant in all trials. A modality in which anchor effects are at a minimum is to be preferred. For this reason, auditory signals are preferred to visual.

(b) Uncontrolled movement in any part of the field must be avoided during presentation of the standard signal.

(c) A comparison of the results of Kruup (1961) and Siegman (1962) who used, respectively, auditory and visual stimulation, indicates that auditory stimuli are more reliably judged. This may be an effect of the greater distractibility of the subject during visual inspection of a signal, whereas auditory signals may easily be presented so as to block out other auditory stimuli.

(d) A continuous sound is to be preferred to an empty demarcated interval because it is difficult to take into account the effects of the intensity and duration of the terminal signals.

(e) The frequency of the sound must be kept constant, since rate of stimulation affects time judgement.

(f) Intensity appears to effect judgements, especially of short durations, and should be kept constant.

It will be seen in subsequent discussion that I have been content to stimulate the subject with a constant type of stimulus, varied only in length, and to devote most of my attention to the efferent or motor aspects of time judgement. For the reasons outlined above, a continuous auditory signal of constant intensity and frequency, varied only in length to produce different time intervals for judgement, was selected.

We turn now to an examination of the efferent aspect of the time judgement.

2.3 Methods of/............

2.3 Methods of Judging Time Intervals.

Methods may be grouped under the headings of production, verbal estimate, reproduction and comparison.

When making time judgements by the method of production the subject is given verbal information and asked to produce a response of duration equal to the objective time to which the verbal information refers. No standard is given in the experiment. A subject is asked to make a response lasting, say, 10 seconds without being given a 10 second stimulus for comparison. Such a method may measure the accuracy of a subject's concept of various time intervals. It may also be useful in measuring fluctuations in a subject's experience of time under the influence of drugs, as when subjects are asked to tap at a rate of once per second under the influence of quinine (Frankenhauser, 1959). This method depends on the stability of the concept of time involved, but assumes fluctuations in the non-verbal experience of time. If we think of the verbal instruction as activation a spatial structure in the brain - perhaps cyclic, if we adopt F.H. Allport's 1955 model - which is probabilistic in nature and subject to the influence of level of arousal, satiation or inhibition, and possibly metabolic rate of specific nerve centres, then provision is made for an analyser of the duration of the production which is itself subject to the cortical factors which influence time perception. In other words, neither a constant nor a single analyser is postulated. The analyser is as variable as the time experience analysed. This reminds us of Pavlov's statement. that the power to reckon time is inherent in the cortical cells of all analysers, and that it is not necessary to postulate a special time analyser (cited by Dmitriev and Kochigina, 1959).

The importance of this conception of the verbal instruction as arousing a spatial structure in the brain which will be similar in each case but not identical is that it provides for the relative constancy of verbal concepts of time intervals without removing them from the influence of other cortical variables.

The second/..........

The second method of time judgement is verbal estimation of the duration of a signal. This is the reverse of the method of production. Instead of a verbal instruction being required to activate a non-verbal process, a non-verbal process is required to activate a verbal process. Siegman (1962) has found that production and verbal estimation produce more reliable results than the method of reproduction. This confirms a rather obvious point - that verbal concepts of time have a rather reliable relationship with the non-verbal processes which they initiate or which intiate them. The finding by Kruup (1961) that there is a negative correlation between results obtained by the method of verbal estimation and the method of production confirms our view that they are to a certain extent reversals of each other. The subject who attaches a high verbal estimate to a short objective time is likely to produce a response which lasts a short time when given a high verbal cue.

The difficulty of comparing inter-individual scores obtained by the method of production or the method of verbal estimate was dealt with in the introduction. It appears that the only way to study inter-individual differences in time experience by this method is to establish intra-individual quotients or standards.

The method of reproduction has the advantage that the level of time-function need not be changed. A non-verbal comparison of the signal and the response is possible. The same applies to the method of comparison, in which the individual is presented with two signals and asked merely to state what the relationship is between them (longer, shorter, indentical). The method of comparison has been used in establishing subjective time scales (e.g., Gregg, 1951; Stevens and Galanter, 1957) which show that equal ratios of stimulus change lead to equal ratios of sensation change. The method of comparison has been used to establish this revision of the psychophysical law of Weber and Fechner.as applied to many types of judgement (Stevens, 1957). Generally, when the method of reproduction is used, the signal is discontinued while the response is made.

The subject/..............

The subject has, therefore, either to retain some nerve process directly activated by the signal, or he has to convert his impression of the duration of the signal into symbols and reconvert these symbols into non-verbal action during the process of reproduction. There may be very interesting differences in the degree to which subjects use symbolic aid in reproducing signals, but the problem is unexplored. Another interesting problem, also unexplored, is the rate of counting where the subject does use counting to assist him in accurately reproducing the signal. Would the rate of counting (since many subjects attempt to count at a rate of once per second) be affected by the sensory mode of the stimulus, as was found by Goldstone and others (1959) in a different problem? It is also tempting to think that the rate of counting might be an approximation of the indifference interval of Vierordt, but this is hardly likely. At one time this interval appeared with fair regularity in investigations (see James, 1890, p 633), but more recently it seems to have become rather elusive (Woodrow, 1930). Fraisse (1959) has attempted to relate the indifference interval to the psychological refractory period, and it is interesting to note that this revives an old idea of Wundt (cited in James, 1890, p.634), that the indifference interval of about $\frac{3}{4}$ second is related to association time of about the same duration. The indifference interval is the interval judged with the minimum of error and the association time is the time required for the succession of distinctly apperceived objects before the mind. "This association-time he regards as a sort of internal standard of duration to which we involuntarily assimilate all intervals which we try to reproduce, bringing shorter ones up to it and longer ones down". (James, 1890, p.634). 304 It is curious to compare this with Welford's (1959 p. 304) comment on the indifference interval. "Professor Fraisse's theory would presumably imply that the overestimation of short intervals was due to the second signal being referred to the point in time at which it began to be dealt with in single-channel mechanisms. Why longer intervals are underestimated is less clear, but might be due to the second signal tending to be referred back to the point of time at which the mechanisms became free".

It seems/.............

It seems that Wundt's argument is still, with slight modifications, viable - provided that the indifference point makes its appearance. Woodrow (1934) cautions that the indifference interval varies from subject to subject as well as with experimental technique. Nevertheless, the rate of counting which subjects employ as assistance in reproduction of time would be worth studying to see if it approximates these figures.

Studies of the accuracy and consistency of different methods of reproduction are not common. Doehring (1961) asked 8 subjects to tap a telegraph key in four different ways to reproduce the length of an auditory signal. but found no differences among the methods. The method of reproduction has been found to be less reliable than the methods of production and verbal estimation (Siegman, 1962; Kruup, 1961; and Clausen, 1950) but it is more accurate. The low reliability generally found associated with the method of reproduction is a serious disadvantage in any extensive study of individual differences or in studies of variables which might be associated with time experience. Too much of the variance will be chance variance, beyond the control of the experimenter. Key-pressing is an unsatisfactory method of reproduction of time signals.

In the next section another method of reproduction, possibly more reliable, will be considered.

2.4 The Method of Linear Movement

X The body exists in space-time. Rhythmic movements of the body, which commence even before birth, involve both voluntary and involuntary muscles. The repertoire of involuntary rhythmic movements includes such basic activities as breathing, alimentary movements, and the beat of the heart. The repertoire of voluntary rhythmic movements includes such activities as performing music, dancing and counting. But rhythmic movements of the voluntary muscles are repetitions of single movements which we also learn to make with rather precise timing. Obviously, in interception movements, as in catching a ball, a hand, or catching a moving bus, rather predisely timed movements through space are required.

There are/....................

There are no doubt very considerable differences between individuals in the ability to co-ordinate space-time relations, but each individual receives from his earliest years a continuous training in such co-ordination. Some forms of this training are directed specifically to maintaining tempo (tapping a drum, dancing, marching in step) and other forms of this training are directed to converting exteroceptive stimulation into precisely timed movements (as in grasping a moving object). It is not our purpose to present here a detailed or even an introductory account of what is known about tracking behaviour, and we cite the above evidence purely to show that it is quite reasonable that the conversion of an exteroceptive stimulus into a movement might be rather reliably done by the individual.

There is some evidence to bear out this point. Allport and Vernon (1933) found that each of 14 measures of speed studied was extremely reliable. They found three broad speed factors - verbal, drawing, and rhythmic - the second and third of which might be relevant to the tempo of reproduction of time intervals by extensive linear arm movements. Adams (1935) also found a high reliability for various speed measures, such as tapping, speed of writing and cancellation. In general, those tests which required the greatest attention also yielded the most variable results. From this it would appear that the tempo of reproduction of time by linear movements might be less reliable than unstructured motor speed. Rimoldi (1951) tested subjects on 59 measures of tempo and isolated 8 factors, one of which is identified as large movements of the trunk and limbs. He also found that measures of tempo are highly reliable. A later study (Rimoldi and Cabanski, 1961) is even more pertinent. It was found that the tempo of tapping in response to visually presented patterns is extremely resistant to change. Even fatigue had to be considerable to disrupt the tempo. Now, here is direct evidence that not only are measures of speed reliable, but that exteroceptive stimuli are converted into motor activity in a reliable way.

The evidence so far dealt with is not conclusive. We have shown the reliability of each measure of speed, but we have not shown that the actual duration of the movement is constant.

What has/.................

What has been shown is that the same time over distance relationship will be preserved in each trial. In a situation in which the individual can keep his distance fairly constant, though, the time score should also be reliable. This was found by Weber (1927), who asked subjects to reproduce durations by moving loaded carriages. Some subjects in his experiment appeared to pay particular attention to the distance moved, and reproduced the time interval reliably by attempting to move the same distance on each occasion. Other subjects appeared to pay more attention to duration, and to achieve consistency of distance as a consequence of consistency of tempo.

When one considers these experimental results, a method of reproducing time by extensive arm movements seems to be a likely way of enhancing reliability. Weber, though he used very small samples, found results which at least encourage us to hope that this may be so. The method of reproduction of time intervals by extensive linear arm movements was, therefore, adopted for trial as a possibly reliable method which might also reveal further facts about space-time interrelationships in judgement. With the exception of Weber's (1927) work, all the studies of spatial effects on time judgement have dealt with the influence of exteroceptive stimulation. Would anything like the same effects appear where the external stimulus is given no properties of extension or movement, but the response is? In other words, will "spatial" signals received from proprioceptors have the same effect on time judgement as spatial signals from exteroceptors?

What, then, is the method of reproduction of time by linear arm movement? Essentially, the subject is asked to move a handle horizontally across a frame in such a way that the duration of his movement equals, in his judgement, the duration of a time signal. He makes the movement after the time signal has ceased. The duration and distance of the subject's movement, made at his own speed, are then recorded and analysed. In the next chapter both the apparatus and the procedure will be described in detail.

CHAPTER 3

THE MEASUREMENT OF INDIVIDUAL DIFFERENCES IN TIME JUDGEMENT, TEMPERAMENT AND PERSONALITY

In Chapter 2 are outlined some of the reasons for attempting to measure time judgements by means of a linear movement lasting (in the judgement of the subject) as long as the time signal. Briefly, it was hoped that (a) the method would be reliable and that it would be suitable for measuring individual differences in time judgement; and that (b) the method would advance our knowledge of motor space-time relations.

In this chapter, only the main aim of each experiment, the apparatus used in the experiment, and the procedure in the experiment will be described. Most of the hypotheses tested, the results, discussion of the results, and conclusions will be found in subsequent chapters.

3.1 Experiment I

This experiment was conducted as a pilot experiment to discover whether the assumption, that the reproduction of time intervals by linear movement is reliable, can be verified.

3.1.1 Subjects

Forty-three subjects of both sexes, ranging from first year undergraduates to seniors drawn from several different courses, were tested in the first session. All were students at the University of Cape Town. Only 31 of these subjects returned for a second session, unfortunately, and reliability co-efficients were calculated using their results only. The implication is that the 31 subjects whose results were used for the calculation of reliability co-efficients were the most co-operative and highly motivated for the experiment. But this should certainly not be regarded, as an objection. A test can only be reliable if the subjects are co-operative and motivated to do well.

3.1.2 Apparatus

The standard stimulus which had to be reproduced was provided through earphones by an audio-oscillator set at 210 c.s. The duration of the auditory stimulus was controlled by a Hunter decade interval timer. The subject was seated in front of an ordinary table on which was placed a black wooden screen 20 inches high and 42 inches long. A thin cord ran along the bottom of this screen and over pulleys at either end. A handle was attached to the cord, and this could be moved horizontally by the subject for the whole length of the screen. The distance over which the handle was moved on each trial could be read off on a measuring tape which ran along the experimenter's side of the screen, out of sight of the subject. On this side of the screen was also placed an electric stop-clock which was used to read off the time taken by the subject's movement. The clock was started and stopped by a relay operated by the amplified output of a gramophone pickup, the stylus of which rested on a disc turned by the motion of the cord when the handle was moved.

3.1.3 Procedure

The subject was seated facing the middle of the screen with the handle at the left. He was instructed to move the handle for a period of time which he judged to be equal to the duration of the auditory stimulus. The distance over which he moved was left to his discretion, provided only that the direction of movement (left or right) was not changed until the edge of the frame had been reached. Thus, the subject could move at the speed he prefered. On successive trials the starting position of the handle was placed alternately to the right and to the left of the subject. 30 seconds elapsed between the end of one trial and the beginning of the next.

The durations presented for reproduction were 4.3 sec., 2.0 sec. 3.7 sec., 6.1 sec., and 0.9sec., in that order.

Each stimulus/..........

Each stimulus was presented and reproduced three times during each session, the average reproduction time being the score used to calculate reliabilities. In all cases a second experimental session, identical with the first, was given at an interval of between one week and two months. For the great majority of the subjects the interval between experimental sessions was about one month.

3.1.4 Results

The scores are to be found tabled in Appendix B and are discussed in Chapter 4. At this stage we may say that satisfactory levels of reliability were found. It was, therefore, decided to proceed with a second experiment.

3.2 Experiment 2

Since the hypothesis of reliability was confirmed, a larger investigation was conducted into (a) motor space-time relations (Chapters 6 and 7), (b) relationships among different methods of judging time (Chapter 5), (c) the effects of delay on time judgement (Chapter 8), and (d) various individual differences in time judgement (Chapters 9, 10, 11 and 12).

3.2.1 Subjects

The subjects for this experiment were 77 men and women first-year students of psychology attending the University of Cape Town. The reason for choosing first-year psychology students was that a certain amount of data from other tests to which they had been subjected was available on many of the subjects. Some of these data were analysed in the investigation of individual differences. The difficulty of obtaining comprehensive data on unpaid subjects is obvious, and this was the main reason for choosing this group for our experiment. The subjects were persuaded to participate in the experiment out of normal class or laboratory hours, so that only the most co-operative and interested were used. This ensured a reasonably high level of motivation. Of the 77 who attended the first session, 56 returned for a second session, between two weeks and two months after the first.

For the majority of the subjects the interval between the sessions was about one month. The fact that such a high proportion of the subjects attended a second session shows that motivation to perform well was at a reasonable level.

3.2.2 Apparatus

The apparatus for producing the auditory time signal and for reproduction of the duration of the signal by linear movement were the same as that used in experiment I.

In addition, a key wired in series with an electric clock was used. Depression of the key started the clock, release stopped the clock.

3.2.3 Experimental Design

The experiment was designed to measure inter-session reliability, the effects of delay on reproduction, and to measure immediate reproduction of time signals. Several immediate reproduction scores were desired so that averages could be calculated for correlation with other measures.

Two sessions were held. In the first session, attended by all the the subjects (77), auditory time signals were reproduced by linear movement both immediately after hearing them and after various intervals of delay. In the second session, attended by 56 subjects, all signals were twice reproduced immediately after hearing the signals.

In addition, all subjects made verbal estimates of each signal and some subjects (43) reproduced each time signal a third time by key-pressing.

3.2.4 Procedure

The 77 subjects used in the first session were allocated to seven groups of eleven each. The group into which a subject fell was determined by his serial position in the whole sample tested.

That is,/..................

That is, the first subject tested fell into group I, the second subject tested fell into group II and so on until the seventh subject tested fell into group VII. This was repeated until there were eleven testees in each group.

For the rest, the testing procedure was to a great extent the same as in Experiment I, with the exception that different time intervals were used. The signals were 1, 2, 4, 8 and 16 seconds and were presented to alternate subjects in an ascending or in a descending order. In the first session, each set of five time signals was reproduced twice by linear movement under two different conditions. Firstly, each subject produced each signal immediately after hearing it. Immediate reproduction scores were, therefore, available for all subjects. Secondly, each group of eleven subjects produced the second set under a different condition of delay. Group I reproduced each signal of the second set without delay. Group II delayed for 5 seconds before reproducing the signals. Group III delayed for 10 seconds; group IV for 15 seconds; group V for 20 seconds; group VI for 30 seconds; and group VII for 60 seconds. In each case the experimenter gave the signal for the subject to commence reproduction, and in each case the signals of the first and second set were presented in the same order.

Two additional time judgements were obtained. Firstly, each subject gave a verbal estimate of the length of the signal immediately after reproducing the signal by linear movement. Secondly, 43 subjects were asked to reproduce the whole set of signals a third time, by the method of key-pressing. That is, they had to depress a key for a period of time which they judged equal to the duration of the signal.

In the second session the 56 subjects who returned were tested, using the whole set of signals in the same order for each subject as in the first session. No delay was imposed. Each subject, therefore, reproduced the whole range of signals twice, immediately after hearing each signal, by the method of linear movement, Verbal estimates were asked for as before, after each reproduction. Of the 56 subjects returning for the second session, 32 had reproduced the whole set for a third time by key-pressing

in the/...............

in the first session. These 32 were asked to do so again.

3.2. 5 Results

The full results of this experiment may be found in various Tables in Appendix B. They will be referred to in various chapters, as hypotheses are tested against them. (a) The reliability of these data is discussed in Chapter 4; (b) the relations among various methods are discussed in Chapter 5; (c) motor space-time relations are dealt with in Chapters 6 and 7; and (d) individual differences in time judgement are studied in Chapters 9 - 12.

3.3. Experiment 3

In both Experiment 1 and Experiment 2 the subject was allowed to move any distance he wished. This condition will be called "free movement". The question arises whether the same individual differences will occur when the distance moved is controlled. This will have the effect of altering the tempo of movement, and could conceivably reduce the reliability of time judgements. This condition will be called "controlled movement". An experiment was conducted in which the distance moved as well as the length of the signal were controlled.

3.3. 1 Subjects

The subjects tested in this experiment were 40 men and women students at Rhodes University. They were drawn from a variety of courses of study as well as a variety of levels, and ranged in age from 17 to 27 years. The majority of them were about 19 years of age. Subjects were approached on the campus and an attempt was made to interest them in the experiment. All subjects were volunteers. There were very few refusals. All experimental sessions were conducted at times to suit the subjects, out of normal class hours.

3.3. 2 Experimental Design

The experiment was designed to directly compare free linear movement reproduction, controlled linear movement reproduction, and key-pressing.

Each Subject /.........

Each subject attended four sessions, spaced about a month apart, in which his judgement of two intervals of time was tested and retested by three methods. The methods were (a) linear movement reproduction under conditions of free movement, in which distance was not controlled; (b) linear movement reproduction under conditions of controlled movement, in which the distance to be moved in reproducing the time interval was determined by the experimenter; and (c) reproduction of the signal by key-pressing without linear movement.

In the first session each subject moved an ascending and descending order of distances ranging from 0 to 60 inches in reproducing 8 seconds. Half the subjects started with an ascending order and the other half with a descending order of distances, but both groups went right up and down the scale. This was followed by a break in which the Maudsley Personality Inventory was filled in. Then, after filling in the questionnaire, the subject was asked to reproduce 8 seconds twice by free movement, in which the distance moved was left to his discretion.

In the second session, about a month later, reproduction of 8 seconds was tested in precisely the same way. This time, the break between controlled and free movement reproduction was occupied with filling in the Taylor Manifest Anxiety Scale.

In the third session, the time interval was changed to 16 seconds, but the procedure in reproduction was the same. The break between controlled and free movement reproduction was occupied with filling in a Metaphor Preference Scale.

In the fourth session, again about a month later than the third, each subject reproduced 16 seconds in the same way as in the third session. The break between the controlled and free movement reproduction was occupied with filling in the shorter version of the Maudsley Extraversion Scale.

3.3.3 Apparatus

The apparatus for delivering the time signal was the same as that described in Experiments I and 2. The apparatus for reproducing

the time/...............

the time signal was slightly modified and must be described again in full.

The handle, instead of moving on cords as before, now moved on a metal rod which passed through its centre. At one end a fixed wooden support held the rod, but at the other end the wooden support was movable, so that the length of the metal rod could be varied from 5 inches to 60 inches. The movable and the fixed support were placed on a wooden frame and held the rod firmly. Three switches in series with an electric stop-watch were used to measure the time taken by the movement. Switch A was placed on the handle, and consisted of a thin long metal spring which made contact when the subject gripped the handle. Switch B was a lever switch attached to the fixed wooden support of the rod, and was switched on when the subject commenced his movement. Switch C was a contact switch attached to the movable support and was switched off when the handle made contact with it at the completion of the movement. A summary of the positions of the switches during reproduction can now be made.

(i) Readiness:- A off; B off; C on. The clock is not running.

(ii) Grip:- When the subject grips the handle but has not yet moved: A on; B off; C on. The clock is not running.

(iii) Move:- The subject commences the movement: A on; B on; C on. The clock is functioning.

(iv) Finish:- A on; B on; C off. The pressure of the handle switches off C and the clock stops.

This describes the way in which movement of controlled distances was timed. When it was desired to time free movement, the movable support was placed at a maximum distance from the fixed support (60 inches) and switch C was switched on and guarded, so that the contact of the handle could not switch it off. This was done so that the subject could move more than one length in reproducing the time interval, if he wished. The subject started the clock as before, by gripping the handle, making the spring contact A, and then moving, thus switching on the lever-switch B. But to stop the clock at the end of his movement he had to release A instead of coming into contact with C, as in timing controlled movements.

Thus, the/..................

Thus, the positions of the switches for (i) readiness, (ii) grip, and (iii) move were the same as those outlined above. The only difference was in the finish position, when the switches were: A off; B on; C on.

3.3.4 Procedure

The subject was seated facing the apparatus which had already been adjusted to a 5" or a 60" length. He was then instructed. "Through this pair of earphones you will hear a sound. When the sound has ceased I want you to reproduce the duration of that sound by making a movement lasting an equal time. You are to move from the one support to the other, once only, at such a speed that you cover the distance in the time of the signal. The clock timing your movement will start only after you have started your actual movement, not from the time you grip the handle. Grip the handle firmly while moving it. The clock will stop when you press gently against the terminal support. In each case, move immediately after the sound has stopped."

This instruction was repeated, if necessary, when the distance was changed. Distances used were 0, 5", 20", 40" and 60". Each subject reproduced over the distance series twice, once in ascending and once in descending order. When the distance was 0 the handle was placed at the centre of the rod with switches B and C on. The subject started and stopped the clock by gripping the handle for the appropriate time without moving the handle.

After the controlled movement reproduction trials, the subject was asked to fill in a questionnaire. There were four questionnaires which will be dealt with in more detail later in this chapter. A different one was completed in each of the four sessions which the subject attended.

Then, the subject was asked to reproduce the time interval twice by the method of free linear movement. The instruction this time was: "I want you to reproduce the duration of the sound, as before, by making a movement. But this time you may move any distance you like at a tempo which seems natural to you. You may move more than one length,

provided only/.............

provided only that you do not change the direction of your movement until you have covered the whole length of the rod. You may move less than a complete length, stopping anywhere you like. The main point to remember is that you are to attend purely to the duration of your movement. The distance is irrelevant. While you are moving the handle, keep a firm grip on it, but when you feel that your time of movement equals the time of the signal, let go the handle and keep your arm moving. Do not stop first and then let go. As before, the duration of your movement will be timed by a clock which will be started only when you commence your movement. It is not important how long you grip the handle before moving, because the clock will not be started, until you move the handle. The clock will stop the moment you release your grip on the handle".

These instructions were repeated until there was full understanding of the procedure. The reason for asking the subject to release the spring while still in motion was to eliminate, as far as possible differences in reaction time which might be expected to show up if the subject stopped first and then released the spring.

After each reproduction, the subject was asked to verbally estimate the duration of the signal.

3.3. 5 Results

The results of this experiment are to be found in Tables in appendix B. They will be referred to in various chapters, as hypotheses are tested against them. In Chapters 7 and 8 space-time and method relations will be discussed; and in chapters 9 - 12 individual differences in reproduction will be discussed.

3.4 Measures of Individual Differences in Personality, Temperament and Time Imagery.

Hypotheses concerning the individual differences associated with differences in time judgement are to be found in Chapters 9 - 12. In this chapter the various tests will be mentioned, but not discussed. Detailed discussion of the rationale of the tests and their application will be found in the appropriate chapters.

3.4. 1 Extraversion

Fifty-four subjects of Experiment 2 were asked to fill in the short M.P.I. (Eysenck, 1957) immediately after they had completed their time reproduction trials in the second session. All the subjects of Experiment 3 were asked to fill in both the short and the long forms of the M.P.I. (Eysenck, 1959). Testing is described in detail in Chapter 9.

The results are tabled in Appendix B and are discussed in Chapter 9.

3.4.2 Tests of Tempo

Subjects of Experiment 2 who returned for the second session were given a number of tests of tempo related to primary-secondary functioning and unstructured motor speed (Biesheuvel and Pitt, 1955). These tests were: preferred and maximum tapping speed, speed of making crosses, and speed of handwriting. Testing is detailed in Chapter 10.

The results are tabled in Appendix B and are discussed in Chapter 10.

3.4. 3 Taylor Manifest Anxiety Scale

Thirty-eight subjects of Experiment 2, and all subjects of Experiment 3, filled in the Taylor Manifest Anxiety Scale (1953). Testing is described in detail in Chapter 11.

The results are tabled in Appendix B and discussed in Chapter 11.

3.4. 4 Need Achievement

Forty of the subjects of Experiment 2 wrote imaginative stories which were scored for n Achievement. Testing is described in detail in Chapter 12.

The results are tabled in Appendix B and discussed in Chapter 12.

3.4. 5 Time Imagery

Forty of the subjects of Experiment 2 and the 40 subjects of Experiment 3 filled in the Metaphor Preference Scale of Knapp and Garbutt (1958). Details of the testing are given in Chapter 12.

The results are tabled in Appendix B and discussed in Chapter 12.

3.5 General Remarks.

In this, as in almost all psychological experiments, the experimenter is extremely dependent on the good faith of his subjects.

For this reason, though an attempt was made to persuade the subjects to co-operate by interesting them in the experiment, no attempt was made to be over-persuasive. Most of the subjects who came were interested, though results had to be withheld from them because of the danger that they might reveal to others what the durations of the various signals were. They were not told before the experiment that they would not be informed about their accuracy. This was one of the deceptions employed by the experimenter. But after the whole series had been completed a small number did come to inquire how accurate they had been.

Only two results were discarded because the subjects were obviously not attempting to be accurate. There may have been a few others who were not adequately motivated, but there could not have been many. Undoubtedly the motivation varied considerably.

Most of the subjects appeared to try their best. That is, unfortunately, all that can be said. Because they were individually tested, a better check on this was possible than in many experiments. And any one of the subjects tested could easily have avoided the experiment.

CHAPTER 4

INTER-SUBJECT AND INTRA-SUBJECT VARIATIONS IN TIME JUDGEMENT

4.1 Introduction

For the detection of individual differences, a test with a wide inter-subject spread of scores and a low intra-subject variability in response to a constant signal, is desirable.

Obviously, a test in which there is little spread of the scores cannot reveal individual differences in the testees. And a test in which the score obtained by each subject varies greatly between test and retest is telling us about the subject as he is at the time of each test only. Momentary factors or combinations of factors might explain the fluctuation in score, but it would be useless to look for relatively permanent determinants of each particular score taken separately. There might, of course, be individual differences in the extent of intra-subject variability.

A low reliability does not necessarily mean that a test is of no value. Such a test might be used to measure differences in intra-subject variability. But if we wish to deal meaningfully with particular scores obtained by means of such a test we have to specify the conditions which bring about fluctuations in score. To take a simple, pure and unfortunately hypothetical example: If we can specify that the cause of low test-retest reliability in production of time is a change in body temperature only, then we can correct for this and still deal successfully with individual differences in score. The implication of this is that, if we control the conditions of change, test reliability should be high.

It is by means of intra-subject studies that we are most likely to arrive at the conditions of change of score. Our custom, in psychology, of concentrating our attention on inter-individual group studies, makes conclusions about intra-individual, systematic relations difficult to attain.

Since we/...................

Since we are unable to specify the contributors to change in the large number of systems (subjects) studied and treated statistically, we prefer tests which give reliable scores with wide inter-system (inter-subject) differences. Our hope is that these may lead to the detection of common relatively stable factors or combinations of factors entering into them.

4.2 Different Methods of Time Judgement and Inter-Subject Distribution of Scores

The reproduction of time intervals by linear movement results in a larger inter-subject standard deviation of scores than does reproduction by key-pressing. In Experiment 2 key-pressing reproduction of 8 seconds yielded an inter-subject standard deviation of 1.18 seconds, and free linear movement reproduction yielded one of 1.93 seconds. The null hypothesis that these standard deviations are not significantly different is rejected at the 5% level of confidence. Also in Experiment 2, key-pressing reproduction of 16 seconds is performed with an inter-subject standard deviation of 2.07 seconds, and free linear movement reproduction with one of 3.96 seconds. The null hypothesis that these standard deviations are not significantly different is rejected at the 1% level of confidence. These scores are tabled below.

TABLE 1

Inter-subject standard deviations of key-pressing and free linear movement reproduction of time in Experiment 2.

Signal	Free linear Movement	Key-pressing
8 sec.	1.93 sec.	1.18 sec.
16 sec.	3.96 sec.	2.07 sec.

In Experiment 3, significant differences are found between the inter-subject standard deviations of scores when the stationary handle is gripped and when it is moved under either controlled or free conditions. In Table 2 below in the text are all the standard deviations obtained in Experiment 3.

Table 2/....................

TABLE 2

Inter-subject standard deviations of grip, free linear movement, and controlled linear movement reproductions of time in Experiment 3.

Signal	Free linear movement	Controlled l.m.	Stationary grip.
8 sec.	2.71 sec.	2.99 sec.	1.51 sec.
16 sec.	5.68 sec.	4.05 sec.	2.40 sec.

The inter-subject standard deviation for reproduction of both 8 seconds and 16 seconds by free linear movement is greater than the inter-subject standard deviation for the reproduction of these time intervals by stationary grip. In both cases, we may reject the null hypothesis at the 1% level of confidence. The standard deviation of controlled linear movement reproduction of both 8 seconds and 16 seconds is significantly greater than the standard deviation of reproduction of these intervals by gripping the stationary handle. In both cases we may reject the null hypothesis at the 1% level of confidence.

It is clear, therefore, that the introduction of extensive movement into the method of reproduction raises the level of inter-subject variability. This should be useful in the detection of individual differences, provided that intra-subject variability is not correspondingly raised. Before we examine the experimental evidence on this issue, it is worth turning to the subject variables which might affect reliability.

4.3 Subject Variables Affecting Reliability

Weber (1927) found that, at a critical point, further increases in the load which subjects had to move no longer affected judgement of duration or distance. In his study of "the properties of space and time in kinesthetic fields of force" he asked subjects (a) to move a constant distance while the load moved was varied, and (b) to move for a constant duration while the load moved was varied. He found that both the distance and duration of movement tended to vary with the load, but that both were reliable under identical conditions.

In his/.................

In his own words "a given time interval under load is phenomenally equivalent to a smaller time interval (as measured by clock time) under less load" and "a given distnace under load is phenomenally equivalent to a greater distance under less load". In addition, both these load effects were directly proportional to the amount of load. His finding that at a critical point there is a reversal of effect is not an isolated one. The kappa effect, for example, applies up to a distance ratio of about 4:1 (Cohen and others, 1955). Abe (1937) has also found that a critical attitude destroys the space effect on time judgement.

From this it appears that one of the major subject variables which may reduce reliability in testing is a sudden shift in attitude. Any new information, or change in attitude (not necessarily produced in the testing situation) can result in a completely new perceptual configuration which radically reduces reliability of the test. One finds this, especially, in verbal estimates, because a subject can check on the accuracy of his concepts of clock time between sessions. There may well be subject differences in the degree to which either consistency or accuracy are made the prime goals. Some subjects, after a few trials, may attempt to achieve internal consistency rather than attempt to improve their accuracy. We should expect such subjects, as trials proceed, to show fewer and fewer alterations of judgement. Others may remain dependent on the actual stimulus and more open to shifts in judgement. Witkin (1954) has made a distinction between field-dependent and field-independent subjects, which refers to the kind of cue which the subject uses in judgement. The field-dependent subjects refer more to the characteristics of the external field in making their judgement; the field-independent subjects are capable of a greater degree of detachment from the external field. Another subject distinction which is relevant is Klein's (1954) dichotomy of levellers and sharpeners. This dichotomy has been shown to be useful in the study of time order errors. In an experiment, levellers and sharpeners were selected by size judgements, and their time-order errors with visual, auditory, and kinesthetic stimuli were measured (Holzman, 1954).

Subjects/..................

Subjects were required to judge the intensity of a comparison stimulus which equalled that of a standard stimulus, but with interpolated stimuli (between the standard and comparison) of various intensities. Normally, when no stimulus is interpolated, time error is positive up to 3 seconds and negative thereafter. Köhler's explanation of this is that the first stimulus sets up a trace which increases up to about 3 seconds and then begins to decrease. Up to 3 seconds, therefore, a succeeding stimulus seems to be less intense than an equal preceding stimulus, and after 3 seconds, more intense. But Holzman argued that the interpolation of a stimulus more intense than either the standard or the comparison stimulus would produce positive time error even after 3 seconds because of the assimilation of neighbouring brain traces (of the standard stimulus and the interpolated stimulus), and that levellers would show greater assimilation effects than sharpeners. The hypothesis that levellers would show greater positive time order effects with a more intense interpolated stimulus was confirmed, and it was concluded that cognitive attitudes are general dispositions of personality which affect responses in a wide variety of behavioural situations. No explanation is offered for the assimilation of the standard and interpolated stimulus-trace rather than the assimilation of the comparison and interpolated stimulus-trace. There seems to be no reason why assimilation should not occur as easily in the latter direction as in the former. But the fact that there may be differences in the assimilation of neighbouring processes is of great importance in considering reliability. A question of importance is the remoteness of the traces which can affect each other. According to Helson's (1947) theory, these effects may be quite persistent, in the form of an adaptation level. In his formulation, judgement of any stimulus depends upon the ratio of the physical value of that stimulus and the physical value of the subject's current adaptation value. And the adaptation level, which is the physical value of the stimulus which is judged neutral (equal to the standard) is a weighted geometric mean of the various stimuli to which the subject has been exposed. More recent stimuli carry a greater weight than more remote stimuli, but they are effective.

There may/....................

There may be a difference with procedure and the kind of scale which is used. For example, Parducci (1959) found that when subjects classified lengths in categories, an increase in the number of categories used reduced the effect of adaptation level. Possibly, when the method allows for very fine discriminations, adaptation level is at a minimum. This appears to be probable in view of the study by Weiss, Coleman and Green (1955) of 130 successive bisections of an angle. They found that the best prediction of a setting could be made with knowledge of only the preceding setting. From this they conclude that the effect on judgement of remote past experience is less potent than is assumed by adaptation level theory.

But even if this is so, there are still important antecedent effects on judgement, and there are, possibly, differences between levellers and sharpeners in the extent to which antecedent effects may operate. We certainly do know from the study of Goldstone and others (1957) that both cross-modal and intra-modal anchoring effects on time judgement are possible.

Relevant to this is the finding that obsessives are more accurate in their judgements, and more stimulus-bound than normal subjects (Angyal, 1948). They might be expected, therefore, to show less anchoring effect, as is the case with schizophrenics, and test reliability might be expected to be higher in studies of obsessive subjects than in studies of normal subjects. On the other hand, studies of anxious and hysterical patients might be expected to yield lower reliability (Davis and Cullen, 1958).

Reliability in a perceptual-motor task is probably influenced by an interaction of several test and subject variables.

4.4 Reliability of Motor Speed

The high reliability of motor speed is well established and has already been mentioned. Briefly, there is the finding of Allport and Vernon that the average of the uncorrected repeat reliabilities in

their measurement / ...

their measurement of speed was +.684. Since the median time devoted to each separate test was 30 seconds, the authors conclude that very much higher reliabilities might have been attained with more protracted testing. They state that "single habits of gesture, as we have measured them, are stable characteristics of the individuals in our experimental group" (p.98). Rimoldi and Cabanski (1961) also showed the high reliability of tempo in an interpretive task in which the subject was required to transform visual patterns into patterns of motor activity, by tapping on a telegraph key. They found tempo to be constant over repeated sessions and estremely resistant to modification by fatigue.

But there ~~is~~ are a number of factors which affect the consistency of motor tempo. One of the best known of these is body temperature. It has been shown that subjects attempting to tap at a rate of once per second accelerate tapping speed when body temperature is artificially raised (Francois, 1952). An extrapolation of the available experimental data shows that the unit equal to one subjective second is shortened 2.8 times for every 10° C rise in temperature. Hoagland (1933) and Hoagland and Perkins (1935) found a straight line curve of negative slope when the logarithm of the relative speed of counting seconds is plotted against the reciprocal of the absolute temperature. Tempo preference when listening to a metronome is also correlated with body temperature (Raslikes and Raslikes, 1962). If tapping speed and tempo preference are a fundtion of the speed of chemical equations in the body, the results could be explained by means of an Arrhenius equation. Hoagland has suggested that enzyme systems involved in central nervous system respiratory processes are involved. This view is strengthened by the fact that central nervous stimulants (such as caffeine) produce acceleration of subjective time (a lengthening of subjective judgement of a constant objective unit), but sedatives (such as quinal barbitone) have the opposite effect (e.g. Goldstone, Boardman and Lahmon, 1958).

The effedts of temperature, barometric pressure (Raslikes and Raslikes, 1962) and several drugs could reduce reliability of speed preference in motor activity. But they are special instances which do hot affect the main conclusion that motor speed is very reliable.

4.5 Reliability of Time Judgements

The reliability of time judgements by the method of reproduction is known to be low. Siegman (1962), whose subjects reproduced auditory signals by depression of a key, found a reliability coefficient of .59 for a 5 second interval and .40 for a 20 second interval. Clausen (1950) obtained reproduction reliabilities of approximately the same order. Kruup (1961) obtained no significant intersession reliability coefficients, but this may have been - at least partly - because he used a visual signal.

The reliability of time judgements by the method of verbal estimation is higher. This has been noted by both Clausen (1950) and Siegman (1962). Siegman obtained reliability coefficients of .82 (5 second interval) and .84 (20 second interval). On the other hand, much lower coefficients have been obtained by Bakan and Kleba (1957) who asked subjects to judge intervals ranging from 15 seconds to 240 seconds in two sessions separated by one week. They report coefficients ranging from .00 to .51, corresponding to the longest and the shortest intervals. The verbal estimates of young children are extremely variable (Gilliland and Humphreys, 1943; Smythe and Goldstone, 1957), but it is not so certain that their reproduction ~~scores~~ reliabilities are lower than those of adults. This is partly, of course, because the reproduction scores of adults seem to show such high intra-subject variability that comparisons are not very fruitful. It would be an interesting problem to investigate with a reliable method of measurement, because it might shed some light on the question of the extent to which concepts of time enter into reproduction of time. In a subsequent chapter (5.4) it will be shown that verbal estimates of time are more closely related to reproduction estimates when the natural tempo of the subject's linear movement is disturbed. This suggests that technique of measurement may play an important part, even when the method of reproduction is used, in determining the extent to which the subject verbalises his experience of time. There are two problems to be considered, therefore. One is the possible increase in verbalisation of the time experience with increase in age, and a possibly closer relationship between verbal estimates and reproductions of time; and the other is the relationship between type of reproduction technique and degree of

verbalisation at / ...

verbalisation at any given age. There may also be individual differences in the degree of verbal penetration into perceptual motor activities.

The relative reliability of the method of verbal estimation is probably partly a function of the crudeness of the categories used. It has already been noted that estimates ending in 0 and 5 tend to predominate (Weber, 1933). Strong cognitive controls are also exercised over verbal activities. Cohen and Mezey (1961) have shown that subjective changes in the rate of flow of time do not necessarily result in changes in verbal estimate. In their experiment, the scores of doctors about to make speeches were compared with their own scores under normal working circumstances. Though they reported a distortion in their experience of time, this was not reflected in their estimates. They were able to make allowances for the state of their excitement. This would lead us to suppose that measures of intellectual performance might be related to time judgement. This has been confirmed (Spivack, Levine and Sprigle, 1959).

What are the factors which probably contribute to a low reliability coefficient when the method of reproduction is used? The first is that the subject is usually prevented from making use of those rhythmic cues, such as counting, tapping, and nodding, which he might normally use in measuring out a period of time. The longer the period of time, the more dependent a subject probably is on breaking it down into rhythmic activities. When the subject is specifically instructed not to use rhythm he is unable to be consistent. A second possible factor is that a subject may not always pay attention to the same cue. Usually, this effect is experimentally demonstrated by comparing judgements under changed instructions, but it is quite likely that such a change in attention can occur without the experimenter being aware of it. For example, subjects may be instructed to pay attention to either the initial or the terminal stimulus, where an empty interval is used. In the first case reproductions are significantly shorter than in the second (Woodrow, 1933). Even time order error may be reversed by instructing subjects to attend maximally to the second of two comparison intervals

(Quasebarth, 1924). The direction of the subject's attention is probably only approximately the same in each trial, when no special instructions are given.

There are, of course, numerous momentary factors subh as changes in motivation, serial position of the trial, fatigue, mental activity, level of arousal and adaptation level which affect time judgement. But these apply to other activities, such as motor tempo, as well. If we have to isolate the main factor responsible for low reproduction reliability, we might hazard the guess that it is the absence of kinesthetic cues from rhythmic motor activity.

Now, let us turn to the evidence concerning the reliability of reproduction by linear movement.

4.6 Reliability of the Method of Free Linear Movement and of other Methods

Experiments 1 and 2 have provided most of the evidence on which we shall base our argument. In Experiment I, 31 subjects reproduced signals ranging from 0.9 to 6.3 seconds in two different sessions separated by a median period of one month. In Experiment 2, 56 subjects reproduced signals ranging up to 16 seconds in two sessions separated by a median period of one month. In addition, subjects made verbal estimates, and key-pressing reproductions of the time intervals in Experiment 2 were obtained from 32 subjects on both occasions.

A full account of Experiments 1 and 2 may be found in × Chapter 3.1 and 3.2.

4.6. I Results

Only the results which have a bearing on reliability will be considered here. In Appendix B, Table I, may be found the average first and second session linear movement reproduction scores of Experiment I. In Appendix B, Table III, may be found the average first and second session linear movement reproductions of 8 and 16 seconds obtained in Experiment 2. In Appendix B, Table V, may be found the first and second session verbal estimate and key-pressing reproductions of 8 and 16 seconds obtained in Experiment 2. Average speed of linear movement

reproduction in / ...

reproduction in the first and second session of Experiment I are found in Table II, of Appendix B. Average speed of linear movement reproduction in the first and second session of Experiment 2 are found in Appendix B, Table IV.

Inter-session reliability co-efficients for time judgements and speed were calculated. In Table 3 in the text below are the coefficients of reliability of linear movement reproduction times and speeds.

TABLE 3

Inter-session reliability of linear movement reproduction of time, and speed of linear movement

SIGNAL	RELIABILITY COEFFICIENTS Time	Speed
0.9	.70	.74
2.0	.50	.67
3.7	.77	.70
4.3	.71	.76
6.1	.65	.73
8.0	.57	.92
16.0	.69	.70
MEAN COEFFICIENT	.66	.75

The average coefficient of reliability for speed is slightly higher than that for reproduction of time, but both are satisfactory. Certainly, the coefficient for reproduction of time is higher than that reported anywhere else in the literature. Distance moved is also highly reliable as might be expected. The coefficients of reliability of distance moved in reproducing 8 seconds and 16 seconds are .76 and .84 respectively.

Verbal estimates tend to be slightly more reliable than reproduction estimates, as is the general finding. The coefficients of reliability of verbal estimates of 8 seconds and 16 seconds are .79 and .64 respectively.

The reliability of key-pressing reproductions in our experiments tend also to be higher than those reported elsewhere. The

coefficients of / ...

coefficients of reliability of reproduction of 8 seconds and 16 seconds by key-pressing are .59 and .49 respectively. Only at the 16 seconds interval does there appear to be a drop in reliability below that obtained by linear movement.

These results appear to show that the reliability of the method of reproduction may be raised to the level of reliability obtained by the method of verbal estimation. It is tentatively suggested that additional kinesthetic cues obtained by subjects from movements of the arm are important in maintaining a consistent level of reproduction. The view that the experience which every individual has in converting auditory time into bodily time (as in dancing, singing, and clapping hands) can contribute to high reliability in time judgements expressed by extensive bodily movement, is to some extent supported by these findings.

But another problem remains. If the tempo of the movement is disturbed by forcing the subject to move a certain prescribed distance, will inter-session reliability be maintained? One cannot predict with any degree of assurance, but the fact that individuals may adjust the distances of rhythmic movements without apparent difficulty, suggests that no difference in reliability should be found. On the other hand, if we regard the reliability of the natural tempo of the subject's movement as a determinant of reliability of time scores obtained by lower movement, then any disturbance of that tempo might be expected to reduce reliability.

There seem to be two possible views. One is that muscular cues in movement help to maintain consistency in time, irrespective of the speed of movement. The other is that consistency in time is dependent on the consistency of preferred speed of movement. According to the former view, rates of movement may be reliably adjusted to changes in both time signal and distance. Since subjects are continually adjusting their rates of movement according to circumstances, this is not implausible. But according to the latter view, the reliability of the time, distance, speed relationship can be maintained only where the subject is allowed to move freely at natural tempo.

The data of / ...

The data of Experiment 3 are of value in enabling us to answer this question.

4.7 Reliability of the Method of Controlled Linear Movement and of Other Methods

4.7.I Experiment

The experiment tests the hypothesis that kinesthetic cues derived from controlled-distance movements are as effective in contributing to reliability of time judgements as those derived from free-distance linear movements. The data used here are obtained from Experiment 3, in which 40 subjects reproduced 8 seconds in two separate sessions separated by a median period of one month, and 16 seconds in two separate sessions separated by a median period of one month, making a total of 4 sessions. The methods of reproduction used were free and controlled linear movements, so that they could be directly compared. Since only one length of signal was used in each session, reliability might be expected to be slightly higher than in Experiments I and 2. x Experiment 3 is fully reported in Chapter 3.3.

4.7.2 Results

In Appendix B, Table VI, may be found the average test and retest reproduction times obtained by the method of controlled linear movement. In Appendix B, Table VII, may be found the average test and retest times obtained with the method of free linear movement. Inter-sessions reliability coefficients were calculated, and are shown below in the text Table 4.

TABLE 4

Inter-session Reliability of Free and Controlled Linear Movement Reproduction of Time Signals in Experiment 3.

SIGNAL	RELIABILITY COEFFICIENT Free Movement	Controlled Movement
8 seconds	.64	.80
16 seconds	.58	.73
MEAN COEFFICIENT	.61	.76

These coefficients / ...

These coefficients show very clearly that the reliability of time judgements by controlled linear movement is as high as the reliability by free linear movement. We should notethat the controlled movement reliabilities are calculated with the averages of eight trials in each session, whereas the free movement reliabilities are calculated using the average of two trials in each session. Small fluctuations are more likely to upset reliability when a small number of trials is averaged. Another possible cause of the relatively low reliability of free movement reproductions as compared to controlled reproductions is that they were made after the eight controlled movement trials. Possibly, a considerable readjustment was required of the subject. But even allowing for this we cannot fail to be impressed with the fact that reliability is as high when distance is prescribed as when it is left to the discretion of the subject. The mean free movement coefficient of .66 obtained with the subjects of Experiments 1 and 2 and the mean controlled movement coefficient of .76 obtained in Experiment 3 probably represent the same order of reliability, if we take into consideration the fact that subjects in Experiments 1 and 2 reproduced several intervals in each session, whereas subjects in Experiment 3 reproduced only one interval.

Anchoring effects where more than one signal is used may lower reliability, and the range of adjustment demanded of the subject is considerably greater. On the other hand, the subjects of Experiment 3, though they may not have had to adjust to changes in signal length, did have to adjust to changes in distance.

4.8 Conclusions

The first conclusion which seems justified is that reproduction of time by extensive linear arm movements raises reliability to the level of reliability obtained with verbal estimates.

A second conclusion which seems to be strongly supported is that this enhanced reliability is not dependent on the subject's natural speed of movement. The implications of this cannot be fully

explained, but / ...

explained, but some attempt should be made to suggest explanations. Firstly, it is suggested that the kinesthetic cues of movement, regardless of the speed of movement, are important in determining reliability. This explanation seems to be necessary in view of the fact that the subjects performed more reliably under the rather difficult circumstances in Experiment 3, when they were deprived of the cues of a constant preferred speed in reproducing durations, than when they were allowed to reproduce the signal by key-pressing or gripping the handle. The second suggestion is that perception of space and movement is much clearer than perception of time. Spatial boundaries of action, for example, may be clearly perceived by the subject, whereas the temporal boundaries of action are to a large extent abstractions, which the subject is not able to perceive clearly before him in the way that he can say, a door frame through which he must pass. He cannot perceive at once the beginning and the end of a period of time. He may experience illusions of space, but its structure is rather definite. When a person is acting, or moving in relation to the spatial world, he is not so much aware of the time properties as such of his movements, as of the rates at which various changes are achieved. He is aware of the rate at which he approaches the door; of the rate at which bodies change location relative to him and to each other, but he is not aware of the time properties of these changes as distinct from the changes themselves, unless by a process of abstraction. He is equipped to achieve and to reliably repeat, under identical conditions, certain rates of movement. The skeletal musculature deals in movements, and movements have time properties which may be abstracted, but which are secondary. What the subject achieves is, essentially, a reliable rate of performing a certain task. The motor system of the skeletal musculature, subjected to extensive training throughout life, is probably able to analyse rates of movement. The reliability of natural tempo appears merely to reflect one aspect of this ability. That the duration of the movement is an abstraction, imperfectly achieved, from the movement, is shown by the fact that, though reproduction by linear arm movements is more reliable than by key-pressing, it is far less accurate. The subject achieves a reliable speed of performance which has an inaccurate duration. The accuracy of reproduction by different methods will be dealt with in Chapter 5, but for convenience differences in proportion of error obtained in Experiment 2 are shown below.

TABLE 5

Differences in proportion of error* obtained with different methods of judging 16 seconds in Experiment 2.

METHOD	PROPORTION OF ERROR	STANDARD DEVIATION	
Reproduction by arm movement	.276	.208	(N77)
Reproduction by key pressing	.096	.083	(N43)
Verbal estimate	.353	.348	(N77)

* prop. error = error, irrespective of sign/signal length

All these differences in errors between methods are significant at the 1% level, except for the difference between reproduction by arm movement and verbal estimate, which is not significant.

The curious fact emerges that the two most reliable methods of time judgement (linear arm movement and verbal estimation) are also the least accurate. But the correlation between the two is low, (.31 at 8 seconds, .29 at 16 seconds), so that we cannot suspect them of being merely alternative.forms of the same process.

SUMMARY

The reliability of time reproductions by free and controlled linear movements is of approximately the same order (the mean coefficients obtained are .66 and .76, respectively). There are differences in procedure between Experiments 1 and 2, and Experiment 3, which probably account for the slightly higher reliability of reproduction by controlled linear movement. Reproduction by key-pressing is slightly less reliable (.54), but verbal estimates are of the same order of reliability as linear movement reproductions (.72). The

reliability of /...

reliability of the verbal estimates is in agreement with that generally reported, but our key-pressing reliability is higher. A tentative explanation advanced for the high reliability obtained by linear movement reproduction of time is that the motor system of the skeletal musculature is well adapted to analysing speed of movement. This results in consistent rates of movement under identical conditions. The reliability of voluntary, preferred tempo is taken to be only one instance of this. The achievement of consistent rates of movement under identical conditions means, naturally, that consistent durations of movement are achieved where the distance is held constant. In Experiments 1 and 2, subjects moved practically identical distances in each trial; and in Experiment 3, the distances were controlled by the experimenter.

CHAPTER 5

RELATIONS AMONG DIFFERENT METHODS OF JUDGING TIME

5.1 Introduction

In the previous chapter the problem of the relations among different methods of judging time was touched on, but not analysed in detail, using the data at our disposal. It was noted that linear movement reproductions tended to have different means and distributions from stationary reproductions by key-pressing or by gripping the handle. And results obtained by both of these methods differ from verbal estimates, though the distribution of scores by linear arm movement tends to be rather similar to the distribution of verbal estimates. (See Tables 26, 27). Also, it was noted in Chapter 4 that the reliability of verbal estimates and linear movement reproductions tend to be rather similar, of the order .66 to .76 for linear movements, and of the order .72 for verbal estimates. The reliability of key-pressing was rather lower. The general picture is that the two methods which are least accurate and which yield the greatest inter-subject distribution of scores are also the most reliable.

We should like to know how these various methods are correlated. Would we find that verbal estimates are more highly correlated with linear movement reproductions than with key-pressing? Would the scores obtained by the methods of reproduction relate more significantly to each other than to verbal estimates?

In general, the reported evidence shows that verbal and reproduction times are not very closely related. Siegman (1962) found correlations of -.169 and -.184 between reproduction and verbal estimate of a 5 sec. and a 16 sec. interval, respectively. This low correlation has been confirmed by Kruup (1961); and Clausen (1950) has concluded that the low correlations observed between verbal estimates and reproductions show that different underlying processes are involved. Of course, as we have already pointed out, when a subject makes a verbal estimate he is trying to relate the time signal to clock time, whereas when he reproduces a signal the subject is not at all concerned with

clock time /...

clock time. The added complication in verbal estimation is that the subjects do not all have the same clock time standard, so that differences in verbal estimate may refer to differences in perceived time, to differences in notions of clock time, or to differences in the ability to relate perceived time to clock time standard. A way of overcoming some of these difficulties would be to give each subject a standard of comparison before the experiment. This would be similar to the method of fractionation. But, although it is clear that verbal estimates taken without preparation are not closely related to reproductions of time, there is no evidence that even reproductions - without the complication of reference to a time standard - are closely related. There is no reason to believe that they necessarily are, when one considers the differences in the means and the standard deviations obtained by the methods used in our experiments. It is quite possible that each method of reproduction has rather special factors entering into it. But do not all methods refer to the same perceived time interval? Ought not there to be some common core in all these methods of judging time? This problem will be attacked in two ways. The first is by simply correlating the raw scores obtained by each method. The second is by correlating the changes in score obtained by each method. If the methods are related, it is possible that, though raw scores might not correlate because of special determinants entering into each method, the changes in scores will correlate because the scores by different methods are functionally related within the individual, and depend on the same perception of time, in each case.

5.2 Relations of Judgements of Time by Different Methods.

Judgements of time by free linear movement, by controlled linear movement, by key-pressing, by gripping the stationary handle (which gave the same results as key-pressing, as has been shown), and by verbal estimate were obtained in Experiments 2 and 3.

Correlations of these judgements were calculated. The raw scores on which the correlations in Table 6 are based may be found

in Appendix B, /...

in Appendix B, Table XXXIX.

TABLE 6

Correlations of judgements of 8 seconds by different methods in Experiment 2.

		1	2
1.	Free linear movement reproduction		
2.	Key-pressing reproduction	-.07	
3.	Verbal estimate	+.31++	+.23

++ significant at 1%

Correlation 1 - 2 is based on 43 subjects, correlation 2 - 3 is based on 43 subjects, and correlation 1 - 3 is based on 77 subjects. This is because only 43 subjects reproduced the time signal by key-pressing but all 77 subjects judged the time interval by linear movement and verbal estimate.

Raw data for the next table may be found in Appendix B, Table XXXVI.

TABLE 7

Correlations of judgements of 16 seconds by different methods in Experiment 2.

		1	2
1.	Free linear movement reproduction		
2.	Key-pressing reproduction	+.11	
3.	Verbal estimate	+.29+	-.04

+ significant at 5%

Both of these tables show that the method of linear movement is more closely related to the method of verbal estimation than to the method of key-pressing. This confirms a suspicion formed when considering the standard deviations and the reliabilities. Another point of some importance is that the two methods of reproduction are hardly related. The very low correlations among methods tend to support Clausen's contention that there are distinct underlying functions.

But, before considering the matter further, the results of Experiment 3 should be examined. The raw scores for Table 8 below may be consulted in Appendix B, Table XXX.

Table 8 /...

TABLE 8

Correlations of judgements of 8 seconds by different methods in Experiment 3 (N=40)

		1	2	3
1.	Free Linear movement			
2.	Controlled linear movement	+.45++		
3.	Grip	-.20	+.49++	
4.	Verbal estimate	-.20	+.11	+.21

++ significant at 1%

The raw data for the following Table 9 are to be seen in Appendix B, Table XXI.

TABLE 9

Correlation of judgements of 16 seconds by different methods in Experiment 3 (N = 40)

		1	2	3
1.	Free linear movement			
2.	Controlled linear movement	+.53++		
3.	Grip	+.15	+.09	
4.	Verbal estimate	+.31+	+.37+	+.21

\+ significant at 5%
++ significant at 1%

Let us examine firstly the elements common to the results of Experiments 2 and 3. We may take reproduction of time by gripping the stationary handle to represent the same method of reproduction. as key-pressing. At 8 seconds, free linear movement correlates positively and significantly with verbal estimate in Experiment 2 (+.31), but negatively, though not significantly, with verbal estimate in Experiment 3 (-.20). At 16 seconds, reproduction by free linear movement correlates significantly and positively with verbal estimate in both Experiment 1 (+.29) and Experiment 2 (+.31). We are probably justified in assuming that there is generally a significant positive correlation between linear movement reproduction and verbal estimate. When we turn to key-pressing (or grip) and verbal estimate we find, at 8 seconds, a low positive correlation in both Experiment 2 (+.23) and Experiment 3 (+.21). At 16 seconds, the correlation between these two methods is virtually zero in Experiment 2 (-.04) and is positive

but low/...

but low in Experiment 3 (+.21). On the whole, therefore, we may conclude that the relationship between key-pressing and verbal estimate tends to be positive, but slight. It is certainly not as strong as the positive relationship between linear movement reproduction and verbal estimate. Lastly, when we examine the relationship between linear movement reproduction and key-pressing (or grip) we find, at 8 seconds, an insignificant negative correlation in both Experiment 2 (-.07) and Experiment 3 (-.20). At 16 seconds, the correlations are +.11 in Experiment 2 and +.15 in Experiment 3. In both experiments there is a change from a negative to a positive correlation between these methods as the signal is lengthened.

To summarise: the only statistically significant correlation between methods of time judgement is the positive correlation between linear movement reproduction and verbal estimate.

In Experiment 3, the additional method of controlled linear movement reproduction is used, and seems to have almost the same correlates as the method of free linear movement reproduction. At eight seconds, only controlled linear movement correlates significantly with grip (+.49), but at 16 seconds both correlate significantly with verbal estimate (+.37 and +.31 respectively). In addition, controlled and free linear movement correlate more significantly with each other than with any other method (+.45 at 8 seconds and +.53 at 16 seconds).

5.3 Relations of Errors in Time Judgement by Different Methods.

Additional evidence for the inter-relationship of various methods was sought in correlations of variability and error. If variability in score by one method is related to variability in score by another method, and if error in score by one method is related to error in score by another method, then we have additional evidence that the methods are related. No direct causal relationship from one to the other is claimed. But if reproductions by various methods depend on a common core of time experience, then fluctuations in that experience, should affect all methods. In all cases, error was calculated, disregarding sign, and variability in score was calculated by using the formula for variance. In Experiment 2, four scores obtained in two sessions were/

/...

sessions were used to calculate variance of verbal estimate and free linear movement, and in Experiment 3, scores from all four sessions (two for each length of signal) were used in calculating variance.

In Table 10 below, the correlations obtained from the data in Experiment 2 at 8 seconds are shown. The scores may be consulted in Appendix B, Table XLI.

TABLE 10

Correlations of variability and error in judging 8 seconds in Experiment 2.

	1	2	3
1. Free l.m. variability			
2. Free l.m. error	-.18		
3. Verbal estimate variability	+.16	+.21	
4. Verbal estimate error	-.07	-.05	+.58++

++ significant at 1%

In Table 11 below correlations of data obtained at 16 seconds in Experiment 2 are shown. The full scores are listed in Appendix B, Table XLII.

TABLE 11

Correlations of variability and error in judging 16 seconds in Experiment 2.

	1	2	3
1. Free l.m. variability			
2. Free l.m. error	-.01		
3. Verbal variability	+.15	+.17	
4. Verbal error	-.07	-.04	+.50++

++ significant at 1% level of confidence

In Table 12 below correlations of data obtained at 8 seconds in Experiment 3 are shown. The full scores are listed in Appendix B, Table XLIII.

TABLE 12

Correlations of variability and error in judging 8 seconds in Experiment 3.

	1	2	3
1. Controlled l.m. variability			
2. Controlled l.m. error	+.52++		
3. Verbal variability	+.07	-.19	
4. Verbal error	+.31+	+.01	+.29

+ significant at 5%
++ significant at 1%

In Table 13 below correlations of data obtained at 16 seconds in Experiment 3 are shown. The full scores are listed in Appendix B, Table XLIV.

TABLE 13

Correlations of variability and error in judging 16 seconds in Experiment 3.

		1	2	3
1.	Controlled l.m. variability			
2.	Controlled l.m. error	+.56++		
3.	Verbal variability	+.28	+.43++	
4.	Verbal error	+.51++	+.03	+.42++

++ significant at 1%

What is common to all these Tables? The most striking common feature is the high positive correlation between verbal error and verbal variability in both Experiment 2 and 3, at both 8 seconds (+.58 and +.29 respectively) and 16 seconds (+.50 and +.42 respectively). This suggests that subjects who change their verbal estimates of a time interval also make the greatest error. In this case, uncertainty appears to be justified.

Variability in controlled linear movement is significantly related to error in controlled linear movement at both 8 seconds and 16 seconds (+.52 and +.56, respectively). But significant correlation between variability and error is not found where the method of free linear movement is used (-.18 at 8 seconds; -.01 at 16 seconds).

The only other consistently significant relationship is that between error in verbal estimate and variability in controlled linear movement reproduction (+.31 at 8 seconds; +.51 at 16 seconds). The relation between free linear movement variability and verbal error is, on the other hand, consistently close to zero (-.07 at both 16 and 8 seconds). This does suggest that the more difficult the task is made, the greater the use which the subject makes of verbal, or symbolic aid, in reproducing the time interval. At the 16 second interval there is also a significant positive correlation (+.43) between verbal variability and error in controlled linear movement reproduction. Error in free

linear movement/...

linear movement reproduction is also positively related to verbal variability, but the correlations are not significant at either 8 seconds (+.21) or 16 seconds (+.17).

There appears to be an increasing relationship between verbal estimate and reproduction of time as the method is changed from key-pressing to free linear movement to controlled linear movement. The correlation between verbal estimate and key-pressing in Experiment 2 is +.11 at 16 seconds; between verbal estimate and free linear movement it is +.29. In Experiment 3 the correlation between verbal estimate and grip is +.21; between verbal estimate and free linear movement it is +.31; and between verbal estimate and controlled linear movement it is +.37.

Not only is there an increasing correlation of reproduction and verbal estimate as movement is introduced, and the conditions of movement are made more demanding, but, as we shall observe (Tables 26, 27), there is a marked similarity between the standard deviations of verbal estimates and linear movement reproductions, though both of them differ significantly from key-pressing. Another similarity is the high reliability found with both linear movement and verbal estimate. And also, it may be noted (Chapter 6.1.3) that the ratio of increase in both verbal estimate and linear movement reproduction when the time interval is doubled, is 1.8, whereas the ratio of increase for key-pressing is 1.9. Key-pressing reproduction follows the signal more closely than the other two methods.

Here, it is not amiss to examine the average error in judgement by the various methods as the signal is increased, in order to determine whether they reinforce our impression of the similarity of linear movement reproductions and verbal estimates.

TABLE 14

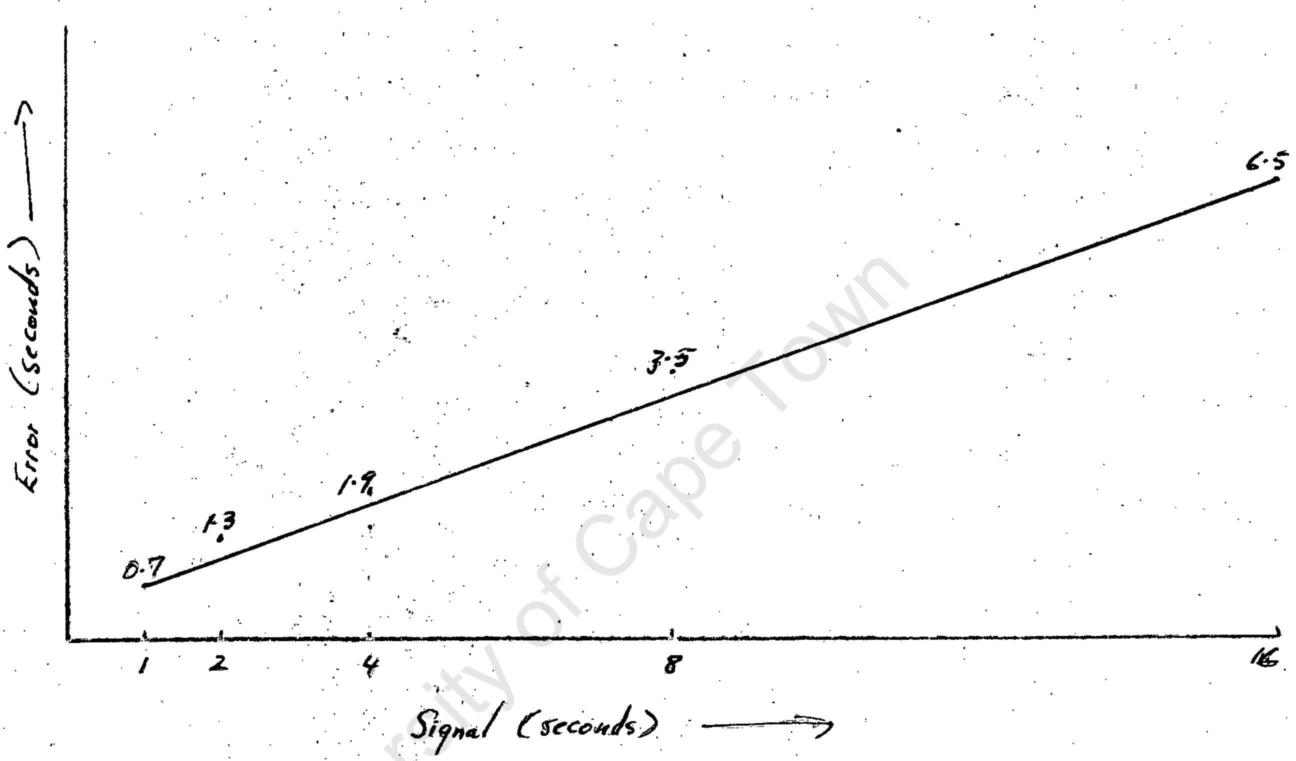
Average error, irrespective of sign, by different methods in Experiment 2.

Table 14 /...

Experiment 2 No. 4I

Error in verbal estimate in relation to length of signal

Scale: I cm = I second

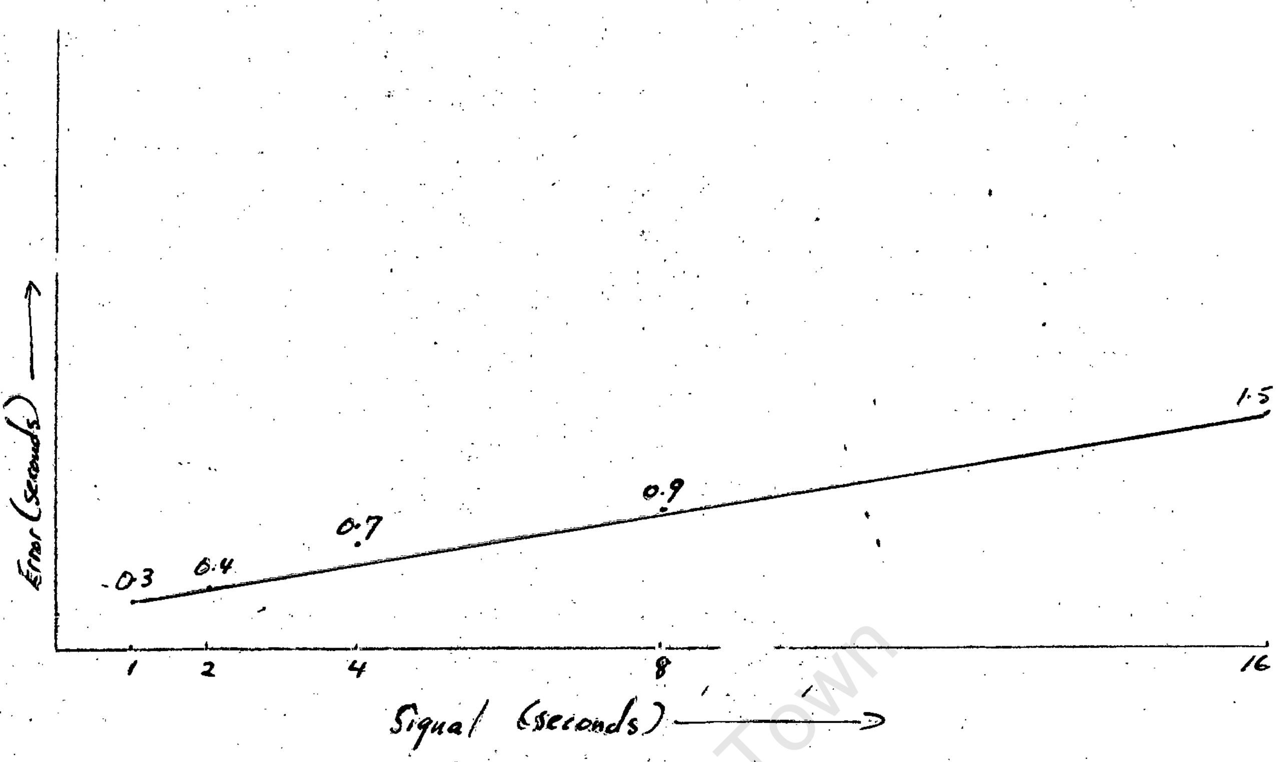


$$y = \frac{4}{10}x + .3 \text{ seconds}$$

Experiment 2 No. 2

Error in time reproduced by key-pressing in relation to length of signal

Scale: I cm = I second (signal axis)
2 cm = I second (error axis)

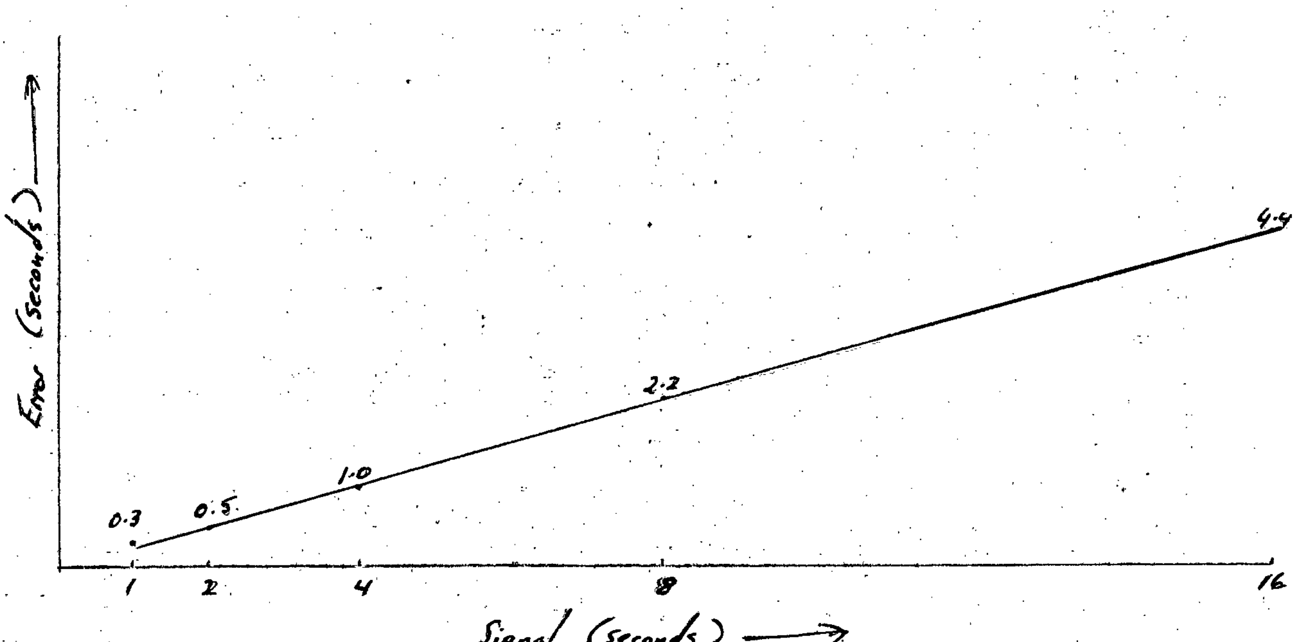


$$y = \frac{I}{10}x + .2 \text{ seconds}$$

Experiment 2 No. 6

Error in relation to length of signal when time is reproduced by free linear movement

Scale: I cm = I second



$$y = \frac{28}{100}x \text{ seconds}$$

TABLE 14

SIGNAL	METHOD					
	Verbal Estimate		Free Linear Movement		Key Press	
	Error	Proportion	Error	Proportion	Error	Proportion
1 sec.	0.7s	0.70	0.3s	0.30	0.3s	0.30
2 sec.	1.3	0.65	0.5	0.25	0.4	0.20
4 sec.	1.9	0.48	1.0	0.25	0.7	0.18
8 sec.	3.5	0.44	2.2	0.28	0.9	0.11
16 sec.	6.5	0.41	4.4	0.28	1.5	0.10

The graphs of the data on the previous pages show clearly that the relationship between error and length of signal may be treated as a linear function in each case. The equation for the graph of verbal error in relation to length of signal is

$y = .4x + .3$ sec. (y = error in seconds; x = signal in seconds)

The equation for the graph of linear movement error in relationship to length of signal is

$$y = .28\ x$$

The equation for the graph of key-pressing error in relation to length of signal is

$$y = .1x + .2 \text{ sec.}$$

To show how well these equations fit, the calculated values may be compared to the actual errors as shown in Table 15.

TABLE 15

Calculated error, irrespective of sign, according to the equations for different methods used in Experiment 2.

SIGNAL	METHOD		
	Verbal Estimate	Free Linear Movement	Key Pressing
1 sec.	0.7	0.3	0.3
2 sec.	1.1	0.6	0.5
4 sec.	1.9	1.1	0.6
8 sec.	3.5	2.2	1.0
16 sec.	6.7	4.5	1.8

Though the / ...

Though the graphs make it clear that the relationship between error and signal length is linear in each case, a test for linearity, of regression was performed, using a formula which has as its basis the difference between the correlation ratio, eta, and the product-moment correlation coefficient (Guilford, 1954, p.294). If there is any departure from linearity of regression, then the correlation ratio, which does not depend on linearity, will be significantly greater than the product-moment correlation, which does. When the correlation ratio of error by free linear movement and length of signal is calculated, a figure of 0.916 is arrived at. The product-moment correlation of these two variables is 0.915. Application of the formula in Guilford yields an F value of 0, which means that we can accept that regression is linear. For verbal estimate and key-pressing the F values are also 0, taken to one decimal place. In all cases, therefore, we may accept that regression of error on signal length is linear.

These results do not separate verbal estimate and free linear movement reproduction from key-pressing. All methods have different equations.

Our conclusion, from the evidence presented so far, is that though verbal estimate and linear movement reproduction have more in common with each other than with key-pressing, the relationship is still fairly low. But this does point to the inaccuracy of separating methods of reproduction from verbal estimates as though they are distinct methods, the assumption being that the methods of reproduction must necessarily be more closely related to each other than to verbal estimates.

Now that we have examined the evidence to be obtained from levels of performance, we may turn to the evidence of changes in levels of performance.

5.4 The Relationships Among Methods of Time Judgement as Shown by Intra-Individual Changes in Performance.

The possible value of correlating changes in performance as well as levels of performance has already been mentioned. Extreme scores are minimised and functional relations within the individual may be revealed.

A sample of scores from one subject may be used instead of scores from a sample of subjects, but there are certain problems in this. Firstly, one does not know that the relations found in one subject hold for another. Secondly, even if one has a subject who is highly motivated, cooperative, willing to do his best, and able to spare the time for a large number of testing sessions, it is possible that after a number of sessions the subject's scores become stereotyped. He comes to recognise the signals being used in the sessions as being identical, and tries to make identical responses. Verbal estimates, especially, would be subject to rapid stereotyping.

We have compromised by taking observations at different sessions from a number of subjects, calculating the ratios of change between sessions, and correlating these. Provided that all responses change at the same rate in the different subjects, functional or system relations of time judgements by different methods should be revealed in this way. There is, of course, the possibility that the ratios of change may be individually different.

The procedure outlined here seems to combine the virtues of Allport's (1937, 1963) personological approach, which stresses systems within the individual, and the nomothetic approach, which attempts to represent the individual as the point of intersection of a number of dimensions.

Intra-individual changes in judgement of 8 seconds by different methods in Experiment 2 were calculated and correlated. The raw scores may be seen in Appendix B, Table XL. The correlations are shown below in the text.

TABLE 16

Correlations of intra-individual changes in judgement of 8 seconds by various methods in Experiment 2.

	1	2
1. Linear movement change		
2. Key pressing change	+.23	
3. Verbal estimate change	-.06	+.24

Intra-individual /...

Intra-individual changes in judgement of 16 seconds by different methods in Experiment 2 were calculated and are listed in Appendix B, Tables XXVIII and XXXVIII. The correlations of these data are shown below.

TABLE 17

Correlations of intra-individual changes in judgement of 16 seconds by different methods in Experiment 2.

	1	2
1. Change in linear movement		
2. Change in key pressing	+.36+	
3. Change in verbal estimate	+.38++	+.48++

Intra-individual changes in judgement of 8 and 16 seconds by linear movement and by verbal estimate were also calculated for the subjects of Experiment 3, and are listed in Tables XXXIV and XXXV, Appendix B. The correlations between change in free linear movement and change in verbal estimate are +.16 at 8 seconds and +.64 at 16 seconds.

If we firstly examine what is common to all the correlations, then we see that at 16 seconds, for the subjects of both Experiment 2 and 3, correlation between a change in free linear movement reproduction and change in verbal estimate is significant (+.38 and +.64). In neither Experiment 2 nor 3 is the corresponding correlation significant at 8 seconds. Table 17 shows us that changes in all time judgements are significantly related at 16 seconds, and Table 16 shows that no changes in time judgements are significantly related at 8 seconds. Any hypothesis that there is a systematic relationship of time judgements by various methods at all lengths of signal may, therefore, have to be modified. It appears that systematic or intra-individual relationship of time judgements is found when longer time intervals are judged, but not when shorter time intervals are judged. At first sight this appears inexplicable, but it is possible that shorter time intervals are perceived by the subject independently of symbolic aid, whereas longer time intervals have to be conceived by him, with the assistance of symbols of relationship. The common denominator of systematic

covariation may /...

covariation may be conception of time intervals above a certain length, by use of symbols. Shorter time intervals, being independently perceived, are more capable of unrelated variation. This fits rather well with Pavlov's view that there is no separate analyser for time, since all cortical analysers are capable of analysing time separately.

The view that there is a space of time which may be perceived as a unit is an old one, as reference to William James (1890, pp. 609 - 613) shows. According to James, this directly perceived unit of time was placed between 3.6 and 6 seconds (by Wundt), up to 12 seconds (Dietze), and up to 6 or 12 seconds, depending on conditions of the experiment (Estel and Mehner). James, following Ward, attached great importance to this directly perceived unit of time (the "specious present") which he held to be "the original paragon and prototype of all conceived times" (p. 631). Boring (1933) has proposed that a much shorter interval of time, the indifference interval, should serve as a measure of the conscious present.

If our tentative explanation of systematic covariation is correct, then we should have to assume that the longer periods assigned to the conscious present by the older writers are correct.

There is a final possibility to be noticed, which may account for the low correlations of changes in scores by different methods. It is possible that there are large differences in the degree to which individuals functionally integrate all their time judgements. As we have remarked earlier, some subjects may attempt to judge consistently, others may be more concerned with judging each signal freshly, as it comes. And there may be different individual rates of change by different methods.

5.4 General Conclusions

Taken as a whole, correlations of time judgements by different methods are rather low. Some of the correlations are significant, but several are not. There is no evidence that time judgements by the methods of reproduction are more closely related to each other than to verbal estimates of time. Correlation of reproduction of time with

verbal estimate /...

verbal estimate appears to rise as the method of reproduction is made more difficult - if we can fairly rank key-pressing, free linear movement, and linear movements of prescribed distance in order of ascending difficulty (the rise in average error makes this plausible).

Since intra-individual changes in time judgements by different methods correlate significantly at 16 seconds, but not at 8 seconds, we may tentatively conclude that a change in the method of judgement takes place as the signal is lengthened. The unifying factor proposed is an increased reliance on symbolic aid as perception of time turns to conception of length of time.

5.5 SUMMARY

Time judgements obtained by various methods in Experiment 2 and 3 were correlated. Verbal estimations appear to correlate more with linear movement reproductions than with key-pressing or grip. The correlation among different methods of reproduction is not higher than correlations of these methods with verbal estimation. The exception is that controlled and free linear movement reproductions correlate highly with each other. Correlations of intra-individual changes in score from one session to another are significant only at 16 seconds. It is suggested that intra-individual, systematic relationship of time judgement by different methods becomes greater as the time interval judged lengthens, because of an increase dependence on symbolic activity. In addition, the suggestion that increasing the difficulty of the task increases the symbolic content of the performance in that task, is born out by the increase in correlation between verbal estimate and reproduction as the method is changed from key-pressing to free linear movement to controlled linear movement. This assumption is strengthened by the fact that verbal error does not correlate with free linear movement variability or error, but does with controlled linear movement variability (+.31 at 8 seconds; +.51 at 16 seconds).

PART II

TIME-SPACE RELATIONS IN LINEAR ARM MOVEMENTS

According to Brown, a moving stimulus produces an impression of less time than a stationary stimulus presented for an objectively equal interval. Other experimenters have demonstrated the intimate connexion between time and space, when the subject is judging exteroceptively received stimuli. The relationship is such that a greater spatial interval produces the impression of a greater time interval, and a greater time interval produces the impression of a greater spatial interval.

It is an interesting problem whether these relations are found in movements produced by the subject. When the subject moves at a preferred speed, is the time reproduced related to the speed of his movement (Chapter 6)? When the subject is made to move a prescribed distance, is the time reproduced influenced by the distance which he is made to move? (Chapter 7) ?

C H A P T E R   6

TIME-SPACE RELATIONSHIPS IN REPRODUCING AUDITORY TIME SIGNALS BY FREE LINEAR MOVEMENT

6.1 Exteroceptive Time-Space Relationships

6.1.1 Brown's Treatment of the Relationship between Psychological Time and Space.

The fundamental equation for exteroceptive time-space relations appears to be Brown's (1931) :

$$\text{phenomenal velocity} = \frac{\text{phenomenal space}}{\text{phenomenal time}}$$

From this equation may be derived the fact that phenomenal time increases as phenomenal space increases, provided that phenomenal velocity is kept constant. It is possible to explain both the suto and kappa effects in this way. It will be recalled that the suto effect is produced when three successive unequally spaced stimuli are applied to the skin (Suto, 1952) and the kappa effect (Abbe, 1936, 1937; Cohen and others, 1955) is produced when three successive unequally spaced visual stimuli are presented. In both cases, the two stimuli between which there is the greater distance in space also appear to the subject to be separated by the greater interval in time, when the time intervals are equal. If the subject is asked to adjust the time interval between the second and third stimuli so as to equal the interval between the first and second stimuli, he makes it shorter when the distance 2 - 3 is greater than the distance 1 - 2, and longer when the distance 2 - 3 is shorter than 1 - 2. If the presentation of three successive stimuli produces an impression of movement, as is not unreasonably claimed by Cohen and others (1955), then this spatial effect on time may easily be explained by the Brown equation. The kappa effect is produced by the subject's impression of the time taken by an object moving at a constant velocity to cover unequal distances. Where the distance is greater, the impression of time taken to cover that distance is greater. Provided that the subject perceives the velocity as constant this effect is bound to occur. The same effect occurs in vertical descent, so that even a falling body must appear to

the subject /...

the subject to be moving at a constant speed. If this explanation is to apply to movements in all directions, then the tendency to perceive velocity as constant must be very strong.

Brown's equation holds not only for the spatial effect on time judgement, but also for the time effect on judgement of space, as is shown by Helson and King's (1931) study. When three successive tactile stimuli are presented at uneven intervals of time, the two stimuli between which there is the greater time interval also appear to be more widely separated in space. Again, if we assume that the subject perceives a movement at a constant velocity, it is understandable that as perceived time interval is increased, perceived spatial interval should also increase.

6. 1. 2 Piaget's Treatment of the Relationship between Psychological and Space.

The work of Piaget leads to the same conclusions about the relations between the experience of time and speed as Brown's work. It is worth digressing a little to see how his thought on this relationship is developed.

The young child's judgement of the time taken by actions is determined by the result; it depends on the work accomplished and the space covered by these actions. In one task, the child generally judges that more time has elapsed because he has been asked to transfer heavier blocks (Piaget, 1946, pp. 253 - 256), and in another, he generally judges that a toy figure which moves further moves for a longer time (ibid., p. 272). The child of about five is unable to distinguish between the spatial and the temporal extension of an action. But, as he develops, he introspectively judges duration during an action. He becomes less dependent on the results of the action in forming his judgement of its duration, and more dependent on an intuition of the relations of speed and time. "While it is being experienced, a rapid or accelerated action brings about a contraction of time (by virtue of the inverse relation of time to speed)... (ibid., p.266). The speed and the distance of an action appear to remain fundamental throughout life in determining the immediate impression of a temporal interval, as is shown by the work of Brown (1931) on

phenomenal time /...

phenomenal time in relation to phenomenal velocity, and by the work of Abbe (1936) and Suto (1952) on phenomenal time in relation to visual and tactile distance. Piaget has stated of the relation of phenomenal time to distance and speed that "the fundamental intuitions are those of distance and speed; time is gradually distinguished from these ... (ibid., p. 42).

This statement of the origin of the concept of time is important to any work dealing with the judgement of the duration of movements. We shall therefore, briefly examine the development of Piaget's ideas about the origin of the concept of time.

The first, sensori-motor, stage in the development of the infant's responses to time is that of acting out a sequence of movements. The chain of these movements is gradually extended. A good example of this is the infant's gradually extended co-operation in such an activity as being dressed.

In the second stage, these activities are transferred to the intuitive plane as egocentric or local time. At this stage, the child does not distinguish between inner and outer time. His judgement of time is finalistic, since it depends entirely on the results accomplished during the period to be judged. It is only at a later stage, according to Piaget, that the quantity of activity felt during a period of time becomes important in assessing duration. Several examples which show that the child's judgement of time at the age of about 5, depends almost exclusively on results accomplished, are given by Piaget. All the experiments are organised on the same principle. The child is set the task of comparing two periods of time during which the work accomplished differs.

In one of the tasks which Piaget uses, the child is asked to compare an interval in which he transfers wood from one box to another with another (objectively identical) interval in which he transfers lead from one box to another. Most of the children thought they had spent more time in transferring the lead from one box to another, because the lead gave the impression of more work (ibid., pp. 253 - 256). Yet, most

of the / ...

of the children transferred more of the wooden blocks. It is not clear why they did not believe that they had accomplished more in this task, and conclude that they had spent more time at it. The criterion of "work accomplished" is, on its own, ambiguous.

Another experiment by which Piaget demonstrates the finalistic judgement of children at the egocentric stage of development is performed with a Y-shaped tube, regulated by a single cock, down which water flows into two flasks of unequal size. The flow of water into both flasks commences simultaneously as the cock is opened; the flow is stopped simultaneously by closing the cock when the smaller flask is full. Even though the child may agree that the flow of water into both flasks stopped at the same time, he may still believe that the total time of flow into the smaller flask was greater. Again, Piaget explains this as a judgement based on the child's belief that more work is accomplished by the filling of the smaller flask. The child confuses greater speed with greater duration. The more rapid filling of the one flask must have taken a greater time, in his judgement, because he is unable at this stage to relate speed to space (ibid., p. 130).

A third experiment, which illustrates the child's inability to distinguish between "further" and "longer", is performed with two toys, which move along parallel lines in the same direction on a table. They start simultaneously, but move at different speeds. A yellow figure moves faster and further than a blue figure, but stops a little before it. The 6-year old recognises that the yellow figure stops first, but when questioned states that the yellow figure moved for a longer time. Piaget concludes that the error is not a verbal one, but reveals a logical confusion of space and time (ibid., p. 92). This is shown also by an experiment in which the two figures, moving at unequal speeds, start and stop simultaneously. The average 6-year judges that the figure which moves further moves longer. (ibid. p. 106).

A fourth experiment also illustrates the link between accomplishment and duration, in the child's judgement. In this experiment the child is asked to compare two objectively equal intervals

spent drawing / ...

spent drawing lines. In the first interval, he is asked to draw as carefully as possible. In the second interval, he is asked to draw as fast as possible. Young children agree that the time spent drawing lines as fast as possible was longer (ibid., pp. 241 - 250). A third of the children aged between 10 and 13 make the same error as the younger children, but gradually the abstract idea that when we go faster we do more things in the same time is acquired and enables the child to correct his judgement.

At this stage of his development, the child is unable to accomplish decentration from the end state, and therefore bases his judgement of duration exclusively on this state even though he may see that two events started and ended simultaneously. The fact that they start and end simultaneously does not mean that they occupied the same time. Time is local, and belongs separately to each experience of each event. It is only when the child becomes capable of operational or rational time, characterised by homogeneity, continuity and uniformity, that the simultaneous starting and stopping of two events means that they occupied the same time. Homogeneous time refers to time which flows at a fixed rate; continuous time refers to the uninterrupted flow of time; and uniform time is common to all phenomena. But this is an abstract conception. For both the child and the adult, 15 seconds spent looking at an amusing picture are not the same as 15 seconds standing with folded arms (ibid., p. 257). To realise their equivalence takes an intellectual effort. Even where it is possible to see that change is occurring at an even rate, as in watching sand trickling through a timer, the homogeneity of time is still an intellectual construction (ibid., p. 188). This is especially evident when we are waiting for something important. The homogeneity, continuity, and uniformity of time are apprehended gradually as the child realises that his intuitive impressions contradict each other and are contradicted by estimations based on other cues. This is especially so when he learns to use clocks. "This homogeneity is born of the discordance between various modalities of his appreciations, or between his personal appreciation and that of older people" (Fraisse, 1963, p. 265).

The stage of operational thought which develops gradually as the child's actions in the world are internalised, is characterised by decentration and reversibility. The transition to the reversibility and decentration of operational thought from the irreversibility and centration of egocentric thought enables the child to choose the criteria by which he judges an interval of time. Egocentric thought is characterised by immediacy and by an inability to perform mental operations which have no representation in immediate experience. Operational thought is characterised by operations which may be simultaneously present and which enable the child not merely to recapitulate events, but also to set up hypotheses about them.

When the child becomes capable of introspection he is no longer bound to judge duration by the results of an action. He develops an intuition of relations (articulate intuition) and makes the introspective discovery that phenomenal time shrinks as a function of speed (ibid., p. 266). Speed is dissociated from space, and the durations of movements of different speeds and distances may be compared.

Now that we have given a brief account of Piaget's conclusions, it is important to consider some objections which have been raised to them. Piaget believes that the dominant criterion used by the child in judging duration (at the egocentric stage of development) is external. He judges by results. Fraisse, who has repeated some of Piaget's experiments, has reached another conclusion. He interprets his findings as showing that both the work accomplished and the changes experienced by the child during the judged interval are significant in forming an estimate of duration (Fraisse, 1963, pp. 273 - 274). He suggests that work accomplished may be equated with external change; but internal change is also significant to the child. In reaching this conclusion, Fraisse uses children's judgements of the durations of the movements of two toy figures, obtained in a number of experiments similar to those described above. He agrees that when the durations of the movements are objectively equal children generally judge that the figure which has moved further has moved longer. But a substantial majority believe that the figure which moves more slowly moves for a longer time.

They reach / ...

They reach this conclusion by identification with the slow one, and their experience that, under difficult conditions such as might be associated with slow movement, every movement costs effort makes them more aware of each change (Fraisse, 1963, p.p. 241 - 242). Here we see the basis of Fraisse's observation that both internal and external change may be important in forming judgement of duration.

The same comment is also applicable to Piaget's interpretation of the fact that the majority of young children believe that they have spent more time transferring lead than wooden blocks, in spite of the fact that they are able to transfer many more wooden blocks. If the child is judging purely by the external criterion of work accomplished, then surely he ought to believe that he has spent more time transferring wooden blocks? And there are some children who come to that conclusion.

It seems that there are at least three criteria. These are, external change (finalistic), internal change (during action), and effort (during action). Fraisse expresses the relationship of these criteria in the following way (Fraisse, 1963, p. 274): "Thus, everything depends on the resistance to be overcome and this may arise from the effort to go as fast as possible, or from fatigue, or in general from the difficulty of the task. The immediate intuition of duration is that of an interval whose length depends on what happens in it. As in Oppel's illusion, this seems longer the more there is in it to attract our attention".

Another important disagreement between Fraisse and Piaget refers to the origin of the intuition of duration. Piaget, as we have shown above, believes that the origin of this intuition is found in a progressive differentiation of speed and distance. Fraisse believes that the intuition of duration is not derived. The child experiences duration "in the elementary form of an interval which stands between him and the fulfilment of his desires" (Fraisse, 1963, p. 277).

There are several pieces of evidence which support Piaget in his association of time and space. Firstly, even at the adult level, judgements of duration are affected by the distance between stimulis, as in the kappa and suto effects. The importance of this is that it shows that children and adults are susceptible to the same errors. But the adult is able, by adopting a critical attitude, to overcome the illusion (Abbe, 1936). The basic perception is the same, but the adult is able to rationally correct his judgement. The work of Brown (1931) also shows the close association between judgement of duration and speed, even at the adult level. He does not indicate whether or not the adult is able to overcome the illusion, but it seems likely.

Another fact which is relevant to the view that the intuition of time is derived, is the low reliability of reproductions of time where these are not associated with movements. This is something to which particular attention is paid in Chapter 4. The low reliability of reproduced time contrasts sharply with the high reliability of speed of bodily movement. It has also been shown, in Chapter 4, that the reproduction of time intervals by an extensive arm movement raises the reliability of reproduced time to a high level, comparable to that for speed of movement.

These facts suggest that children and adults are subject to the same immediate illusions in the judgement of time intervals, but that adults are more capable of using a variety of cues (decentration) than children are.

Piaget's statement that "rapid or accelerated action brings about a contraction of time ..... " (ibid., p. 266) leads to the same conclusions as Brown's equation. In the next section we shall see what testable hypotheses may be derived from both Brown's and Piaget's work.

6. 1. 3 Hypotheses derived from Brown and Piaget.

In most studies, the subject judges the time-space relationships of stimuli entirely outside of himself. Would

the same /...

the same perceptual relations hold when the subject produces the movement with his own limbs? Jaensch (1905) apparently offers evidence that this is so. He found that judgements of the distance of an arm movement are at least partly determined by the time taken to complete that movement. But there has been no comprehensive study of the subject. Furthermore, a set of hypotheses derived by strict application of Brown's equation to limb movements shows signs of absurdity, which suggest that the relationships are different. It is worth examining some of the predictions which would be made in terms of Brown's equation, if applied to reproduction of time by arm movements.

a) The speed of the linear movement made by the subject in reproducing the time interval is positively correlated with the duration of the movement. In terms of Brown's equation, phenomenal time is reduced by an increase in speed. Therefore, a subject who moves faster might be expected to move for a longer time to attain subjective equality between the duration of the signal and the duration of his movement.

b) The extent of the movement is negatively correlated with the duration of the movement. That is, since phenomenal time increases with

phenomenal space / ...

phenomenal space when speed is constant, an increase in phenomenal space ought to result in an increase in phenomenal time, and the subject will reduce the objective duration of his movement to achieve subjective equality between the time taken by his movement and the signal.

But, even as one states these hypotheses, one cannot help feeling that they are entirely inapplicable to the case. The relations found when the subject is a spectator of external stimuli and when he moves himself are not identical. According to hypothesis (b), an increase in the distance moved by the subject must be associated with a shorter time for the movement. Now, if a subject is maintaining a constant velocity, this is impossible. It means, therefore, that the velocity of the movement must be increased. Such an increase would be entirely in agreement with the prediction of hypothesis (a) that an increase in speed is associated with a decline in duration of the movement, but it would also mean that we should have to regard the reliability of speed as rather low, which it is not. Speed tends to be an extremely reliable feature, as we have seen. But the next consequence of hypothesis (b) is even more difficult to concede. If the time signal is lengthened, the subject might be expected to move further, at a constant velocity, to express his perception of a longer time interval. But the further he moves, the greater the ratio of phenomenal time / objective time becomes. Therefore, the longer the signal and the further the subject has to move, the greater the disparity between the time signal and the time reproduced. A curve of sharply diminishing returns should be set up. The alternative to this is that the subject move a shorter distance at a slower rate as the signal is increased. Both of these possibilities may easily be tested. The second possibility may be summarily dismissed: subjects increase the distance moved as the signal is increased, but move at a constant speed. The figures are shown below, in Table 18.

TABLE 18

Average distance and speed of linear arm movement in reproducing time intervals in Experiment 2. (N=77). Distance scores are inches, and speed scores are inches/second.

Signal	Distance	Standard Deviation	Speed	Standard Deviation
1 second	8.67 ins.	7.24 ins.	8.05 ins/sec.	5.35 ins/sec.
2	16.31	11.18	8.44	5.43
4	26.13	17.47	8.48	5.47
8	46.64	30.58	8.31	5.07
16	99.58	67.48	8.41	5.23

All the speed data may be found in Appendix B, Tables XXII to XXVI. The distance data may be consulted in Appendix B, Tables XIX to XXI.

It can be seen from this table that the speed is virtually constant for all lengths of signal. The null hypothesis that there is no significant difference among any of the speed scores is accepted, since the highest t value for differences among them is 0.49. The distance is seen to increase at an almost constant rate as the signal is doubled. The mean ratio of increase is 1.8. That is, as the time interval to be reproduced is doubled, the distance moved in reproducing the time interval is, on the average, increased 1.8 times. The separate ratios are: 2/1 = 1.9; 4/2 = 1.6; 8/4 = 1.8 and 16/~~4~~8 = 2.1.

This even increase in the distance moved as the signal to be reproduced is increased does not suit the prediction that an increase in distance moved ought to result in an increase in phenomenal time relative to objective time, and therefore, a decline in the distance which the subject moves to achieve subjective equality between the duration of his movement and the duration of the signal. Or, accepting the even increase in distance, we should expect an increase in speed of movement since the subject has to cover the increased distance in a shorter time to preserve phenomenal equality of the time signal and the reproduced time.

The possibility that there is a diminishing return in time as distance is increased in reproducing increased time intervals may also be rejected. In text Table 19 below are set out the various time judgements as the signal is lengthened. It will be seen that they show a linear increase which is in entire accord with Stevens' (1957) revision of the psychophysical law of Fechner. According to Stevens, after a review of an extensive body of data obtained from a large number of experiments, equal sensation ratios are produced by equal stimulus ratios. An examination of our results shows that they very closely approximate this condition.

TABLE 19

Relation between the duration of the signal and the mean judgement of duration obtained by various methods in Experiment 2. Scores are seconds.

SIGNAL	METHOD							
	1 Key-Pressing (N=43)		2 Verbal Estimate (N=77)		3 Linear Movement (N=77)			
					Delayed		Immediate	
	J*	I^x	J	I	J	I	J	I
1 sec.	1.14		1.73 sec.		1.07 sec.		1.08 sec.	
2	2.20	1.9	3.25	1.9	1.96	1.8	2.04	1.9
4	4.29	1.9	5.62	1.7	3.19	1.6	3.47	1.7
8	7.81	1.8	10.51	1.9	5.98	1.9	6.60	1.9
16	15.61	2.0	20.45	1.9	12.13	2.0	11.92	1.8
Mean Ratio of Increase		1.9		1.8		1.8		1.8

J* = judged time

I^x = Increase, or ratio of increase in judgement when time signal is doubled.

Key-pressing scores in Appendix B, Table XXVII;
verbal estimates in Appendix B, Tables XIII - XVII; and
linear movement reproductions in Appendix B, Tables VIII - XII.

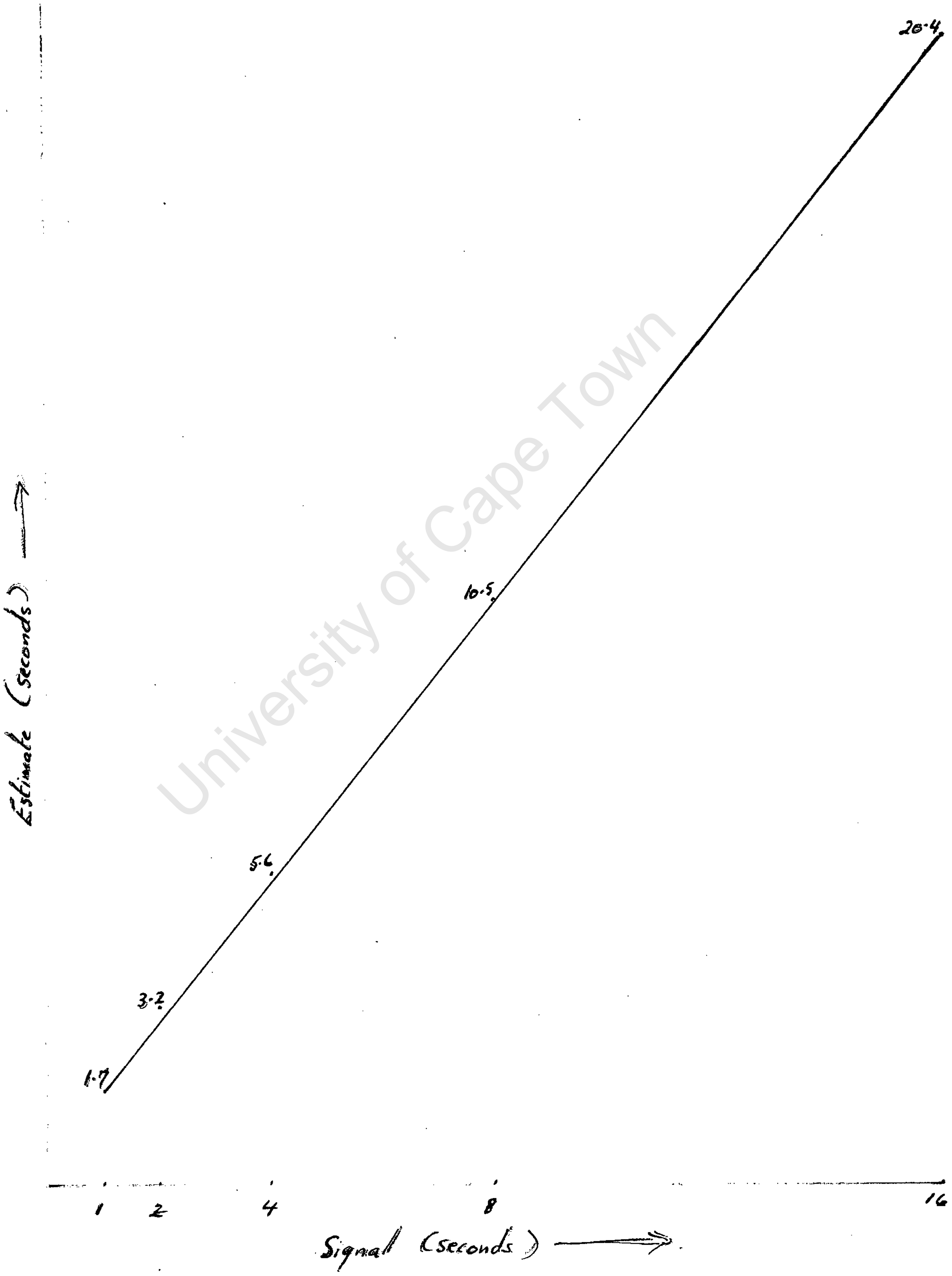
This Table shows clearly that as the signal length is doubled the judgement increases by a fixed ratio. There is no sign whatever of a drop in the ratio of increase, as would be expected in terms of the Fechner law or in terms of an increased phenomenal time

corresponding to / ...

Experiment 2 No. 4.

Verbal estimate of time in relation to length of signal

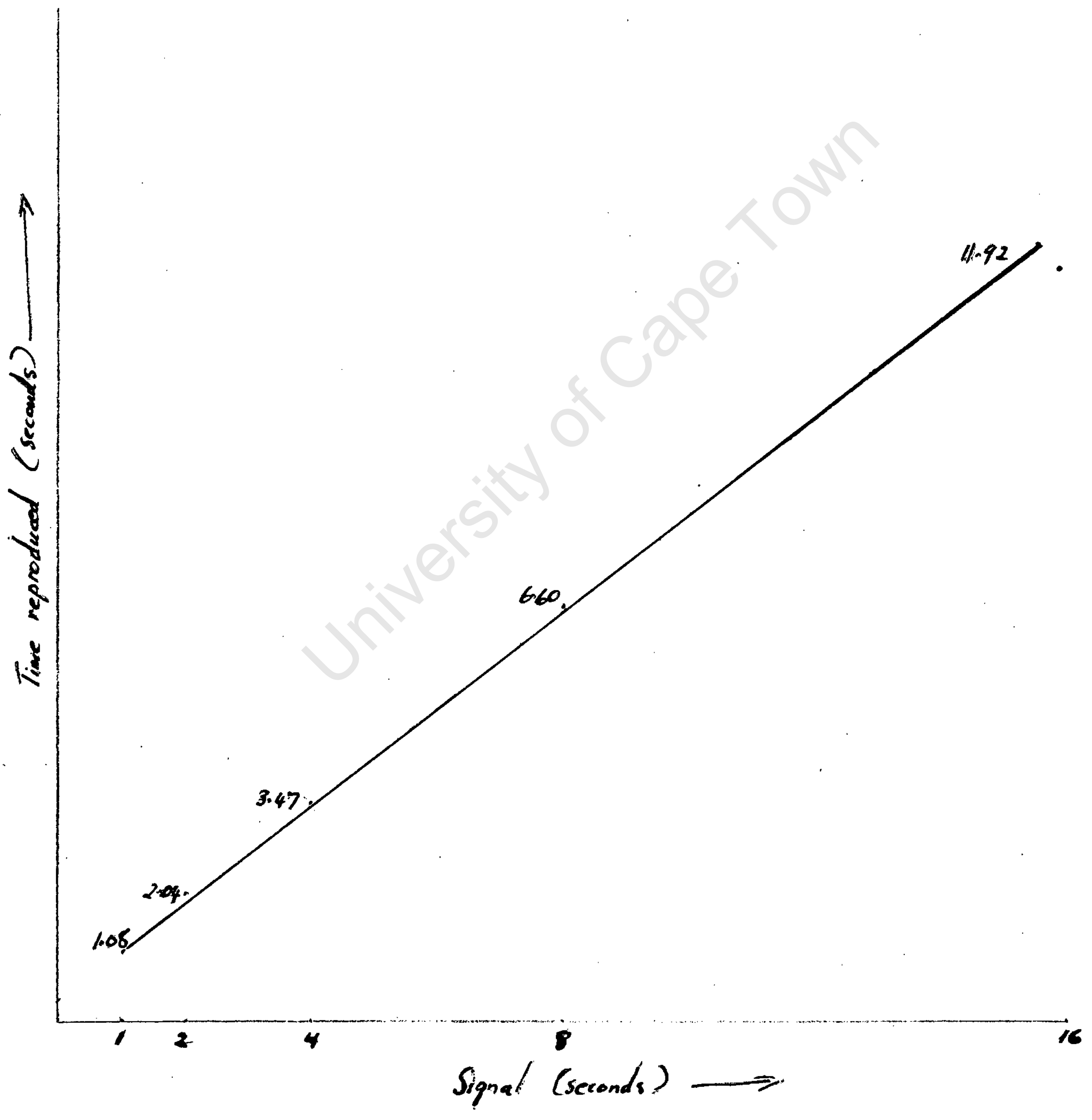
Scale: Icm = I second



$y = \frac{12}{10}x + \cdot 6$ seconds

Experiment 2 No.5

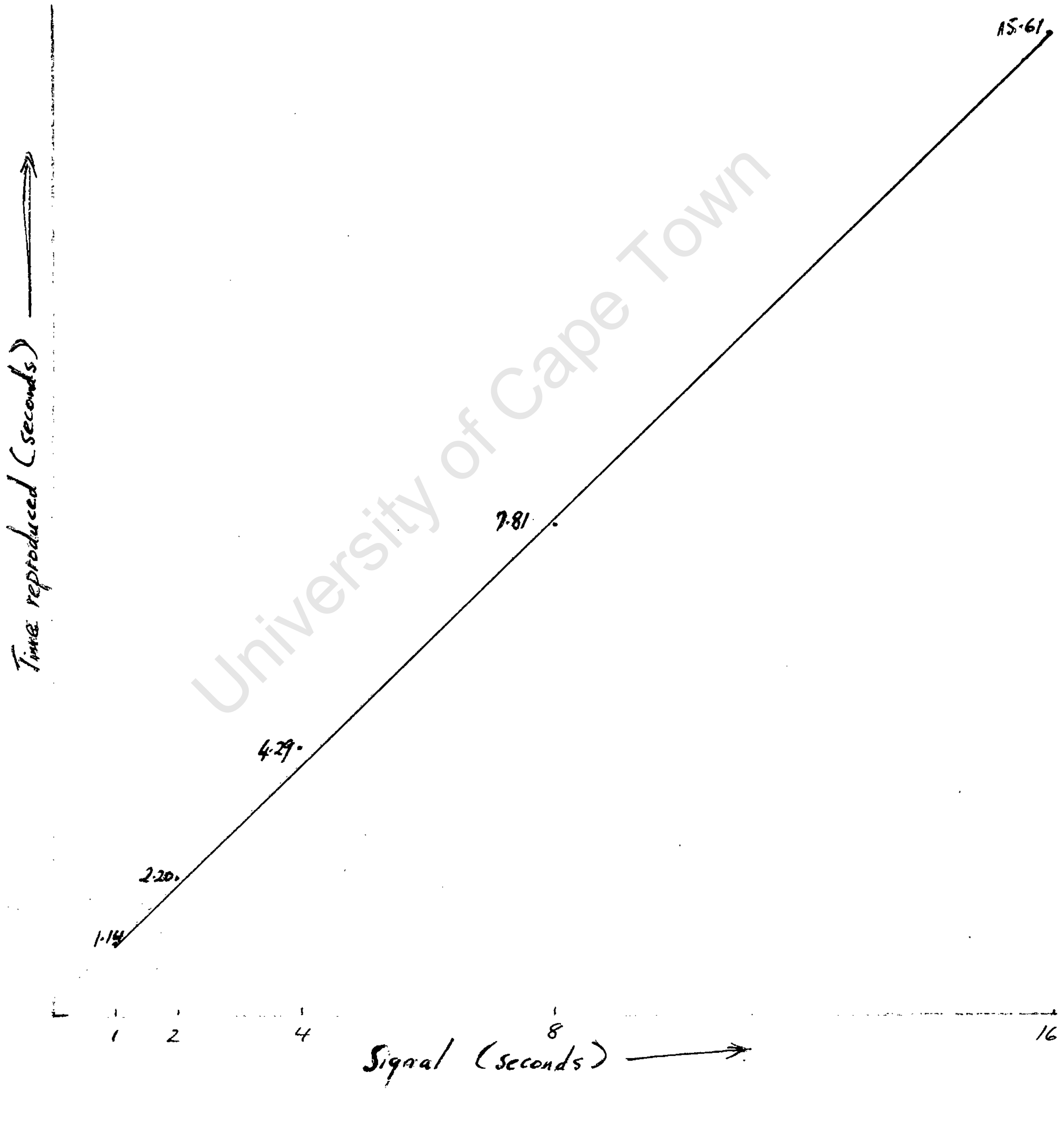
Time reproduced by linear movement in relation to length of signal
Scale: Icm = I second



$y = \frac{8}{10} x + \cdot 3$ seconds

Time reproduced by key-pressing in relation to length of signal

Scale: I cm = I second



y = x + ·1 seconds

corresponding to an increase in distance. Furthermore, the ratio of increase is very nearly the same for each method of time judgement.

We can apply Stevens' formula for the prediction of judgement from the stimulus value (once the stimulus-ratio has been established). A good fit is obtained.

The formula is:- Sensation = $k\ S^n$

(Where S = stimulus-level; k is a constant; and n is log sensation ratio/log stimulus ratio).

TABLE 20

Predicted judgements according to the Stevens formula. Scores are seconds.

SIGNAL	METHOD			
	Key-pressing (k = 1.17)	Verbal Estimate (k = 1.8)	Linear Movement Delayed (k=1)	Linear Movement Immediate (k=1.12)
1 sec	1.17	1.8	1.0	1.12
2	2.22	3.2	1.8	2.02
4	4.21	5.8	3.2	3.64
8	8.07	10.6	5.9	6.56
16	15.14	19.1	12.66	11.82

These data leave no doubt that, whatever the method, the same psychophysical law applies. Different k values have to be substituted, but the ratios of increase are highly similar. And the ratio of increase in judgement is the same for all distances moved and signal lengths employed.

The evidence clearly suggests that we reject both hypotheses (a) and (b). On the average, a longer movement in time is associated with a longer movement in space, whereas the speed is not associated with the time reproduced. Of course, this still has to be demonstrated by further evidence, before we can finally accept it as established. It might still be argued that, though average time and distance of movement are both increased when the signal length is increased, time might still be negatively associated with distance moved within any stimulus-length. That is, there might be subjects who move further distances so much faster that in fact their movements actually take less time than do those of subjects who move a shorter distance.

Furthermore, it /...

Furthermore, it might still be maintained that when a subject increases his own speed of movement in response to the same signal, he may move further, but actually diminish the duration of his movement, in accordance with the Brown equation. The first of these possibilities concerns the inter-subject relations among duration, distance and speed of movement. The second of these possibilities concerns the intra-subject relations of duration, distance and speed of movement. Both possibilities may be subjected to further test, the former by inter-subject correlations of raw speed, duration and distance scores, and the latter by inter-subject correlation of intra-subject ratios of speed, duration and distance scores, obtained in different sessions.

6.4 Proprioceptive Time-Space Relationships

It seems probable that, to a very large extent, visual experience of movement and subjective experience of personal, bodily movement underlie the kappa, suto and tau effects. The kappa effect may be seen as a consequence of the everyday observation that (to a large extent) an increase in distance moved at a constant speed requires an increased time. But this effect can, as Abbe (1936, 1937) has shown, be destroyed by a critical attitude. The effect is secondary. It depends on experience of movement, but it cannot affect the actual timing of a limb movement, for example, if our view is correct. The suto effect, as has been mentioned, depends on visual experience. The tau effect, is merely the reverse.

The organism moving in the world cannot be subject to severe spatial distortion of the timing of its movements. If we regard all the exteroceptive spatial effects on time as derived from the organism's daily locomotory activity and visual experience of locomotion, then it appears as if we can accommodate all the facts.

In order to subject these observations to more exact scrutiny, a number of hypotheses is set up for testing.

a) Speed and duration of reproduction by a time interval by linear movement are not related.

The argument / ...

The argument here is that speed of arm movement is a highly reliable individual characteristic of expression. If this is so, then the subject is likely to have adjusted to his own speed of movement in such a way that it is neutral in his perception of time.

b) Distance and duration of reproduction of time intervals by linear arm movement are positively related.

Many of the reasons for believing this have already been stated. Firstly, if speed is a stable characteristic, then a longer duration of movement must be achieved by moving a greater distance. Secondly, the evidence that there is a constant ratio of increase in judged duration to match a fixed ratio of increase in objective duration, and that this increase is associated with an equivalent increase in distance (since the speed remains constant) shows rather strongly that phenomenal time is not affected by distance.

c) Verbal estimation, and reproduction by linear movement of a time interval are positively related.

It has been shown that, on the average, verbal estimate and reproduction ratios of increase are identical in response to equal ratios of increase of the objective time interval. It is possible, of course, that when inter-subject correlations are computed, it will be found that verbal estimates and reproduction time bear a random relationship to each other because of great individual differences in the accuracy with which verbal time references are learnt. The inter-subject differences in accuracy are shown by the large standard deviations of verbal estimates (.86 sec. at 1 sec. interval; 2.07 sec. at 2 sec. interval; 4.43 seconds at 4 sec. interval; 6.94 sec. at 8 sec. interval and 10.4 seconds at 16 sec. interval). Such large standard deviations can only occur when there are very considerable differences in accuracy.

d) Speed and distance of reproduction by linear movement of a time interval are positively related.

This is a rather obvious relationship. If time is constant, the faster the subject moves, the further he will move. If

hypothesis (a) /...

hypothesis (a) is correct, then this will follow. According to (a), the duration of the movement is not affected by speed.

These hypotheses must be established by inter-subject correlations of raw scores and inter-subject correlations of intra-subject ratios or quotients. The first correlations will tell us whether in the population as a whole those who move fast or slow, for example, tend to high or low time reproduction scores. The second correlations will tell us whether, when a subject increases or decreases his own speed of movement, for example, this is generally associated with an increase or decrease in the duration of his reproduction. The former indicates relations of the distributions of a population of system characteristics; the latter indicates the relations of the distributions of a population of intra-system changes in these characteristics.

6.5 Relations of Raw Scores of Space and Time in Reproduction by Linear Movement.

The data for these correlations were obtained in Experiment 2, and are Tabled in Appendix B. All the reproduction times by linear arm movement are to be found in Tables VIII to XII. The verbal estimates of the time intervals are in Tables XIII to XVII. The distances moved are given in Tables XIX to XXI, and the speeds of movements are in Tables XXII to XXVI.

Product-moment correlations were computed and are shown below in the text Table 21

TABLE 21

Correlations of time, distance and speed of free linear movement reproduction of 8 seconds, in Experiment 2. (N=77).

		1	2	3
1.	Distance moved			
2.	Time reproduced	+.32++		
3.	Speed moved	+.76++	-.25+	
4.	Verbal estimate	+.52++	+.31++	+.03

\+ significant at 5% level
++ significant at 1% level

TABLE 22

Correlations of time, distance and speed of free linear movement reproduction of 16 seconds in Experiment 2. (N=77).

		1	2	3
1.	Distance moved			
2.	Time reproduced	+.46++		
3.	Speed moved	+.79++	-.08	
4.	Verbal estimate	+.56++	+.29	-.04

+ significant at 5% level
++ significant at 1% level

It will be seen that these data support our hypotheses. Our first hypothesis is that speed and duration of linear movement reproduction of a time interval are not related. When correlations are computed for the reproduction of the 8 second interval (Table 21), there is a significant negative correlation of -.25 which does contradict the hypothesis; but the correlation computed for the reproduction of the 16 second interval, though still negative, is extremely low.

TABLE 23

Correlation of speed and time in reproduction of 5 lengths of signal by linear arm movement in Experiment 2. (N=77).

SIGNAL	TIME-SPEED CORRELATION
1 sec.	+.12
2 sec.	+.19
4 sec.	-.25+
8 sec.	-.25+
16 sec.	-.08

+ significant at 5% level of confidence

Examination of all the time-speed correlations in Table 23 shows that there is a change from positive to negative, as the signal is lengthened. Only at 4 sec. and 8 sec. do the correlations attain significance. Both of these are negative. This negative relationship is the reverse of what we should expect in terms of Brown's discovery that phenomenal time decreases as a function of phenomenal velocity. For, if the phenomenal time of those subjects who move faster has been reduced, then

the objective /...

the objective duration of their movements should be longer for them to achieve subjective equality between the duration of the reproduction movement and the signal. On the other hand, one might argue that the natural tempo of the subject, even if faster than that of another subject, represents the same phenomenal speed to him. In either case, whether the natural speed of movement of the subject is high or low, it is phenomenally neutral, and another explanation must be sought for the data. The only explanation which seems plausible is that, if we accept the negative correlations as valid, distance does to some extent affect the impression of time received by the subject. The increased speed is achieved by the subject's shortening the duration of his movement relative to its distance. But this effect must be very slight, because we find a positive correlation between distance and duration of movement, as predicted by the second hypothesis. In reproducing both 8 seconds and 16 seconds the correlation between distance of linear movement and duration of linear movement is positive and significant at the 1% level. This indicates that those subjects who move further tend to take a longer time for their movement, instead of covering the increased distance at a sufficiently greater speed to keep the duration constant. Of course, as the very high positive correlations between speed and distance show, subjects who move further do move faster, but they do not sufficiently compensate for the increase in distance to maintain the same time as those who move less far. Or one might reverse this statement to the effect that those who move a shorter distance do not sufficiently slow down their movement to maintain the duration of those who move further. The fourth hypothesis is very substantially supported by these high correlations (+.76 and +.79).

The third hypothesis, that verbal estimate and reproduction time are positively correlated, is significantly supported by positive correlations of +.31 obtained in judging 8 seconds (significant at 1%) and +.29 in judging 16 seconds (significant at 5%). It is interesting to note, therefore, that subjects who have a high verbal reference to a time interval also tend to protract their reproduction of it. But the correlations are not very high, and account for only 9.6% and 8.4% of the

variance, respectively/...

variance, respectively. To a very large extent, the rest of the variance must be accounted for by the vast differences in accuracy of verbal reference. It is noteworthy that verbal estimate correlates very much more highly with distance moved in reproducing both 8 seconds ($r=+.52$; $p<.01$) and 16 seconds ($r=+.56$; $p<.01$) than with time reproduced. In the first casek 27% of the variance is accounted for, and in the second, 31.4% of the variance is accounted for. When one considers the very large standard deviation of the verbal estimates of time, and the large differences in accuracy which this implies, then these correlations must arouse our interest. It will be remembered that verbal estimates were made after reproduction by linear movememt. These results suggest that verbal estimates were influenced not so much by the duration of the linear movement reproduction, as by the distance moved. Speed seems not to have affected the verbal estimates, since the correlatinns are very low indeed (+.03; -.04). Now, we have seen from the extensive review of the Kappa effect that distance positively influences subjective time. The effect obtained is, therefore, precisely the effect which we should expect to obtain if we accept that verbal estimate reflects the subject's impression of time. And the fact that verbal estimate is so intimately linked with the distance rather than the duration of the movement is accounted for by the fact that distance is very much more clearly perceived by the subject than time.

So far we have dealt with relations as they hold among the raw scores of different subjects. We should like to extend our inquiry to find whether the same relations hold for changes within subjects. In our next section we deal with intra-subject changes, and the relationships which these changes have to each other.

6.6 Relations of Intra-Subject Changes in Space and Time in Reproduction by Linear Movement.

Quotients may be calculated of scores in the second session over scores in the first, and these help us to ascertain, within the individual, whether there is covariance of distance, speed, time

reproduced, and verbal/.....

reproduced, and verbal estimate. There are great advantages to this procedure. In the first instance, large individual variations in distance, speed and time judgement are reduced. Each individual, by this method, provides his own standard. To take concrete examples: (a) the distance moved in reproducing 16 seconds ranges from 387 inches (roughly 32 feet) to 8 inches, with a standard deviation of 67.5 inches and a mean of 99.6 inches; (b) the speed of movement in reproducing 16 seconds varies from 28.25 inches per second to 1.63 inches per second, with a mean 8.41 inches per second and a standard deviation of 5.23 inches per second; (c) the time reproduced by linear movement ranges from 21.1 seconds to 2.1 seconds, with a mean of 11.9 seconds and a standard deviation of 3.6 seconds, when the standard is held constant at 16 seconds; and (d) the verbal estimate of 16 seconds ranges from 80 seconds to 9 seconds, with a mean of 20.4 seconds and a standard deviation of 9.1 seconds. Obviously, the range is very great, and there is a probability that extreme deviations reduce some correlations which might exist to levels below significance. But, since the reliability of all these scores is high (see Chapter 4), inter-session quotients can be calculated which may reflect meaningful and not simply chance changes in the level of the score, and the great extremes will be eliminated. A subject who estimates the time signal as 80 seconds in the first session and 70 seconds in the second session will get the same quotient as a subject who estimates it as 8 seconds in the first session and 7 seconds in the second. Proportionately, the same degree of change has occurred in both cases.

The relations of intra-individual changes may be investigated in two ways. Firstly, one may sample the scores of a single individual. That is, one subject is taken and tested, say thirty or forty times. Though this poses certain difficulties, it is in some ways an ideal method. In arriving at conclusions about relations within the system one need not make any assumptions about inter-system regularities. One can say that, within this particular system, space and time covary in a certain way, but then one cannot extend one's conclusions to other systems without further experiment. The second method is to sample

the changes / ...

the changes which occur in a population of individuals. That is, each subject is subjected to at least two identical tests, quotients of the changes in each variable are calculated, and the quotients of the changes in each variable are calculated, and the quotients of change are then correlated. Now, such a procedure can tell us about the ways in which changes in different systems covary. We have to make certain assumptions, such as that proportionate changes occur in the same way in different systems. For example, when verbal estimate is reduced by a tenth, does reproduction time reduce by x in all cases (excluding unknown sources of variance), as is required for our method? In other words, for this method to work, inter-variable changes have to be related in the same way in all systems. This assumption does not have to be made when we are examining one subject only.

There is, of course, some reason to believe that the systems are fairly similar, when an effort is made to obtain roughly homogeneous populations, produced by the same educational system. Their experience is very largely concerned with the relations between various things. It seems reasonable to assume that in all cases a change in perception of objective time will be accompanied by a change in reproduction and verbal estimate of that time interval.

What we cannot be sure of, as we have remarked above, is that in all cases the proportions of change bear the same relationship to one another.

The chief advantage of sampling the changes which occur within a population of individuals is that any relationships found can be assumed to be fairly widespread. There may be, of course, relationships peculiar to certain individuals which are not uncovered by this method.

Quotients were calculated for reproduction variables when the standard was 16 seconds in length. Verbal estimate quotients were also calculated for the same length of time signal. In each case, the quotient was found by dividing the score obtained in the

first session / ...

first session into the score obtained in the second session. These ratios are shown in Appendix B, Table XXVII. Product-moment correlations of these ratios or quotients of change were calculated, and are shown below in the text Table 24.

TABLE 24.

Correlations of intra-individual changes in time, speed, and distance in reproducing 16 seconds by free linear movement in Experiment 2 (N=56).

	1	2	3
1. Change in distance			
2. Change in time reprod.	+.59++		
3. Change in speed	+.65++	-.04	
4. Change in verbal est.	+.62++	+.38++	+.42++

++ significant at 1% level of confidence

There is only one correlation in this Table which is strikingly different from those obtained with raw scores. This is the significant positive correlation of +.42 between a change in speed and a change in verbal estimate. Since Brown found that an increase in phenomenal speed was associated with a decrease in phenomenal time, this result is particularly interesting. Additional ratios of change, in response to a signal of 8 seconds, were calculated, to discover whether they would affirm this result. These are shown in full in Appendix B, Table XXIX. The correlations of these ratios of change were computed and are shown below in the text Table 25.

TABLE 25.

Correlations of intra-individual changes in time, speed, and distance in reproducing 8 seconds by free linear movement in Experiment 2 (N=56).

	1	2	3
1. Change in distance			
2. Change in time reprod.	+.34++		
3. Change in speed	+.77++	+.02	
4. Change in verbal est.	+.14	-.06	+.05

++ significant at 1% level of confidence

In Table 25 we see that the correlation between change in verbal estimate and change in spped, though still positive, is so

close to /...

close to zero that it can lend no support to any interpretation based on the significant positive correlation in Table 24.

All the differences between Tables 24 and 25 concern the relationship between changes in verbal estimate and other variables. It is quite possible that the reason for this is that verbal aids to reproduction play an increasing role as the time interval is lengthened, so that a closer relationship between time reproduction and verbal estimation is found above a certain length of time signal than below.

It is noteworthy that in both Tables the correlation between change in verbal estimate and change in distance moved in reproduction is higher than the correlation between change in verbal estimate and change in time reproduced. This parallels the relationships found with the raw scores, and affirms the possibility that verbal estimate is affected by the distance which the subject moves. This would be entirely in accord with the effect on phenomenal time of increased distance.

If the hypotheses are examined individually in the light of these correlations, we see that they are largely confirmed. This means that the same relations hold in the raw scores of a population of subjects and in the intra-individual changes which occur in a population of subjects. The hypotheses have an added validity since they appear to hold both across a number of subjects and within a number of subjects. Hypothesis (a), that speed and duration of reproduction by linear movement are not related, is supported by the very low correlations obtained at both 8 and 16 seconds (+.02 and -.04 respectively). Hypothesis (b), that distance and duration of reproduction of time by free linear movement are positively related, is confirmed by the significant positive correlations at both 8 seconds and 16 seconds (+.34 and +.59 respectively). This means that an increase in distance moved is associated with an increase in time of movement both across the population of subjects and within eahh subject. Hypothesis (c), that verbal estimation and reproduction of time are positively related is not confirmed by the correlation at 8 second interval (-.06), but

is supported / ...

is supported by the correlation at 16 second interval (+.38). This hypothesis is, therefore, subject to doubt as it applies to intra-individual changes. Hypothesis (d), that speed and distance of movement are positively related is very strongly supported at both 8 seconds and 16 seconds (r's of +.77 and +.65, respectively).

The method of intra-individual changes, though it has not supplied us with any radically new information about the relations hypothesised, has extended our range of certainty as to the application of these hypotheses. They can now be safely assumed to apply to the covariance of changes in different systems as well as the covariance of level of performance in different systems.

At the end of the next chapter, in which the effects of imposing certain spatial restrictions on the linear movements of the subject are considered, some attempt will be made to draw further conclusions about the differences between exteroceptive and proprioceptive space-time relations

6.4 SUMMARY AND CONCLUSIONS

An attempt was made to consider the differences between exteroceptive space-time relations and proprioceptive space-time relations, by analysing the correlations between distance moved, duration of movement, speed of movement, and verbal estimate of time interval, when subjects were asked to reproduce time signals by free linear movement. The data used were derived from Experiment 2. Four hypotheses were set up: (a) that time reproduced and speed of movement are not related; (b) that time and distance of linear movement are positively related; (c) that verbal estimate and time reproduced are positively related; and (d) that speed and distance of linear reproduction movement are positively related. The hypotheses were largely confirmed, both by correlation of individual levels of performance and by correlations of intra-individual changes in performance. It was also found that verbal estimate was more closely related to the distance of the linear movement of reproduction than to the time reproduced. This could be interpreted as an affirmation of the phenomenological effect of space on time, as in the kappa effect.

CHAPTER 7

TIME-SPACE RELATIONS IN REPRODUCING AUDITORY TIME SIGNALS BY CONTROLLED LINEAR MOVEMENT.

7.1 Introduction

It has already been remarked that one of the reasons for there not being any negative spatial effect on the duration of the arm movement may be that the preferred speed of movement is phenomenologically neutral to the subject. But it is possible that, should the subject be compelled by the conditions of the experiment to alter the speed of his movement, the phenomenological variations in time observed by Brown might occur.

To test this possibility, the data found in Experiment 3 were analysed. In Experiment 3, subjects reproduced time intervals by free movement, by movements of controlled distances, and by gripping the stationary handle. Before proceding to a study of the results, it is worth examining the relationships which might be expected, if we are to apply Brown's hypotheses to our data. What relations would the controlled movements of various distances bear to each other? What relations would the controlled and free movements bear to each other? And what relations would the stationary grip bear to the movements?

(a) An increase in speed might result in a decrease in phenomenal time. On the average, therefore, subjects could be expected to take a longer objective time for the reproduction movement when the distance is increased.

(b) When subjects do not move linearly (reproduce by gripping the stationary handle) they might be expected to have lower time reproduction scores than when they reproduce by linear arm movements.

(c) Where the speed of movement is phenomenally neutral, as we hypothesised that it might be in the case of free movements, reproduction times might be expected to be higher than when

speed is /...

speed is greatly decreased (since that would increase phenomenological time), and lower than when speed is greatly increased (since that would decrease phenomenological time). In each case there is a negative relationship between phenomenal time and reproduced time.

As in the previous chapter, these hypotheses do not appear to be satisfactory. To take a point of fact first; it was found, in the analysis of data derived from Experiment 2, that reproduction scores were higher when the method was key-pressing than when it was linear arm movement (see Table 19). This discredits hypothesis (b) and casts doubt on the whole set of hypotheses. Once more we emphasise that, when the subject is making the movement, spatial effect on time judgement need not occur because the subject produces all the relationships involved in the judgement. He is not deceived by an unexpectedly greater distance in one part of the field, which he has to 'account for' by the impression that a greater time interval must separate this part of the field. Our contention is that exteroceptive spatial effects on time judgement depend on the stability of speed which is one of the characteristics of individual expression. But where, in the terminology of Osgood (1963, p.263), the subject is at once the "destination-source" of the information which has to be analysed, it cannot be expected that the subject should be subject to the same space-time errors. If this were the case, then we should have to conclude that the sources for the information about time and for the information about space are not in communication, whereas it seems likely that both of these features are abstracted from the common experience of movement.

But if we accept this argument, that the position of the subject as "destination-source" places him in a different position from that of the subject who is destination only, then we have to set up the hypothesis that variations in the distance moved by the subject in reproducing time intervals by linear arm movement should have no significant effect on the durations reproduced.

To test this hypothesis, we shall proceed to an analysis of the data in Experiment 3.

7.2 The Space-Time Relations of Controlled Movement

The full scores for reproduction of 8 seconds by free and controlled linear movements, by stationary grip and by verbal estimate are found in Table XXX in Appendix B. Similar data for 16 seconds are in Table XXXI, Appendix B.

These scores enable us to compare the means and standard deviations obtained by these methods. In Table 26 these data are summarised.

TABLE 26

Mean judgement, in seconds, of 8 seconds by free and controlled linear arm movements, by gripping the stationary handle, and by verbal estimate in Experiment 3 (N=40).

	Free Distance	Stationary	Controlled Distance 5"	20"	40"	60"	Verbal Est.
Mean	10.3s	8.0 sec.	10.1s.	9.4s.	9.3s.	9.1s.	10.77 s.
Standard Deviation	2.71	1.51	2.09	3.55	3.13	3.20	5.85

Reproduction of time by stationary grip is significantly lower than by all other methods. The level of confidence at which the null hypothesis is rejected is, for the differences verbal-stationary grip, free movement-stationary grip, and 5" controlled movement - stationary grip, the 1% level (t values are, respectively, 2.9, 4.9 and 5.1). Differences between controlled movements of 60", 20" and 40", and stationary grip reproduction are such that the null hypothesis is rejected at the 5% level (t values are 1.95, 2.26 and 2.34, respectively). No other differences are significant.

The data obtained in judging 16 seconds are summarised below, in the text Table 27.

TABLE 27

Mean judgement, in seconds, of 16 seconds by free and controlled linear arm movements, by gripping the stationary handle, and by verbal estimation in Experiment 3. (N=40).

Table 27/...

	Free Distance	Stationary	Controlled Distance 5"	20"	40"	60"	Verbal Est.
Mean	18.7 s	14.8 s	17.1s	16.8s	17.2s	17.5s	15.4s
Standard Deviation	5.68	2.40	3.93	3.82	3.91	4.56	7.05

Again, reproduction of the time interval by stationary grip yields a lower figure than by any other method. The only method which does not differ significantly from it is verbal estimation. All other methods yield differences subh that the null hypothesis must in all cases be rejected at the 1% level of confidence. The t values are: free distance - stationary 3.9; 5" controlled movement - stationary 3.1; 20" controlled movement - stationary 2.8; 40" controlled movement - stationary 3.3; and 60" controlled movement - stationary 3.3.

In no instance do free and controlled distance reproduction scores differ from each other. Further evidence that identical processes are at work in both these methods is found in the fact that their standard deviations do not differ significantly from each other, though they do differ significantly from the standard deviation of scores obtained by stationary grip. For example, in reproducing 8 seconds, all the linear movement standard deviations, except for the 5" controlled distance reproduction, differ significantly from the stationary standard deviation. The t values are: free movement - stationary 2.5 ($p<.02$); and 20", 40", 60" controlled movement t's are 3.3, 2.9 and 3.0 respectively, all of which lead us to reject the null hypothesis at the 1% level of confidence. In reproducing 16 seconds, we may also reject the null hypothesis that the standard deviation of movement reproduction is not different from that of stationary reproduction. For the difference between free movement qnd stationary grip we may reject the null hypothesis at the 1% level of confidence. For all the controlled movement - stationary grip reproductions the differences lead us to reject the null hypothesis at the 5% level. The t values at 5", 20", 40" and 60" are, respectively, 2.1, 2.0, 2.1 and 2.6.

It is clear / ...

It is clear from these figures that the reproductions by movements of various distances fulfil the prediction that there would be no differences of significance. But one surprising fact does emerge. Whereas, in Experiment 2, key-pressing results tended to be very similar to the stationary grip results obtained in Experiment 3 (Means are 7.8 and 15.6, standard deviations are 1.18 and 2.07), the free linear movement results tend to be very different. (Means are 6.6, and 11.9, standard deviations are 3.4 and 4.0). The null hypothesis that there is no difference between key-pressing in Experiment 2 and stationary grip in Experiment 3 must be accepted since the t values at the 8 and 16 second intervals are 0.7 and 1.6, respectively. The standard deviations are also, in both cases, not different, and the null hypothesis is accepted for them, too (t values at 8 and 16 seconds are 1.1 and 0.66, respectively). But the free linear movement scores differ very significantly, between Experiment 2 and Experiment 3. At 8 seconds the null hypothesis is rejected at less than the 1% level of confidence (t=6.4) and at 16 seconds the same occurs (t=6.7). The standard deviations are not significantly different (t=1.2 at 8 seconds and 1.64 at 16 seconds). Therefore, the distribution of scores is the same in Experiment 2 and 3, but something has happened to move the whole distribution to different levels in the two experiments. The most obvious suggestion is that when the subjects have to reproduce time by moving different distances they suspect that there is some 'trick' involved and are determined not to be caught. The result is that they over-compensate. When free movement is allowed from the start, subjects do not adopt this critical attitude. The effect of a critical attitude on results has been noted in experiments of this kind by both Abbe and Cohen and his associates.

But if this is so, what conclusions can we draw? The only safe ones appear to be that reproduction by means of linear movement is more subject to inaccuracy than stationary reproduction, and that free and controlled linear movement yield the same reproduction scores. But this is enough to bear out the main hypothesis guiding this inquiry: that the distance of the movement has no bearing (within the limits of our experiment) on the reproduction score. The subjects are on the whole able to adjust speed to the distance which has to be covered, for a given time interval.

In addition to this direct comparison of time scores under various conditions, the scores of Experiment 3 were also used to further substantiate the relations among speed, time, distance and verbal estimate which were found in Experiment 2. Product-moment correlations were calculated and are shown below in Tables 28 and 29.

TABLE 28.

Correlations of time, distance and speed of free linear movement reproduction of 8 seconds in Experiment 3 (N=40)

		1	2	3
1.	Distance moved			
2.	Time reproduced	$+.61^{++}$		
3.	Speed moved	$+.70^{++}$	$-.28$	
4.	Verbal estimate	$+.38^{++}$	$+.31^{+}$	$+.04$

\+ significant at 5%
++ significant at 1%

TABLE 29

Correlations of time, distance and speed of free linear movement reproduction of 16 seconds in Experiment 3 (N=40)

		1	2	3
1.	Distance moved			
2.	Time reproduced	$+.44^{++}$		
3.	Speed moved	$+.53^{++}$	$-.17$	
4.	Verbal estimate	$+.58^{++}$	$+.40^{++}$	$+.08$

\+ significant at 5%

It is interesting to note that these relations agree completely with those found in Experiment 2. The most important confirmations are the negative correlations between speed and duration of movement, which are not significant statistically but confirm the trend. There seems definitely to be a slight tendency, observed in two samples of subjects, for those who move faster to reproduce a lower level of time. Another important confirmation is that verbal estimate is more closely related to distance of movement than to time reproduced by the movement. This may be because the subject can

decide with /...

decide with more reliability how far he is going to move in response to a signal than how long he is going to move. In Experiment 3 subjects were presented with only one time interval in a session, and judged it verbally several times before the free movement trials, so that it is more likely that verbal reference affected distance moved than the other way round. But in the previous experiment, verbal judgements were made after movement, so that there the relationship might have been reversed. It is quite possible that the effect works both ways.

Ratios of change were also calculated, as in Chapter 5. These intra-individual changes were correlated to discover whether they would confirm the results of Experiment 2, which indicated that largely the same relations held when either levels of performance or changes in levels of performance are correlated.

TABLE 30

Correlations of intra-individual changes in time, speed and distance in reproducing 8 seconds by free linear movement in Experiment 3 (N=40)

		1	2	3
1.	Change in Distance			
2.	Change in time reproduced	+.52++		
3.	Change in speed	+.68++	-.19	
4.	Change in verbal estimate	+.21	+.16	-.18

++ significant at 1% level

The main differences between these correlations and those found with raw scores are in verbal estimate relations. The correlation between change in verbal estimate and change in distance moved, though still positive, is not significant, and the correlation between change in verbal estimate and change in time reproduced has also lost statistical significance.

TABLE 31

Correlations between intra-individual changes in time, speed and distance in reproducing 16 seconds by free linear movement in Experiment 3 (N = 40)

		1	2	3
1.	Change in distance			
2.	Change in time reproduced	$+.71^{++}$		
3.	Change in speed	$+.70^{++}$	+.15	
4.	Change in verbal estimate	$+.52^{++}$	$+.64^{++}$	+.28

In this Table the relations are almost precisely those found with raw scores. The same correlates of verbal estimate changes are significant: verbal estimate - distance and verbal estimate - time reproduced.

7.3 Discussion and Conclusions

The first general conclusion to be drawn from the results of Experiments 2 and 3 is that the same effects are not found in the observation and judgement of externally produced space-time relationships and in the production of these relationships by movement of the arm. It is suggested that when the subject is the "destination-source" of the information relevant to his judgement, he has, in fact, more information than when he is merely the "destination". In judging the exteroceptively received impression, the subject is liable to the error of an assumption of constant velocity, but in producing the movement, he knows very well whether velocity is being kept constant or not.

The one relationship which is similar to that found with exteroceptive stimulation, is the positive correlation between verbal estimate and distance moved, which is generally higher than that found between verbal estimate and time reproduced by movement. In Experiment 2 the verbal estimate succeeds the movement of reproduction, and there seem to be three possible ways in which the verbal estimate could be formed. One possibility is that the verbal judgement subjectively precedes the movement. The second is that the verbal judgement succeeds the movement, but is not affected by it. The third is that the verbal judgement succeeds the movement and is affected by it. The evidence does not allow us to decide conclusively among these possibilities, which may vary from individual to individual. The fact that the verbal estimates associated with key-pressing do not differ significantly from

those associated /...

those associated with movement is not useful, because key-pressing reproduction comes after linear movement reproduction, and by that time the verbal estimates are generally determined. We cannot, therefore, on the basis of Experiment 2, say that verbal estimates are definitely affected by the distance moved, rather than that the distance moved is affected by the verbal estimate. But, it is more than possible that the relationship can be effective either way. The data of Experiment 3 in which verbal estimates of the time interval were made before the free movement trials, make it probable that this is so. A comparison of the mean correlation coefficients can easily be made. The mean correlation between distance and verbal estimate is +.51, which accounts for 26% of the variance. The mean correlation between reproduced time and verbal estimate is .33, accounting for 11% of the variance. The mean correlation of the change in verbal estimate and the change in distance is .38, accounting for 14% of the variance. The mean correlation between change in verbal estimate and the change in time reproduced is .28, accounting for 8% of the variance. It is probable that the higher relationship between verbal estimate and distance than between verbal estimate and duration may be interpreted as a consequence of the relative accuracy of space perception as compared to time conception. If the subject forms his verbal estimate before his movement, he can also form a clear idea, in terms of distance to be moved, how one signal compares to another. Such a comparison, in terms of distance, is a much more vivid and easily grasped comparison than one of time intervals, grasped as durations. On the other hand, if the subject forms his verbal estimate after the movement, the distance which he has moved is a clear indication of the degree to which the signal is longer or shorter than other signals. It was observed, in the course of the experiment, that the two most popular ways of assessing the duration of the signal were by counting and by fixing in the mind the distance to be moved in reproducing the signal. Allowing for small fluctuations in the speed of movement, it may be seen that time will deviate relatively more from the verbal decision than distance, under such circumstances.

Another general /...

Another general conclusion which may be drawn is that the distance moved by the subject may be altered experimentally without affecting his time judgement, but where he alters the distance himself, between sessions, moving at his own tempo, there is a change in the time reproduced. In all cases, in both Experiments 2 and 3, the positive correlations between change in distance moved and change in time reproduced are statistically significant. This means that the individual may adjust his speed of movement to cover various distances in the same time, but that the reliability of his preferred tempo is such that an increase in the distance moved, even in sessions widely separated in time, brings about an increase in time reproduced.

The finding that a change in speed between sessions is associated very strongly with a change in distance, but not with a change in time reproduced by free linear movement, is congruent with the finding that when the distance is controlled, the subject may alter his speed of movement so as to maintain constant time.

Another general conclusion which may be drawn is that the methods of controlled and free linear movement produce the same time reproduction results and the same distribution of scores, but that both of these methods differ from the method of reproduction by key-pressing, which tends to approximate the standard time signal more closely and to have a very narrow distribution of scores. The similarity of the methods of controlled and free linear movement is born out not only by the fact that their means do not differ (in Experiment 3) and that their standard deviations are practically identical, but also by the fact that both have high reliability as compared to key-pressing.

Some attempt will be made in the next section to draw up a model of the relations involved in time reproduction.

7.4 A Model of the Relations in Time-Space Judgements

An attempt will be made to present a model of the relations involved in space-time judgements in which the subject is the destination-source, and judgements in which he is only the destination of information. In the former case the subject has available proprioceptive information as

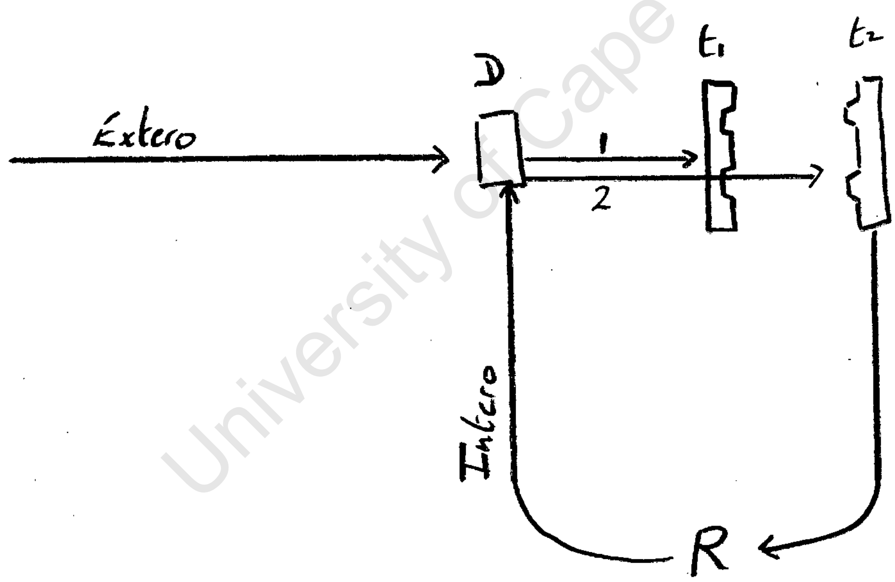
well as /...

well as exteroceptive information. He feels the movement of his muscles and he sees the movement of his arm. In the latter case, the subject has only exteroceptive information. He sees the succession of, let us say, visual stimuli.

Let us try to set up a model for the reproduction of an exteroceptive signal which has no properties of spatial extension. The time signal may be, for example, a light which is switched on for a certain interval of time. Now, let the subject reproduce this duration and the relations of his actions are represented in Model I. It is important to note that this is a diagram of relations, not a physiological model.

Model 1.

Reproduction of a time signal without spatial extension (e.g. a point of light).



Extero = exteroceptive information about duration.

D = decoder of information.

tI = cortical time process, initiating response, acting as acceptor.

R = kinesthetic response of movement.

t2 = cortical time process resulting from response, acting as the accepted process.

Intero = interocpptive information about duration of the response.

The important /...

The important features of this model are that the exteroceptively received information produces a time process, tI, probably in the cortex, which then acts as an internal source of information for the response, R, of linear movement. Information from the movement and the process tI are then fed back into the decoder, and the accepted process, t2, is produced. Thus, information about the rate of movement, the distance of movement, and the process tI all enter into the final accepted process t2. The accepted process, t2, need not represent the same time interval as the acceptor, t1. The time reproduced is rarely identical with the signals.

Now, let us consider what happens when the duration of exteroceptively received movement is judged. We shall take this to include judgements of the intervals between successive stimuli. This assumption appears to be fully justified by the readiness with which motion is ascribed to a body occupying a succession of places. The work of Michotte (1963) amply illustrates this tendency. We refer here not to the phi phenomenon, when points of light separated in space flash in such rapid alternation that the subject experiences the illusion of movement, but to the ascription of movement to a stimulus presented in separate locations at such intervals of time that the stimulus may easily be seen to be stationary. Nevertheless continuous motion is readily ascribed to the stimulus. There is only one extra assumption in the second model. It is the assumption that when the subject perceives motion he makes a tonic response of the kind which Hull described as a "pure stimulus act". There is, in the work of Werner and Wapner (1952), a considerable body of evidence that such tonic responses may occur and that they do affect judgement. This response would be a subliminal motor response, perhaps of the eyes, the neck, the trunk and even of the limbs.

Though this seems to be a plausible assumption there is not, of course, any direct evidence that such a "pure stimulus act" occurs when the subject is judging the time intervals taken by motions through space. Evidence could be procured with a simple experiment, though,

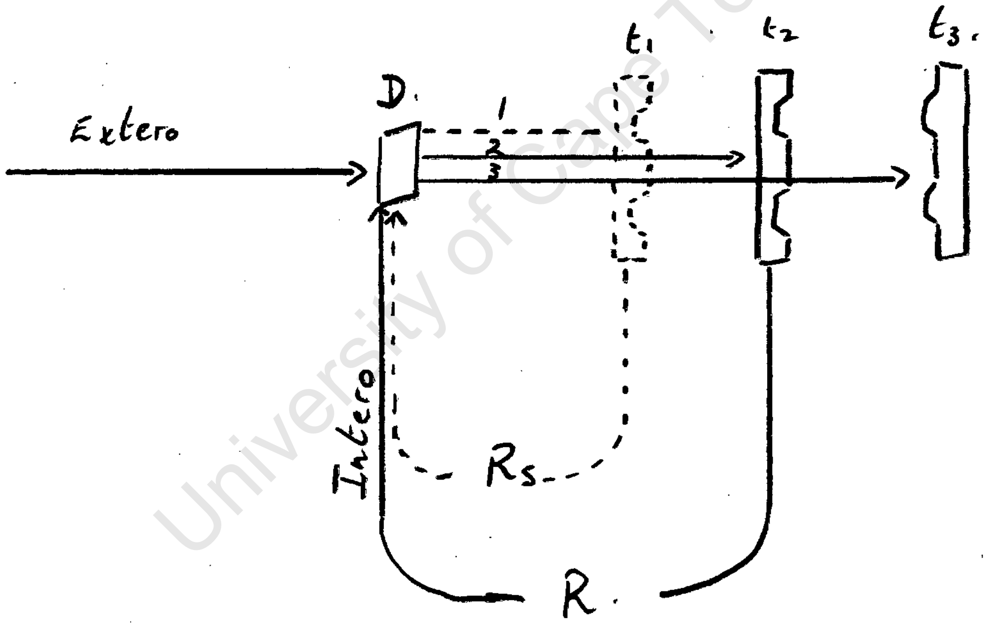
to show /...

to show whether or not tonic effects of the kind demonstrated by Werner and Wapner do affect time judgement. If equidistant signals are presented at equal intervals of time, unilateral stimulation (by light, or faint shock, for example, or by body tilt) should produce a kappa effect, if this assumption is correct. The spatial equivalent of various kinds of stimulation could be found by this method.

But for the moment, let us accept that the tonic effect of observed movement does occur. Then, we can draw up a model of the relations of the processes entering into the perception and judgement of the time relations.

Model 2

Reproduction of a spatially extended time signal.



Extero = exteroceptively received movement-duration
D = decoder of information
tI = cortical time process which initiates pure stimulus act, Rs.
Rs = pure stimulus act which leads to illusion
t2 = acceptor cortical time process, result of pure stimulus act.
t3 = accepted cortical time process, produced by R.
R = supraliminal response (pressing key, adjusting time interval, etc.)
Intero = interoceptive information about duration of the response.

The main /...

The main way in which this model differs from the previous one is that the acceptor cortical time process is assumed to be altered by the pure stimulus act of the subject in response to his perception of motion. The acceptor process is t2 instead of tI, as in the previous model, because there are in fact two responses instead of one. One of the responses (Rs) occurs subliminally, and is not allowed for by the subject.

These models are intended to serve as vehicles of communication for the relations involved in abstracting time interval from motion under two conditions. They merely help to define these relations and prevent ambiguity. If they do that much, they serve their function.

To summarise: in Model I the subject is the destination of information leading to process tI and the destination-source of the information leading to t2, the process accepted by tI; and in Model 2 the subject is the destination of the information leading to processes tI and t2, and the destination-source of the information for t3, the process accepted by t2. We may treat the subject as the destination for information leading to t2 until he becomes aware of the illusion and adopts a critical attitude, as Abbe remarked. Until that happens, the interoceptive information from the pure stimulus act, Rs, and the exteroceptive information from the sight of the stimuli, are both external to the judging subject. Once the subject adopts a critical attitude, something like a gating or inhibition of the interoceptive input may occur. By now, the ability of the central nervous system to shut out ~~external~~ stimulation is well established.

7.5 SUMMARY AND CONCLUSIONS

Controlled-movement, free-movement, and stationary reproduction by key-pressing and grip are compared, using data from Experiments 2 and 3. It is found that the linear movement reproductions do not differ from each other, but that both differ from reproduction by key-pressing and gripping a stationary handle. Reproductions by linear movement are less accurate and have a wider distribution than reproductions which do not require linear movement. The exteroceptive spatial effects on time judgement (kappa effect, suto effect) are reversed when the subject makes the movement himself. This is explained by the hypothesis that the exteroceptive effects are secondary, and depend on the assumption of a constant rate of movement. When the subject is able to maintain a constant rate of movement, or to analyse any changes which occur, as in making the motion himself, these spatial effects on time judgement do not occur. Two models of the relations involved are presented to clarify the assumptions involved.

PART III

DELAYED REPRODUCTION OF TIME

If the hypothesis is advanced that time reproduced reflects the strength of a cortical trace produced by a time signal, then delayed reproduction of time might be expected to indicate what changes occur in that trace. Various trace theories, and the validity of the hypothesis, are considered in Chapter 8.

C H A P T E R 8

THE EFFECT OF DELAY ON THE REPRODUCTION OF SHORT TIME INTERVALS

8.1 Introduction

In the study of memory, one of the main problems is the way in which brief neural processes are converted into structures of greater persistence. The distinction between primary, elementary, or immediate memory, as it has variously been called, and secondary memory is an old one. James (1890) distinguishes between "elementary habit" - the phase before the initiating processes in the nerve tissue have died away - and "memory" - a revival of the initiating processes, or of some representative. There are a number of theories of memory. In the course of the next few pages some of them will be reviewed before we proceed to examine the effect of brief periods of delay on the reproduction of short time intervals.

8.2 The Gestalt Theory of Memory

Koffka (1935) distinguishes between the stimulus-excitation process and the trace, or residue. The trace, which is conceived of as a neurophysiological change, stores the remembered information. The trace theory, as a reference to Gomulicki's (1953) monograph shows, is an extremely old one in Psychology, and has, broadly speaking, two forms: the "wax tablet" and the "pathway". The "wax tablet" form conceived of the brain (or memory substance, in versions which precede the establishment of the brain as the locus of memory) as a material upon which experience makes its marks, writing as with a stylus upon the plastic material. This view has been adopted from Plato through Locke to William James. The "pathway" model of the memory trace views memory as a facilitation of existing neural pathways. This model depended on the development of neuro-anatomy in the 19th century and finds distinguished modern exponents, such as Hebb and Penfield. The Gestalt theorists have, in general, not been specific about the

kind of /...

kind of memory model to which they adhere. But they have advanced the important theory that the memory process is subject to the same dynamic influences as perception. The trace, according to Gestalt theorists, gradually becomes more symmetrical - it obeys the laws of pregnancy, closure and significance.

The information which the stimulus-excitation process makes available to the individual is then stored, according to Koffka, in a different place. The reason for separating the stimulus-excitation and the retention process in space is to explain the difference between remembering an object and recognising it, or comparing an object with something previously seen and remembered. A spatial interval in the cortex represents a temporal interval. Comparisons of persently perceived objects with remembered objects must be by means of selective communication between the stimulus-excitation process and the trace. The form which this selective communication takes is more explicitly stated than the manner in which it functions. It takes the form of a field-excitation which covers the spatial interval between the process and the trace, but the way in which this field selectively communicates is not clear.

We may interpolate some evidence which will be fitted more exactly into the account in a later section : evidence from neuro-surgery supports the view that immediate processes and traces of more distant memories are spatially separated in the brain (e.g. Penfield, 1959).

Kohler (1923), on the basis of experimental work on negative and positive time order, proposed that the immediate stimulus-excitation process increases up to about three seconds, and then declines. Fraisse (1959), on the evidence that EEG traces of cortical excitement persist for 60c.s. after stimulation with light, believes that the initial excitation of perception lasts a much shorter time. The evidence of the psychophysical refractory period also supports a time interval of this length. It may be that there are at least three phases to be distinguished in memory : perception, immediate memory, and long-term memory. Information may be lost during each of these stages, but probably the greatest loss occurs during perception.

The main /...

The main causes of the loss of information which occurs during retention are, according to Koffka, the dynamic processes which improve the "goodness" of the trace. Since the original percept is very rarely perfectly organised, these dynamic processes cause a loss in detail to occur.

No particular curve of forgetting can be deduced from the Gestalt theory of memory. Traces may be confirmed or consolidated; they may be available with varying degrees of readiness, and they may alter according to the dynamic field laws mentioned above, We may deduce from the theory the fact that a trace may alter, but not that it can disappear. This seems to be substantially correct.

8.3 The Effect of Satiation on the Trace.

Satiation effects last a fairly short time, so that it is possible that they affect the stimulus-excitation process of the original percept rather than the long-term trace, or residue of that percept. The time-relations of the various processes are not very clear. Vernon (1934) found that visual after-effects lasted up to 5 minutes after an inspection period of 10 minutes. Hammer (1949) found that satiation was at a maximum after 1 minute inspection, and declined to zero with 90 seconds' delay. The exact time which satiation effects last is clearly a matter of minutes. Satiation effects are, therefore, only important in immediate comparison.

Auditory after-effects as well as visual after-effects have been demonstrated. Deutsch (1951) has shown that listening to a prolonged tone increases the tonal interval between neighbouring tones. Christman (1954) found the same effect. Satiation with a standard pure tone lasting one minute could shift the pitch of test tones away from the standard. He found that the magnitude of the effect varied positively with the duration of the tone and inversely with the time between satiation and test. Krauskopf (1954) comes to the conclusion that figural after-effects represent a general characteristic of place-systems, since Köhler and Wallach have demonstrated displacement in

vision, Köhler /...

vision, Köhler and Dinnerstein in kinesthesis, Deutsch and Christman in pitch localisation, and Krauskopf in auditory place localisation.

Köhler's (1940) primary postulate is that a percept is a dynamic process which tends more and more to block its own way. The word "satiation" was used (Köhler and Wallach, 1944) to describe the alteration in the brain medium brought about by the prolonged presence of a given figure in a particular cortical area. Figural after-effect is a result of this alteration in the brain medium. Continued presence of figural currents creates an area of impedance which makes the contours of subsequently inspected figures recede. Changes may occur in size, luminosity, depth, and displacement of test figures. Cross-modal satiation effects have been found (Jaffe, 1956). Large and small strips of paper were presented for visual inspection before kinaesthetic judgement of a standard bar of aluminium. The kinaesthetic standard appears to increase in width after visual fixation of the narrow strip, and to decrease after inspection of a wide strip. These results cannot be explained by a theory, such as that of Köhler, which posits a spatial relationship between the inspection and test figure as the basis of figural after-effect.

An attempt to test the field theory was made by laying strips of gold foil under the dura mater of the visual area, and by inserting pins of gold foil touching the pia mater. The experimental subjects were two rhesus monkeys (Lashley and others, 1951). The pins and the gold foil were intended to short-circuit the field. The animals were then tested on visual discrimination problems which they had mastered before the operation. Both animals performed normally. The conclusion is that a cortical field process cannot account for perception of visual figures. That means also, of course, that a cortical field theory cannot account for figural after-effects. In the same paper, Lashley, Chow and Semmes make a further criticism of the cortical field theory which is difficult to refute. Köhler and Wallach dealt with the discrepancies between retinal distribution and cortical representation in their theory of permanent satiation by positing that the distance between contours of fields will be smaller in cortical

regions which /...

regions which represent related portions of the retina on a smaller scale than in those which represent related portions of the retina on a larger scale. Consequently, given a uniform density of contour on the retina, satiation will be greater as the scale of representation decreases. But the evidence suggests that "the number of excitations per unit time and cortical area is uniform". Satiation must be evenly distributed in Area 17. In addition, there is the problem of the way in which currents spread selectively in both hemispheres. Köhler and Wallach suggested, tentatively, the possibility that the corpus callosum might form a highly conductive connexion, but Lashley points out that there is normal sensory integration in cases of congenital absence of the callosum.

Furthermore, it has been generally assumed that a central process is responsible for after-effects, and this has been shown by the fact that they may be monocularly induced. But, McEwan (1958) shows that when the unused eye is covered with a black cup during the inspection period the after-image transferred to that eye may be absent. He concludes that peripheral effects may be more important than allowed for in the theory.

This review, though it shows that the explanation of after-effects is not clear, does show that after-effects do occur, and may effect judgements following soon after stimulation. For this reason, a knowledge of after-effects is relevant. A number of further theories to account for after-effects will be dealt with in the section below (8.4) and in the next chapter.

8.4 Excitation-Inhibition and After Effects

The view that inhibition (subsuming the processes of reactive inhibition, basal cortical inhibition and satiation) may explain after-effects has been adopted and developed by Eysenck (e.g. Eysenck 1956, 1957). The concept of inhibition was used by Pavlov (1955) first to explain reductions in conditioned response, and later to explain individual differences between dogs. Pavlov distinguished between external and internal inhibition. It is with the latter that we are concerned.

He did

He did not think that the loss of the conditioned response could be explained as merely the decline of a single process (excitation), because it would then be difficult to account for spontaneous recovery, or disinhibition. It seemed to him that the extinction of a response could only be described as an active process. He postulated that every stimulus produces both an excitatory process and an inhibitory process, but that the inhibitory process decays faster than the excitatory. If this were not so, no learning could occur. Later, Pavlov used this balance of excitation and inhibition to account for individual differences in dogs and in humans. He noticed that some dogs are easy to condition, but extinguish slowly. Others condition slowly and extinguish rapidly. Again, others condition and extinguish rapidly; or they might condition slowly and extinguish slowly. Differences in the ratios of the strengths of excitation and inhibition might explain these observations.

Hull (1943) elaborated on Pavlov's construct of inhibition by distinguishing conditioned inhibition (sIr) and reactive inhibition (Ir). The former might be characterised as the habit of ceasing to respond (Reid, 1960), and the latter is the decrement in performance which follows repeated exercise, generally of a motor activity. Eysenck (1955) has related different concepts of inhibition. In his view reactive inhibition (generally motor) and satiation (perceptual) are the result of the same central nervous process. Conditioned inhibition remains a habit, distinct from those inhibitory processes, such as reactive inhibitions and satiation, which decline rapidly during rest. But subjects who develop reactive inhibition more strongly will, since it functions as a drive, also develop conditioned inhibition more rapidly. Duncan (1956) who supports Eysenck's view that reactive inhibition and satiation are identical, has listed six similarities between the two processes. These are that (i) both result from afferent stimulation; (ii) the locus of both is central;
(iii) both distort behaviour away from some standard;
(iv) such information as there is suggests that both appear after as little as 5 to 10 seconds;

(v) with /...

(v) with continuous stimulation both seem to develop quickly to a maximum beyond which additional stimulation does not produce further distortion; and (vi) both decrease rapidly after stimulation ceases.

All that remained to be done was to show that satiation and reactive inhibition are the same process, by means of experiment. The first question is whether individuals who develop satiation rapidly in one sensory modality necessarily satiate rapidly in another modality, as is implied. Before we can link two processes, we need to be sure that each of these two processes is in fact one process. The work of Rodger and McEwan (1960) suggests that there is no single process of satiation to cover kinaesthetic after-effects and visual after-effects. The work of Becker (1960) shows that satiation and reactive inhibition cannot be attributed to the same central process. Both of these experiments will be described in more detail in Chapter 9.

From this we may conclude that inhibitory (satiation) effects may occur in perceptual tasks in various sensory modalities, but that the theoretical attempts to explain these effects are not sufficient. The possibility of a satiation effect in short-delay perceptual tasks must still be taken into account.

8.5 Piaget's Theory of Transports

Another attempt to explain the effects of a short period of delay on judgements is Piaget's Theory of Transports. When the length or the height of some visually presented stimulus has to be compared to a previously inspected equal standard, it is thought to be less than the standard when distance separating the two is large, and more than the standard when the distance separating the two is small (Vurpillot, 1959). There are great individual variations, but the data are not statistically treated. When two elements are to be compared which are separated too far to be seen in a single fixation, it is necessary to transport the one element to the other. The element transported enjoys a privileged centration. It is usually the standard and not the comparison which is transported, and which is, therefore, seen as larger. When the distance between the standard and the comparison is small, the two are seen in a

single centration/...

single centration, but the comparison will be more fixated, because it is the unknown. The further the distance between the initial and the terminal fixation, the stronger the effect of enlargement of the standard, initially fixated. One explanation which has been advanced is that the focussing of attention leads to an increase in the intensity of excitation and an extension of the area involved.

If the most general explanation of the law of relative centrations is accepted, as stated in the last sentence above, then it is clear that it could apply to the judgement of time at short intervals of delay. As the delay is increased, the fixation of the original signal leads to an increase in the intensity of excitation corresponding to it. This should lead to an increase in the amount of time reproduced.

The theory may be criticised for the lack of statistical treatment of the data, which makes it impossible to assess how consistently the effects of transport on judgement occur.

8.6 Circuit Theories of Memory

Lorente de No's (1938) discovery that internuncial neurons are arranged in multiple or in closed chains which are capable of maintaining activity independently of stimulus-input for an indefinite period is of great importance to any theory of memory. These circuits have been used by Hebb (1949) as carriers of brief memory traces until neurophysiological growth changes can occur which form permanent memory paths. The length of time for which traces can be carried in closed reverberatory circuits and the time which it might take for growth changes responsible for permanent memory are unknown. It may be that we should distinguish three and not two memory processes. The first may correspond to the indifference interval (possibly given by the length which the perceptual process is supposed to last, according to Fraisse, 1959). The second may correspond to the X "specious present" (possibly given by the length of time which the perceived data reverberates in the circuits unless reinforced). The third may correspond to the past (given by the commencement of the process of permanent recording, either by molecular change or by pathway change).

The view /...

The view that memory traces might be recorded by protein molecular changes in the neurones of the brain was apparently first put forward by Monné (1949). Gaito (1961) suggests that nerve activity results in the rearrangement of monomers of high molecular weight polymers in the brain cells, or in the synthesis of additional, novel polymers, and that these code memory traces. Briggs and Kitto (1962) vigorously criticise this hypothesis on the grounds that DNA molecules are very stable and replicate only during cell division, when they are formed on the template of other DNA molecules. There is no known way in which nerve action could affect DNA production. Only by the production of mutagens in the brain (which would be disastrous) could nerve action affect brain nucleic acid. Briggs and Kitto propose that memory is basically dependent on neuron pathways maintained by high levels of transmitter substances due to induced biosynthetic enzymes. They argue that all somatic cells contain the same genes, but do not produce the same enzymes. One of the factors is probably the presense or absence of the enzyme substrate. Repeated nerve action could produce a concentration of transmitter (acetylcholine) substrate in an axon at a synapse, and a rise in the level of transmitter substance produced. The greater concentration of choline esterase (which removes acetylcholine) with age, strain, learning and increased stimulation could be the result of this.

This view tallies well with the operation of frequency in building up pathways and also accounts for the decline of a trace with disuse (since the concentration of transmitter substrate could be expected to diminish), but it does not account for sudden, vividly retained memories. One might use it in conjunction with Gomulicki's (1953) theory that there is a thalamocortical system which sustains certain privileged traces (more "interesting" traces) by boosting their activity. This repetition of the pathway by a boosted recurrent circuit until it is consolidated might ensure that exceptional events are remembered without external repetition. Alternatively, I should like to propose, it might equally well be supposed that recurrent circuits will automatically carry perceived

stimuli until /...

stimuli until they are cleared by the thalamocortical system. But either of these views would account for the repeated firing of a nerve pathway by a stimulus which occurs only once.

Though the discovery of recurrent circuits in nerve action has enabled the psychologist to form many hypotheses not possible with the linear connexion model, there is still considerable doubt about the extent of the role which they play in memory. As the immediately preceding paragraph has shown, one doubt is the extent to which recurrent circuits are autonomous, and the extent to which they have to be boosted to maintain memory. But, as Northrop (1948) has shown, a circuit theory of neural action enables the psychologist to see how the form of an event may be retained without referring to the particular manner or moment of arousal. Memory as a whole may be visualised as a system of "cycles and subcycles at various orders of elaboration" (F.H. Allport, 1955, p. 647). These cycles and subcycles are thought by Allport to be dynamically tending towards closure in a manner biased by the behavioural situation of external and internal conditions. Certain cycles of this system could be thought of as having a higher concentration of transmitter substrate and being, therefore, more easily aroused.

Long-term forgetting might be a result of a gradual decline in the concentration of transmitter substrate; short-term forgetting might be a decrease in the firing of a recurrent circuit. There is no certainty at all on this point. We cannot know how we forget until we know how we remember.

8.7 Perseveration Theories

The discussion of perseveration theories of memory follows naturally after the discussion of reverberating circuits, which may be the mechanism of perseveration. Perseveration theories are historically older than circuit theories, since one of the first X dates from 1900, when Müller and Pilzecker, propounded their theory. The view that reverberating circuits play an important part in the consolidation of memory traces has been advanced by Hebb (1949), Young (1953) and Gerard (1955), who propose that these circuits

maintain the /...

maintain the memory until permanent recording has occurred. Support for this view is found in the work of Burns (1954, 1958), who has shown that isolated areas of cortex, as long as the blood supply is maintained, can continue with electrical activity, initiated by a single train of impulses, for 30 minutes or more. The activity seems to become easier to evoke with repeated stimulation. Burns (1958) rejects the activity of these preparations as a general model for memory because the activity is too susceptible to external interference. Yet, as Glickman (1961) pointed out, it is this very susceptibility that has formed one of the main bodies of evidence for perseveration theory.

It has been found that electrical shock, or trauma, or the initiation of other activity immediately after learning, causes a complete or considerable loss of learning. It has been proposed that this is because perseverative traces have been eliminated before they can be transferred to a more persistent record. As an example of this interference, we may quote the evidence of retroactive amnesia. Russell and Nathan (1946) have found that among 1,029 cases of head injury, only 133 experienced no retroactive amnesia. Amnesia for events up to 30 minutes before injury was reported by 707 cases; amnesia for more than thirty minutes was reported by 133 cases; and for 56 cases there were no data. Barbiturate hypnosis reduced the period of amnesia in only 6 out of 40 cases studied. Therefore, hysterical repression does not appear to account for the results. The authors suggest interference with a perseverative process as a possible explanation.

There is also a fairly large amount of evidence to show that ECS after learning a response produces a loss of that response. The study by Duncan (1949) in which shock was administered between 20 seconds and 14 hours after learning, shows that the amount of loss in performance decreases as the ECS is more delayed after the learning trial. Decrement plotted against delay of ECS yields a negatively accelerated curve. This finding has been confirmed (Thompson, 1958). It may be objected that decrement is a result of avoidance conditioning, but it would be difficult to explain the effect of long-delayed shock in this way. Thompson has reported single-trial attenuation effects even with ECS delayed up to 60 minutes. Gerard (1955) has found that lowering body

temperature /

temperature increases the period during which ECS may produce decrement. Cool hamsters, according to Gerard, show asgreat a disruption of a learnt response when ECS is delayed one hour as warm hamsters do when ECS is delayed only 15 minutes. EEG records show that brain processes are slowed down when body temperature is lowered.

There is evidence that separate parts of the brain act in long-term and short-term memory. The hippocampal zone of the brain underlying the temporal cortex is essential in recent memories, but not in distant memories (Penfield, 1955). The locus of permanent memories is not known.

From this review, it appears that the perseverative theory of memory has some evidence to support it. The physiological hypothesis that reverberatory circuits may carry perseverating processes is not implausible.

8.8 Summary of the Effects of Delay

Various theories do not agree on what happens to the trace with the passage of time. Some theories hold that the trace is permanent, and some that it decays. If we examine the various views outlined above to discover what sort of effect delay might have on a trace, we see that there are differences.

According to Köhler, the stimulus-excitation process increases for about three seconds and then declines. With an increasing length of stimulation, there would be an increasing satiation, impeding the process aroused by stimulation. We could, therefore, expect a decline in the strength of the trace with increased stimulation. For all signal lengths above three seconds (to be on the safe side) we should expect level of reproduction to be lower when response is immediate than when it is delayed. The longer the signal, the more persistent the satiation effect might be expected to be. Obviously, if we preferred to use the term "inhibition" instead of "satiation", it would not change our account of the immediate effects.

According to Piaget's Theory of Transports, the greater the

length of /...

length of time separating the standard from the comparison, the more it should increase subjectively. It is possible that this increase would be reflected in a higher reproduction score, where the subject has to judge a time interval. Therefore, the same prediction may be made from this theory as from the Gestalt theory.

By a circuit theory we should expect either a constant level of reproduction or a decline, depending on the time it takes for the circuit to reduce activity. But, according to perseveration theory there should be an increase in response as the memory trace is consolidated (Muller and Pilzecker, 1900). This is difficult to explain purely by circuit theory, unless one assumes that a circuit will involve more and more neurones as it continues to act, or that traces carried by the circuits are not as readily available as traces permanently stored, or that continued action facilitates transmission across synapses and enlarges the trace.

With the exception of pure circuit theory, therefore, all the theories predict a rise in the level of response with short periods of delay. It would be important to add evidence in support of one or other of these groups of theories by experiment.

8.9 Reproduction of Time and Memory

Reproduction of time signals of various lengths under various conditions of delay might be an accurate way of studying immediate memory.

Marianne Frankenhaeuser (1959) has conducted a number of experiments linking judgement of time and memory. She has shown that the retention quotient of estimate of past time over present-time estimate is less than unity, which would be expected in terms of a fading trace theory. In her experiments, subjects were asked to move a strip with randomised digits at a rate of one per second, reading the numbers aloud to prevent counting. The number of digits read within a given time gave the present-time estimate. Subjects were then asked to estimate the length of time elapsed. This gave the past-time estimate. An obvious flaw in this experiment is that

two different /...

two different methods of judgement are used. We have shown at length that different methods of time judgement do not yield results which can be readily converted into each other.

Another fact which has to be remembered is that, generally, in memory experiments, content has to be correctly remembered. In time judgements, it is quantity that has to be remembered. The accuracy of reproduction may give a better index of the strength of the trace than the length of the estimate.

Frankenhaeuser has also shown that time judgements shortened under barbiturates and lengthened under metamphetamine and caffeine, which affect memory in opposite ways. Barbiturates decrease memory and metamphetamine and caffeine increase memory. Her prediction that decreased memory is associated with a lower time judgement is met.

A reason for using reproduction of time as a measure of the strength of the stimulus-interval trace is that very fine distinctions may be recorded by the subject. The method seems suited to reflect rather sensitively any changes in the trace.

For this reason it was decided to essay a measurement of the strength of the trace by reproduction of time signals of various length after various intervals of delay. By using one method only - the method of reproduction - a more accurate check on Frankenhaeuser's hypothesis could be made. It will be noticed that Frankenhaeuser's results show that the trace fades - if we can accept her result as being an accurate reflection of trace strength. This is contrary to what we should expect in terms of satiation theory, the transport theory, and perseveration theory. In terms of recurrent circuit theory we should expect a constant level of activity to be maintained for a long period. The interesting results obtained by Frankenhaeuser seem to be contrary to what most theories predict, at least for short periods. In terms of gestalt theory, circuit theory, and perseveration theory, there may be a decline in the long-term strength or availability of the trace, but this should not occur in measurements of immediate recall.

8. 10 Experimental Measurement of Reproduction of Time After Delay

The experiment was undertaken to ascertain whether the trace left by the stimulus-interval does, in fact, decline with very short periods of delay. One method, the method of reproduction, was used throughout because of the difficulty of converting one form of time judgement into another.

8. 10. 1 Experiment

The first-session data of Experiment 2, described in detail in Chapter 3, were used. Briefly, 77 men and women reproduced each signal twice by the method of linear movement in the first session. The signals were 1 sec., 2 sec., 4 sec., 8 sec. and 16 sec., and were presented to alternate subjects in ascending or in descending order. Firstly, each subject reproduced all the signals immediately. Secondly, each subject reproduced each signal after a short delay, according to the delay group into which he fell. There were 7 delay groups (0 sec., 5 sec., 10 sec., 15 sec., 20 sec., 30 sec., and 60 sec.), each consisting of 11 subjects. Each subject fell into one delay group only, and did not reproduce the time interval at other periods of delay. The average score of each delay group could therefore be compared with the average scores of all the other groups under delay, as well as with its own immediate reproduction average. In all cases, it could be assumed that the serial position effects would be the same.

For reproduction of time interval after delay, the experimenter gave a vocal signal that the period of delay had elapsed and that the subject should commence his reproduction.

To make absolutely sure that the grouping of the subjects is clear, a table of allocation is given below.

Table 32 /...

TABLE 32

Allocation of subjects in the first session of Experiment 2. All groups consist of 11 subjects.

Group	Delay of first set of reproductions	Delay of second set of reproductions
I	0 sec	0 sec.
II	0 sec.	5 sec.
III	0 sec.	10 sec.
IV	0 sec.	15 sec.
V	0 sec.	20 sec.
VI	0 sec.	30 sec.
VII	0 sec.	60 sec.

8. 10. 2 Results:- Effects of Delay on Reproduction

The full reproduction scores in seconds are listed in Appendix B, Tables VIII to XII. Intra-individual ratios of delayed reproduction score over immediate reproduction score were also calculated and are listed in Tables XLV to XLIX. By means of the raw scores, one delay group could be compared to another without taking into account very large deviations in reproduction time. But, since, the groups were small, it was felt advisable to eliminate very large individual differences. This was done by the ratio scores. Both sets of scores were used in comparing different delay groups.

The mean reproduction time at each length of signal against each interval of delay is shown below in the text Table 33.

TABLE 33

Mean time (in seconds) reproduced at each interval of delay and length of signal in Experiment 2

Signal (in seconds)	Delay (seconds) 0	5	10	15	20	30	60	Means of Means
1.0	0.99	0.90	1.04	0.96	1.19	1.20	1.24	1.08
2.0	1.86	1.52	1.77	1.78	2.43	2.05	2.28	1.95
4.0	3.32	2.63	3.11	3.24	3.82	3.25	3.32	3.18
8.0	6.46	4.67	5.75	5.72	7.09	5.89	6.30	5.99
16.0	13.05	8.90	12.12	12.23	13.66	12.24	12.74	12.13

An inspection /...

An inspection of this table does not show any trend, but an analysis of variance was made to eliminate all doubt. The method for discovering any significant trend is that of Lindquist (1947). The results of this analysis are shown below.

TABLE 34

Variance of delayed reproduction of time intervals, using raw scores

Length of signal	Sum of squares		d.f.	F ratio
1 sec.	among groups within groups	1.15 1.38	6 70	1.38
2 sec.	among groups within groups	6.71 25.70	6 70	3.05+
4 sec.	among groups within groups	8.11 67.91	6 70	1.39
8 sec.	among groups within groups	37.46 255.04	6 70	1.71
16 sec.	among groups within groups	154.29 1051.82	6 70	1.71

+ significant at 5% level

The only significant trend is at 2 seconds. If we examine the scores in Table 33 we see that there is a bowed curve, reaching a minimum at 5 sec. delay and a maximum at 60 seconds' delay. This appears to be a common trend among the scores, though reproduction of 2 seconds is the only one with an overall significant trend. But we are interested in the details of the curve as well as in the overall trend. It is possible that there might be parts of the retention curve which are significantly different from other parts without there being an overall trend of significance. For this reason, t tests of the significance of the differences among all the means at each signal length in Table 33 were calculated. By inspection of the means in Table 33 we can see that in every instance the mean reproduction time at 5 seconds delay is lower than at any other delay. The results of the t tests show that reproduction of time at 5 sec. delay is less than at 60 sec. delay for all signal lengths except 4 sec. (1 sec., $p<.05$; 2 sec. $p<.01$; 8 sec. $p<.05$; 16 sec. $p<.05$) and less than at 20 sec. delay for all signal lengths except 1 sec. (2 sec. $p<.01$; 4 sec. $p<.05$; 8 sec. $p<.01$; 16 sec. $p<.01$). Reproduction of time

intervals at /...

intervals at the trough, which occurs at 5 seconds' delay, is generally significantly different from reproduction of time at the peak, which occurs at 20 or 60 seconds' delay.

A convenient way of showing up the bowed curve is to express all the means as quotients of the mean at zero delay. That is, all the means in Table 36 are simply expressed as quotients of the first (0 delay) column in the same Table. The results of this are shown below.

TABLE 35

Means of reproduced time expressed as ratios of the mean reproduction time at zero delay.

Signal	Delay in Seconds						
	0	5	10	15	20	30	60
1 sec.	1.00	0.91	1.05	0.97	1.20	1.21	1.25
2 sec.	1.00	0.82	0.95	0.96	1.31	1.10	1.23
4 sec.	1.00	0.79	0.94	0.98	1.05	0.96	1.00
8 sec.	1.00	0.72	0.89	0.89	1.10	0.91	0.98
16 sec.	1.00	0.68	0.93	0.94	1.05	0.94	0.98
Means	1.00	0.78	0.95	0.95	1.14	1.02	1.09

This brings out very clearly the minimum reproduction at 5 sec. delay rising to a maximum at about 20 seconds.

But though these figures suggest a bowed curve with a minimum at 5 seconds' delay rising to a maximum at 20-60 seconds' delay, they do not establish that there is such a curve. All the differences may be due to the presence in these groups of high or low reproducers of time intervals. One or two such individuals might, where such small groups are used, shift the mean significantly, regardless of the delay effect. For this reason, the individual delay scores were divided by the immediate reproduction scores. These were then totalled, and the means are shown below. It must be clear that individual quotients were calculated for each subject.

TABLE 36

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TABLE 36

Means of delayed reproduction scores expressed as quotients of immediate reproduction scores at each interval of delay and length of signal.

Signal	Delay in seconds						
	0	5	10	15	20	30	60
1 sec.	1.08	1.25	1.15	0.98	1.22	1.20	1.38
2 sec.	0.93	0.86	0.98	0.99	1.07	0.95	1.40
4 sec.	0.92	0.93	0.99	0.95	0.95	0.93	1.03
8 sec.	1.01	0.79	0.91	0.90	0.88	0.94	1.15
16 sec.	1.16	0.94	0.95	0.93	0.99	1.08	1.24
Average.	1.02	1.96	1.00	0.95	1.02	1.00	1.24

An inspection of these results does not appear to add much weight to our hypothesis that there is a bowed curve in the delayed reproduction scores. They were, nevertheless, subjected to analysis of variance to see whether any overall trends of significance could be found. The results of the analysis are shown below.

TABLE 37

Analysis of variance of delay quotients in Experiment 2.

Signal	Sum of squares		d.f.	F ratio
1 sec.	among groups	0.94	6	
	within groups	17.45	70	0.63
2 sec.	among groups	2.1	6	
	within groups	14.7	70	1.67
4 sec.	among groups	.04	6	
	within groups	5.27	70	0.00
8 sec.	among groups	1.02	6	
	within groups	6.05	70	1.97
16 sec.	among groups	1.00	6	
	within groups	7.23	70	1.62

None of the trends is significant. Furthermore, examination of Table 36 shows that the maxima and the minima are hot consistently placed, though on the average the minimum is still at 5 seconds' delay and the maximum is at 60 seconds' delay. Calculation of t tests of the significance of the differences among all the means at each length of signal shows that at a delay of 5 seconds reproduction is significantly less than at a delay of 60 seconds when the length of signal is 2 seconds, 8 seconds and 16 seconds ($p < .05$).

The evidence /

The evidence favours the view that reproduction of time remains at a constant level with delays up to the limits of those studied in this experiment. The few significant differences would be a very slender foundation for the hypothesis that there is a bowed curve in the reproduction time, reaching a minimum at 5 - 15 seconds' delay. But acceptance of either of these possibilities means that our results are not in agreement with those of Frankenhaeuser. Possible explanations will be considered later in the present chapter.

8. 10. 3 Results:- Effects of Delay on Accuracy.

The amount of error in the reproduction score was taken as an index of accuracy. All errors were converted to proportions of the total time signal, so that they would be easily comparable, irrespective of signal length. The full scores for proportion of error in linear movement reproduction are listed in Appendix B, Tables L to LIV. The mean proportion of error at each length of signal and interval of delay is shown in the test below.

TABLE 38

The mean proportion of error at each length of signal and interval of delay in Experiment 2.

Signal	Delay in Seconds						
	0	5	10	15	20	30	60
1 sec.	.26	.23	.23	.29	.48	.42	.33
2 sec.	.17	.25	.17	.29	.32	.34	.26
4 sec.	.18	.33	.24	.22	.17	.29	.28
8 sec.	.21	.42	.28	.31	.20	.30	.23
16 sec.	.18	.45	.28	.26	.22	.34	.20
Mean	.20	.33	.24	.27	.28	.34	.26

The maxima and minima of error are not to be found with great regularity at any particular delay interval. The maximum error in reproducing 1 second occurs at 20 seconds' delay; 2 seconds occurs at 30 seconds' delay; and 4 seconds occurs at 5 seconds' delay; 8 seconds occurs at 5 seconds' delay; and 16 seconds at 5 seconds' delay. The minimum error in reproducing 1 second occurs at 5-10 seconds' delay;

2 seconds /...

2 seconds at 0 seconds' delay; 4 seconds at 0 seconds' delay; 8 seconds at 20 seconds' delay and 16 seconds at 0 seconds' delay. If one has to generalise, one should say that the minimum error appears to occur when reproduction is immediate, and maximum error when reproduction occurs after 5 seconds' delay. This is reflected in the means of the means, with the exception that at 30 seconds' delay the proportion of error is as high as at 5 seconds' delay. An analysis of variance was conducted to discover whether there are any significant overall trends. The results are shown in Table 39.

TABLE 39

Variance of error in delayed reproduction of time intervals in Experiment 2.

Signal	Sum of squares		d.f.	F ratio
1 sec.	among groups within groups	0.47 4.81	6 70	1.13
2 sec.	among groups within groups	0.32 2.73	6 70	1.36
4 sec.	among groups within groups	0.23 2.78	6 70	0.96
8 sec.	among groups within groups	0.36 1.77	6 70	2.4+
16 sec.	among groups within groups	0.542 2.784	6 70	2.27+

+ significant at 5%

There is a significant overall trend of error against delay in reproducing both 8 and 16 seconds, both of which exhibit the hypothetical trend of minimum error at 0 delay and maximum error at 5 delay very strongly. If t tests of the significance of differences between particular delay groups are calculated, then the proportion of error in reproducing 8 seconds may be shown to be greater at 5 sec. than that at 0 sec. delay; 20 sec. delay; and 60 sec. delay (all at the 5% level of confidence). The proportion of error in reproducing 16 seconds may be shown to be greater at 5 sec. delay than at 0 sec., 20 sec., 60 sec. delay (at the 5% level of confidence), and than at 15 sec. delay (at the 1% level of confidence).

The finding that error is minimal at 0 sec. delay is understandable. /...

understandable. The finding that error is maximal at 5 seconds' delay agrees with satiation theory. A more complete discussion of all results will be conducted later in this chapter.

8. 10. 4 Results:- Effects of Delay on Speed of Movement

All the scores for speed of linear arm reproductions are listed in Appendix B, Tables XXII to XXVI. The means were calculated for each length of signal and interval of delay and are shown below.

TABLE 40

Mean speed of linear arm movement in reproducing each length of signal at each interval of delay in Experiment 2 (scores in inches/second).

Signal	Delay in seconds						
	0	5	10	15	20	30	60
1 sec.	7.7	6.7	10.6	8.5	7.6	9.5	5.7
2 sec.	8.4	7.4	10.5	8.7	7.5	9.7	7.0
4 sec.	7.6	8.0	11.0	9.5	7.5	8.9	7.0
8 sec.	7.2	8.5	10.1	8.8	7.7	8.9	7.0
16 sec.	7.6	8.1	11.1	9.3	6.7	8.4	7.7
Mean	7.7	7.7	10.7	8.9	7.4	9.1	6.8

The maximum speed in this table occurs consistently at 10 seconds' delay and the minimum occurs consistently at 60 seconds' delay. An analysis of variance was computed to see whether any overall differences are significant. The source of variance in the table below, which summarises the results of the analysis, can only very rashly be said to be delay. A glance up each of the columns reminds us of the stability of speed, and of its resistance to extraneous influence. The t tests of the significance of differences among means show that only one difference (60 seconds' delay and 10 seconds' delay in reproducing 1 second) is significant.

TABLE 41

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TABLE 41

Variance of speed in delayed reproduction of time intervals in Experiment 2.

Signal	Sum of squares		d.f.	F ratio
1 sec.	among groups within groups	177.2 2030.6	6 70	1.02
2 sec.	among groups within groups	108.5 2163.8	6 70	0.59
4 sec.	among groups within groups	132.0 2175.7	6 70	0.71
8 sec.	among groups within groups	78.9 1900.0	6 70	0.48
16 sec.	among groups within groups	133.0 1971.0	6 70	0.79

No significant overall trends are found.

A further analysis of the possible effect of delay on speed was attempted by calculating intra-subject quotients of delayed reproduction over immediate reproduction. These subject quotients were calculated individually for each subject, using only his own scores. It was argued, as with the reproduction scores, that large individual differences might obscure any trends which might occur. A full list of the calculated ratios may be found in Appendix B, Tables LV to LIX.

These quotients were summed and averaged for each length of signal against each interval of delay. The results are summarised in Table 42 below.

TABLE 42

Means of delayed speed scores expressed as ratios of immediate speed scores at each interval of delay and length of signal in Experiment 2.

Signal	Delay in seconds						
	0	5	10	15	20	30	60
1 sec.	.91	.89	.99	.89	1.15	.77	.71
2 sec.	1.14	.97	1.05	1.05	1.01	1.00	0.80
4 sec.	1.10	1.16	1.08	.94	1.08	.98	.98
8 sec.	.96	1.13	1.05	1.11	1.23	1.02	.82
16 sec.	1.07	1.05	1.06	1.04	1.34	.93	.91
Mean	1.04	1.04	1.05	1.01	1.16	0.94	0.84

These/...

These quotients show that maximum increase in speed with delay occurs three times at 20 seconds (signal lengths 1 sec., 8 sec., and 16 sec.), once at 0 delay (signal length 2 sec.) and once at 5 seconds (signal length 4 seconds). The highest mean is at 20 seconds' delay. The lowest quotient is consistently at 60 seconds' delay.

If t tests are calculated to see whether any of the differences between groups are significant, then the groups showing the maximum quotient (the 20 seconds' delay group) may be shown to differ significantly from the minimum quotient group (the 60 seconds' delay group) when signal lengths are 1 second ($p < .01$), 8 seconds ($p < .01$), and 16 seconds ($p < .05$). The only other significant differences are between the 20 seconds' delay group and the 30 seconds' delay group for signal lengths 1 sec ($p < .05$) and 16 sec. ($p < .05$).

An analysis of variance was also calculated, to see if there were any overall trends, even though after the t tests there did not appear to be any possibility that significant overall trends could exist. The results of the analysis are shown below.

TABLE 43

Variance of speed quotients in Experiment 2.

Signal	Sum of squares		d.f.	F ratio
1 sec.	among groups within groups	1.40 9.17	6 70	1.78
2 sec.	among groups within groups	0.74 14.81	6 70	0.88
4 sec.	among groups within groups	1.47 10.33	6 70	1.66
8 sec.	among groups within groups	1.16 8.06	6 70	1.68
16 sec.	among groups within groups	1.32 15.43	6 70	1.00

These calculations show that, as expected, there are no overall differences of statistical significance among the groups.

On the basis of our analysis of the speed data, it may be tentatively accepted that there is a slight decline in speed at 30

to 60 /...

to 60 seconds' delay. Up to that stage, the quotients are almost identical. If one were to suppose that the speed of movement reflects, at least partially, the strength of the trace, then this would support a fading trace theory. But this is contradicted by both the error trend, which appears to be minimal at 60 seconds' delay and maximal at 5 seconds' delay, and the trend of the actual level of reproduction, which is maximal at 60 seconds' delay and minimal at 5 seconds' delay. If one takes the error trend to be inversely related to the strength of the trace, and the reproduction level to be positively related to the strength of the trace, then both these trends point to the same thing. The trace is weakest at 5 seconds' delay, but then grows stronger. This is contrary to the speed finding. We must conclude that the effect of delay on the speed of movement is not congruent with the effect of delay on reproduction of time signals and error in reproduction of time signals. Since there is considerable difficulty in interpreting the decline in speed at 30 seconds' and 60 seconds' delay, it will not be considered further.

8. 10. 5 Discussion

Whether we accept that there is a bowed curve in the reproduction scores, or whether we believe that the evidence for the curve is unsatisfactory and prefer to accept merely that there is no decline, the results are not in agreement with those obtained by Frankenhaeuser and do not support a fading trace theory of immediate memory.

The evidence that there is a bowed curve with a minimum at from 5 to 15 seconds' delay consists of both the raw scores and the quotients of delayed reproduction scores over immediate reproduction scores. The objection that might be raised against the raw scores - that the groups are small and that differences might be accounted for by sampling errors - can hardly be raised against the quotients, considered as evidence for the curve. But in both cases the tendency is slight only, and no statistically significant overall trends are discovered, except in the raw scores for reproduction of 2 seconds,

where the /...

where the F ratio of 3.05 is significant at the 5% level.

The evidence of error in delayed reproduction is congruent with the other evidence for a bowed curve. Maximum error is found to occur rather consistently at 5 seconds and minimum error at 0 seconds. The error at the terminal delay periods studied is less than the error at 5 seconds' delay which would be expected if the trace is, for some reason, weakest at 5 seconds' delay. The overall trend for error is found to be statistically significant at 8 seconds' and 16 seconds' signal length.

Nevertheless, both time reproduction and error in time reproduction do not show smooth curves when plotted against delay. The curves are so irregular that it is difficult to interpret them in a psychologically significant way. For this reason it seems best to accept that the figures provide us with evidence that reproduction of time and error do not decline within the short period of delay studied, but to avoid the hypothesis that there is a bowed curve until more satisfactory evidence can be produced.

In terms of theory, the bowed curve is also difficult to explain. This is not to say that data should be adapted to the convenience of existing theory, but that data ought to be fairly definite before we use them to contradict theory. Satiation effects cannot, for example, be used to explain the bowed curve. Satiation effects could be invoked as an explanation only if there were a constant rise in the level of reproduction or a constant decline in the level of error, within the period of delay in our observation. Then, we should be able to maintain that the original trace was impeded immediately after stimulation, but that it recovered as time elapsed after the stimulus was removed. The same sort of explanation might be made in terms of the constructs of excitation and inhibition (this goes back to Pavlov and has been maintained in detail by Eysenck (1956, 1957)). It is also expected that the inhibitory effect will be greatest immediately after stimulation. Therefore, the sort of curve expected would be a steady rise in the strength of the response. The Theory of Transports,

if applicable, /...

if applicable, would lead us to expect a steady rise as well. The perseveration theory, if maintained in the original manner of Muller and Pilzecker, who postulated an initial growth in the strength of the trace, would also be compatible with a steady rise in the strength of response and an increase in accuracy, but not with a bowed curve. In this theory, and in its later developments as reviewed in section 8.8, reminiscence effects were explained by a gradual consolidation of the trace, possibly in a self -facilitating neural circuit. As the recurrent circuit of the trace persists, facilitation across synapses might increase. But this theory has been criticised by McGeogh and Irion (1952) on several grounds, one of them being that it cannot account for the lack of difference between spaced and unspaced practice when recall is soon after the last practice. The argument here is that differences should be immediately apparent because perseveration should occur between spaced trials. But, whatever the status of the theory, it does not fully explain our results.

The only way in which our results may easily be explained, in terms of trace theory, is that the trace is carried by a recurrent circuit of constant strength. On this assumption, there is no difference between the initial and the final strength of the trace, and, therefore, no difference between the initial and the final response.

There is still another possibility. It is simply that the subject does not depend on a trace of the original signal in reproducing time intervals, especially when they are above a certain length. The subject may simply convert the signal into some symbolic form which is retained until the moment of reproduction.

But this brings us to an important criticism of Ekman and Frankenhaeuser's original (1958) experiment. In their comments on the data they assume that the trace representing the actual present-time interval is fading. In other words, it is not the number of times which the subject has called out a radomised digit which is being forgotten, but the actual period of time is gradually forgotten, as the trace representing it fades. When one examines the experiment reported by

them, and /...

them, and the various experiments reported by Frankenhaeuser (1959), one is struck by the fact that there can be no simple trace for the time interval. What the subject has to retain is, in fact, a very large amount of information which can enable him to form an accurate estimate. The process is really an extremely intellectual one. He reads out a certain number (up to 72) of randomised digits at a supposed rate of 1 sec, so that he is unable to count, and then has to attempt to asses how many seconds have elapsed. This requires the retention of a large number of separate responses, without the subject's being able to reduce them to code. The model which is appropriate to this experiment appears to be different from the model appropriate to the present experiment. For Frankenhaeuser's experiment, Broadbent's (1957) model of immediate memory appears to be appropriate. Broadbent represents immediate memory as a recurrent circuit of a certain capacity to carry information between input and rehearsal. If the circuit is loaded above a certain limit, some or all information is lost. On the other hand, if the information is within the limits of the circuit, there may be no loss at all, for long periods.

Now, the suggestion which I should like to make may be a rather obvious one, but it seems important. It is that retention of time will vary with the amount of information on which the judgement is based. Where the subject has to base his estimate on a large number of events presented in such a way that rehearsal of the events is delayed beyond the capacity of the system of immediate memory, then his judgement is likely to be extremely inaccurate since it will be made without a certain amount of the information necessary for an accurate judgement. In this way, one would speak not of a fading trace, but of loss of certain elements of that trace. One is not to picture a uniform interval contracting or attenuating, but a string losing beads - if one wishes for a concrete model. A question which arises is why the subject does not reach a maximum estimate of, say 15 seconds, and then go no further, no matter how much the period is increased. This is indeed the position one would find one's self in, if one adopted the position that the estimate of the time interval is based purely on the fading

trace of /...

trace of the stimulus (it may be interpolated that Frankenhaeuser is not quite clear as to whether it is the interval or the stimulus which fades). But this is not so. The subject has other cues to let him know that he sat for, say, thirty seconds rather than 60 seconds. He has felt fatigue, strain, and he has a vague impression of a larger or smaller number of events occurring. But exact information of the number of events (which presumably could only be based on an actual memory of all the randomised digits read aloud) has been lost.

It is clear from this that the subject will be less accurate in his estimate as the number of digits read is increased. It is not clear that the subject will necessarily make a lower estimate, though this is what Frankenhaeuser has found, unless one assumes that the only cue used is the number of events. As we have seen, this lands us in difficulties. There seems to be some obscurity here which has not been cleared up.

Where the subject is judging the duration of a continuous auditory signal, he is free to convert its duration into symbolic form and to base his future judgements of its duration on that, rather than on any trace of the original. This would, of course, make reproductions of such time intervals extremely stable, even where delay is considerable. Furthermore, where the subject is able to remember the time interval in terms of distance to be moved, as in our experiment, the stability of speed should ensure a constant duration.

From this we conclude that different explanations apply to retention of time judgements based on different information. It does not seem that a fading trace theory, if that trace is conceived of as uniform, can give a satisfactory account of either Frankenhaeuser's results or the results reported in this experiment.

8. 11 <u>Memory and Reproduction of Time</u>

As a further test of Frankenhaeuser's (1959) hypothesis that memory for perceived units and judgements of past time are related, a brief experiment was undertaken in which judgements of time were correlated with memory for nonsense syllables, audially presented.

8. 11. 1 Experiment

The subjects of this experiment were those who took part in Experiment 3, described in detail in Chapter 3. At the end of the second session in which they reproduced 8 seconds, they listened to a list of 15 nonsense syllables, presented at a rate of one per second. They were instructed to write down immediately, in their correct order if possible, as many of the nonsense syllables as they could remember. The nonsense syllables used in this experiment were:

BAZ	TUJ	KEF
SOM	FOD	RIN
GUK	PED	HAR
NAL	JEG	ZIB
LOD	DIX	MUB

8. 11. 2 Results

Correct serial position and total number of syllables correct were separately scored, and are listed in Appendix B, Table XLIII.

Correlations between both serial position score and total number of syllables correctly reproduced, and time judgements of 8 seconds by verbal estimate and controlled linear movements were calculated. The correlations are shown in Table 44 below.

TABLE 44

Correlations of memory for audially presented nonsense syllables and judgement of 8 seconds in Experiment 3.

	Content memory	Serial position
Reproduction time	-.07	+.12
Verbal estimate	-.08	-.14
Error in reproduction	-.11	-.23
Error in verbal estimate	-.00	-.23

The negative correlations between error in time judgement and serial position memory may be regarded as meaningful, even though statistically insignificant. These correlations support the hypothesis that memory may be related to accuracy of time judgement. But on the whole, the low correlations drive home the difference between memory for

structural material /...

x structured material and time judgements based on unstructured signals. In estimating time, the individual merely changes the quantity of his response. In remembering nonsense syllables, the subject must reproduce the details of the original. In judging time, the subject may rely very extensively on non-cognitive cues, such as rhythm. In remembering detail correctly, the subject cannot use these cues.

8. 11. 3 Conclusion

The differences between past-time judgements and memory for detail are too great for the two to be usefully compared, especially on a small scale. It is possible, though not well established, that in remembering longer periods of past-time, the amount of detail which can be recalled influences the judgement of the duration of these periods.

8. 12 SUMMARY AND CONCLUSIONS

After the discussion of various theories of memory, an experiment to measure reproduction of time at various intervals of delay is described. The results appear to show that a constant level of reproduction is maintained, within the limits of our observation. This contradicts Frankenhaeuser's (1959) view that estimates of past-time are based on a fading trace and ought to decline with lapse of time. There are differences between her experiment and that described here which may account for the differences in result, but it is concluded that a fading trace model is unsatisfactory to account for the decline in time judgement. Some subjects increase their time judgement after delay, nor is it clear how long the time estimate will continue to reduce as the original trace declines. Broadbent's (1957) model of immediate memory is preferred as an explanation of her results. The results of the present experiment appear to be best explained by a recurrent circuit theory, maintaining the trace at a constant level, or by the assumption that reproduction of the time interval is not based on retention of the signal at all, but upon the conversion of this signal into a symbolic form.

CHAPTER 9 / ...

PART IV

INDIVIDUAL DIFFERENCES IN THE JUDGEMENT OF TIME

There are very large and consistent differences in the reproduction of time by linear arm movements which must have their explanation in the organisation of the individual. Differences in personality are the most complex psychological product of these organisational differences between individuals, but they may be related to even relatively simple forms of behaviour, such as the adaptation of a response to an unambiguously presented time interval.

A dimension which apparently has many perceptual correlates is that of introversion-extraversion. The relationship of this dimension to time judgement is considered in Chapter 9.

Primary-secondary functioning, which is associated with inertia in the functioning of the nervous system, may also be related to time judgement (Chapter 10).

The role of motivation in time judgement has often been stressed. Manifest Anxiety, which has been treated as a drive variable with some success, might be found to be related to time judgement (Chapter 11).

A motivational variable which appears to be associated with a distinctive attitude to time is n Achievement. This attitude to time and the use of time may have effects on the judgement of short intervals (Chapter 12).

CHAPTER 9

EXTRAVERSION AND TIME JUDGEMENTS

9.I Introduction

A number of recent studies has shown that differences in personality are related to differences in time judgement. There is a number of these studies devoted to personality differences as they enter into other aspects of the experience of time, such as time perspective, but they will not be dealt with or discussed, except in passing. Only those personality differences which have been shown to be related to the judgement of short, accurately timed intervals will be considered.

9.2 Time Judgements of Mentally Ill Patients

When Loehlin's (1959) tasks were used to test the time judgements of schizophrenics, high variability in their verbal estimates of the time taken by the tasks was found (Guertin and Rabin, 1960). This suggests a functional disability in time estimation. But the question of sampling is a difficult one, in such an experiment. The "normal" subjects may have much more accurate concepts of time simply because they have to pay a great deal more attention to time in their daily lives than the institutionalised schizophrenics. If comparisons are to be made, it seems best to use non-verbal judgements.

The hypothesis has been set up that schizophrenics do not incorporate past experience in making time judgements to the same extent as do normals, and should therefore show less anchor effect (Weinstein and alia, 1958). Though it is not very clear what the grounds for the hypothesis are, it has been experimentally confirmed by the authors. The observation that the schizophrenic lives in an autistic world with relatively little reference to experience, and the fact that in sorting tests schizophrenics show themselves unable to form categories based on abstract relations, may be used as evidence for the above view. Using the method of ascending and descending limits, Lhamon and Goldstone (1956) showed that/.......

showed that schizophrenics overestimate a clock second more than normal subjects do. They reason that schizophrenics, who live in an autistic world, experience time with relative freedom from external restraint. The fact that they over-estimate the clock second (refer it to objectively longer stimulus) indicates, to the authors, that schizophrenics live in accelerated mental seclusion. But it seems that the authors are basing their conclusion on a very imperfect study. It is quite possible that the effects of institutionalisation rather than of schizophrenia are revealed. It has been shown that, "under conditions of sensory deprivation, verbal estimates of a given time interval tend to be low (Vernon and McGill 1963). Institutionalisation may function in rather the same way. One would hardly describe it as accelerating the mental world of the patient.

The use of verbal estimates has a limited value in studying experience of time. It tells us more about the accuracy with the subject uses time concepts that about his actual time experience. The experiments with mentally ill patients do not add very greatly to our understanding of the experience of time.

9.3 <u>Personality Differences Among Normal Subjects and Time Judgements</u>

The hypothesis has been advanced that a person who verbally overestimates time may exhibit low inhibition generally (Thompson et alia, 1960). These authors find a low but consistent correlation between time estimation and motor inhibition. Relative underestimation of time (delay in telling the experimenter when a period of 15 sec., 30 sec., or 60 sec. has elapsed) is positively related to intelligence (Spivack et alia, 1959). They advance as an explanation of this the possibility that delay in gratification in childhood may be responsible for the development of cognitive processes which support inhibition or delay in the expression of an impulse. The assumption appears to be that intelligent subjects experience greater delay of gratification in childhood, or carry the results of delay in childhood gratification over into adult life to a greater extent than less intelligent subjects. This seems to be a new theory of intelligence.

It is far/............

compared to the sharpener-leveller dichotomy, nothing in the experimental

x work actually demonstrates that there is anything more than surface similarity.

No items/...........

No items common to both dichotomies have been included in an experiment. But the study of cognitive style in relation to time judgement may be well worth while. The work of Gardner and others (1960) on four methods of cognitive control related to perceptual tasks might be profitably applied to studies of time judgement, especially of short intervals which may come under the heading of perception (Fraisse, 1957). The four methods of cognitive control which appear to have been established are given below. The first is levelling versus sharpening, which may be defined as the readiness of the subject to accurately judge a change in stimulus. Levellers are more passive and dependent, tending to drift, or to retreat inwards; but sharpeners are active, agressive, and competitive. Levellers appear to use repression as a preferred method of ego-defense. The second cognitive style is field articulation, or the degree of field dependence versus independence (Witkin, 1954). It may be defined as the selectiveness of the subject in actively directing his attention to significant features of the field. The field-dependent subject, compared to the field-independent subject, shows little selectivity. The third method of cognitive control is scanning control, or the degree of deployment of attention of which the subject is capable. It is thought to relate to the ability to isolate thought from emotional influence. The fourth cognitive control is the ability to tolerate unrealistic experiences, which is thought to relate to the ability to harmonise subjective motivations (ideas) and objective reality. These various cognitive controls may be found to relate to time perception under various conditions. For example, in emotion-provoking situations, the time judgements of subjects who are higher on scanning control may show less alteration. Subjects who are higher in levelling should show greater anchor effects in time judgements. Subjects who are more field-independent might be expected to show less spatial effect on time judgement. If a further step can be taken, and reliable personality correlates of cognitive styles are found, the study of personality differences in perception will certainly enter a more fruitful era.

Perceptual/.............

Perceptual tendencies which have been established in other tasks might also be investigated in the judgement of time. For example, Angyal (1948) has shown that obsessive patients tend to be very accurate in visual perceptual tasks, but anxious and hysterical patients tend to be variable and inaccurate. It might be possible to establish the same relations in time judgements by various methods.

Unfortunately, this whole area of cognitive control as related to time judgement has not been explored.

Another study of personality differences entering into verbal estimates of longer periods of time has been conducted by Orme (1962) Unprepared verbal estimates of 30 minute and 20 minute filled intervals were made by patients and normal controls. He found that hysteric and psychopathic patients made longer estimates than normal controls, but neurotic and psychotic depressives gave shorter estimates. The normal groups completed the Maudsley Personality Inventory of extraversion and neuroticism but no relation was found between neuroticism or extraversion and time estimation. This indicates, prima facie, that the mental or subjective time of hysterics and psychopaths proceeds more rapidly in relation to clock time than the subjective world of neurotic or psychotic depressives. But, as we have already remarked repeatedly, there may be large differences in the accuracy with which subjects use verbal concepts of time. If the argument is tendered that there is no reason to suppose that one or other of these groups paid, on the average, more attention to clock time than any other, then the rejoinder is: that being the case, all should be equally capable of matching individual rate of flow and clock rate. It is never satisfactorily cleared up in these studies whether concepts of clock time or experience of time are being studied.

In the present/............

In the present chapter, one further personality factor which seems to enter into time judgement will be discussed. This is the personality dimension of extraversion-introversion.

In subsequent chapters, other personality factors will be discussed.

9.4 The Concept of Extraversion- Introversion

Jung (1923) postulated two major attitudes of the libido: an introverted attitude, in which the libido turns inward to the self, and an extraverted attitude, in which the libido turns outward to the external world. The extravert and the introvert are further defined, according to Jung, by reference to four styles: thinking, feeling, sensation and intuition. The thinking extravert is governed by practicality and necessity, the thinking introvert by absolute principles. The feeling extravert tends to have a powerful but rather coarse emotional expressiveness, but the feeling introvert is characterised by a delicacy, restraint, and distinction of feeling. The sensational extravert searches for new contacts with the environment via exteroceptors and the skeletal musculature, but the sensational introvert may resort to drugs or drink, obtaining his sensation by alterations of the internal environment. The intuitive extravert may take to games of chance or indulge in risky undertakings to obtain success, but the intuitive introvert tends to mysticism. This is, of course, a very condensed and crude account of Jung's typology, which he develops at some length with many niceties.

Jung's typology has lead to many scales purporting to measure the dimension of extraversion-introversion. An early scale based on this dichotomy classed all introverts and all extraverts together, without paying attention to the styles which Jung had carefully described (Heidbreder, 1926). A factor analysis of the Heidbreder scale yielded five factors - social introversion, thinking introversion, depression, cycloid tendencies, and rhathymia (Guilford, 1940).

A still later/...........

A still later version reintroduces Jung's original distinction of thinking, feeling, sensation and intuition (Myers and Briggs, 1961).

9.5 Eysenck's Theory of Extraversion-Introversion

In a large number of books and articles Eysenck has studied the perceptual, learning, and motor corollaries of the dimension of extraversion-introversion. He has developed a test (which will be described in more detail shortly) based on the Guilford factor of rhathymia ("happy-go-lucky"). Most of his studies have involved the classification of subjects according to Guilford's Rhathymia Scale, which is part ~~III~~ of the Inventory of Factors S.T.D.C.R. (1940), or according to the Maudsley Personality Inventory, to a great extent based on the Guilford R Scale, or according to diagnosis as hysterics and dysthymics, where neurotics are used as subjects. This is in accordance with his hypothesis (so firmly held that it is the groundwork of much of his experimental work) that hysterics are extraverted neurotics and dysthymics are introverted neurotics. Generally, the M.P.I. is also administered to the neurotic groups, to demonstrate that they do differ in extraversion. The possibility, that neuroticism and extraversion might interact is ignored, but more will be said of his use of neurotics as criterion groups.

Eysenck's theory of the perceptual correlates of extraversion-introversion is of interest to us for the clear predictions which it makes. He has stated his Typological Postulate so clearly that there can be no doubt (Eysenck, p.114 1957), and in so doing he has performed a service to our thought. One of the methods of science is to limit the possibilities until one has a certainty which can be disproved (or, more rarely, proved!). The Typological Postulate states that extraverts generate excitatory potential weakly and slowly, and reactive inhibition strongly and quickly; but introverts generate excitatory potential strongly and quickly and reactive inhibition weakly and slowly. In a recent revision of these hypotheses (Eysenck, 1962), two are retained, but a third is dismissed. The two maintained are that (a) extraverts

generate reactive/.......

generate reactive inhibition more rapidly and (b) extraverts dissipate reactive inhibition more slowly. The third, rejected hypothesis, is that extraverts generate a greater amount of inhibition. It will be noticed that nothing further is said about the generation of excitation. But, even assuming that equal amounts of excitation are generated by extraverts and introverts, the perceptual corrolary remains the same.

It has been shown that extraversion is related to judgement of time. Eysenck, (1957), following his practice of using hysterics and dysthymics as criterion groups representing, respectively, extraverts and introverts, has shown that extraverts under-reproduce a time signal as compared to introverts. This was originally explained as a consequence of both weaker excitation and stronger inhibition more rapidly generated among extraverts, but the revised explanation would not doubt be that extraverts develop inhibition more rapidly and dissipate it more slowly than introverts. The possibility that neuroticism and extraversion might interact is not considered, although this possibility is illustrated by the results of Wallach and Gahm (1960), who found that extraverts tend to produce larger drawing than introverts, but that the result is reversed when anxious introverts and anxious extraverts are tested. Data from the manual of the M.P.I. and from articles about the M.P.I. (Eysenck, 1959) show that the conditions for such an interaction are favourable. It is found that neuroticism and extraversion are not significantly correlated among normals (-.I), as is required if the two are to be used as orthogonal dimensions, but that they are significantly correlated in neurotic populations (-.3 to -.4). The latter correlations are very high, and seriously point to possible reversal effects such as those in the Wallach and Gahm experiment. It is quite possible that, where normal subjects are used, the results obtained by Eysenck might be reversed.

There is another experiment which tends to bear out Eysenck's result, though, and it was obtained with normal subjects. Lynn (1961) obtained 10 time judgements from 20 extraverted and 20 introverted students, using the method of positive feedback (Llewellyn, 1959).

By this/............

By this method, each subject starts with the same standard time signal, but in the next trial the response to the first trial is used as the time signal. In each successive trial, the response of the previous trial is used as the signal. In this way, any trends which may exist are emphasised. It was found that significant differences between extraverts and introverts began to emerge after the 6th trial, whereas Claridge (1960) and Eysenck (1957), using neurotic criterion groups, had found significant differences after the first trial. The differences found by Lynn were in the direction predicted by Eysenck. These findings appear to support Eysenck's theories.

There is also a considerable amount of support for Eysenck's views to be found in other perceptual experience. Extraverts have been found to exhibit greater tolerance for pain than introverts (Lynn and Eysenck, 1961). In judging intensities of sound by the method of comparison, extraverts tend to adjust the second sound to a lower level of intensity than introverts (Eysenck, 1957). Hysterics show greater kinaesthetic after-effects than dysthymics(Eysenck, 1957). Kinesthetic after-effect is explained as an inhibition (satiation) effect. In their study of 12 brain-injured patients, Klein and Krech (1952) found that brain-injured patients showed greater kinaesthetic after-effects. The authors attributed this to their reaching satiation more quickly and more intensely, and to the greater persistence of satiation effects among brain-injured patients. Jaffe (1954) repeated the study without being able to find the same effects. This tends to throw some doubt on the concept of basal cortical inhibition of Klein and Kresch, and on the identification of this doubtful concept with Eysenck's concept of a central process of inhibition.

In a replication of some of Eysenck's work, using normal subjects classified on the Guilford R Scale, Rechtschaffen (1958 and 1960) was unable to find some of the results obtained by Eysenck. In Rechtschaffen's 1958 study, he was unable to find any differences between

extraverts and/.....

extraverts and introverts on reactive inhibition or visual after-effects. In the 1960 study by Rechtschaffen, he was unable to find differences in kinaesthetic after-effects. Broadbent (1961) used hysterics and dysthymic in a study of kinaesthetic after-effects, but found no differences.

There is some ambiguity about the role which inhibition might be expected to play in kinaesthetic after-effects. One could easily argue that extraverts, in whom the original excitation is most rapidly reduced by inhibition, should show less after-effects than introverts, in whom the original excitation persists longer. It is only the attempt to identify satiation and inhibition that leads to this problem. But now we begin to see that there is some doubt about what is actually meant by inhibition. For this reason, we should specially consider the matter in some detail.

9.6 Eysenck's Concept of Inhibition

Eysenck (1955) subsumes three distinct concepts in his concept of cortical inhibition: satiation, reactive inhibition, and basal cortical inhibition.

The concept of satiation was developed to explain the effect of perception on subsequent perception (Köhler, 1940; Köhler and Wallach, 1944). The concept of satiation is similar to that of electrotonus: an electro-current flowing in a medium alters the state of that medium in such a way as to impede the current flowing through the medium. It is postulated that an electrochemical current is set up in the cortex during stimulation which has a topological relation to the object-pattern giving rise to the stimulation. This topological pattern, which preserves the relationships of the object-paths, is altered by polarisation effects during stimulation. It is this impedance, or alteration of the cortical medium, which leads to satiation. Now, if we were to attempt to explain Eysenck's concept of inhibition on the same model, we should arrive at a conclusion which contradicts his Typological Postulate. It should follow from this model that the more intense the excitation, the stronger the current.

The stronger/.........

The stronger the current, the more rapidly alteration of the medium in which the current flows would occur. If we assumed that introverts developed excitation more rapidly or strongly, then it would follow that they would satiate more rapidly. This is, of course, the opposite of Eysenck's prediction. In his revised (1962) version of the Typological Postulate, the process of excitation is omitted altogether, so that it is not clear whether it is still to be included in his theory. But, in the Köhler theory,satiation is pictured as a consequence of excitation. The one is quite specifically the consequence of the other. This is the sense in which the term satiation is used. Satiation is a consequence of excitation. It is the sense in which the term is used in experiments on kinaesthetic after-effects, which are used as evidence for the Typological Postulate. Yet it is clear, in the Typological Postulate, that excitation and inhibition are seen as two separate and independent processes.

X The second inhibition construct subsumed by Eysenck is that of reactive inhibition, adopted from Hull (1940). Reactive inhibition is measured by the effect which a muscular response has on a subsequent muscular response. Hull theorises that whenever any action is evoked in an organism, there remains a condition (IR) which acts in a manner similar to primary negative drive, reducing the activity which produces the state. Eysenck (1956 and 1962) has produced evidence that extraverts X show greater reminiscence effects on pursuit rotor tasks, and attributes this to the dissipation of inhibition. Extraverts develop inhibition more rapidly during performance, level of performance rises more slowly because practice effects are obscured by reactive inhibition, and reminisence effects are stronger because more inhibition has accumulated to dissipate during the rest period. It is obvious that the more intense the activity, the greater the amount of reactive inhibition. Is this purely because greater intensity of activity leads to greater cortical excitation? If so, why do introverts not show more inhibition, since they develop excitation more strongly?

The third/.............

The third concept of inhibition subsumed by Eysenck is that of basal cortical inhibition, which was used to account for differences in rate of conditioning (Franks, 1956; 1957). It should be distinguished from the concept of basal cortical conductivity, which is measured by satiation effect (Klein and Krech, 1952). In Franks' (1956) experiment, 20 hysterics (extraverts), 20 normal subjects, and 20 dysthymics (introverts) were subjected to eyelid response conditioning. Dysthymics conditioned more rapidly than hysterics, as predicted by Eysenck's theory. The normals were intermediate. In Franks' subsequent (1957) experiment, 55 normal, paid, male, undergraduate volunteers were graded on the M.P.I. scale of extraversion. Significant negative correlations were found between the speed of acquiring the defensive eyeblink response, speed of extinction of the response, and extraversion. Franks abandoned his concept of basal cortical inhibition and adopted Eysenck's unified construct of inhibition as an explanation. But, if it is true that introverts condition more easily, why do they not tend to learn everything more quickly? There is nothing in the Typological Postulate to limit the field within which introverts will not be superior to extraverts in learning. But it is an extremely unlikely prediction that extraverted persons are necessarily more ignorant than introverted persons. It may also be added that Field and Brengelman (1956) found neither extraversion nor neuroticism to be significantly correlated with eyelid conditioning. A variable which did correlate significantly, in their experiment, was rigidity.

All the above forms of inhibition are measured in different ways. There is no evidence that, within any individual, the different forms of inhibition are linked. There is no evidence that each of these concepts of inhibition in fact describes a unitary process. Finally, the relationship between each of these forms of inhibition and extraversion has as much evidence to oppose it as to support it. The only relationship on which there seems to be an encouraging degree of unanimity is that between reactive inhibition and extraversion.

A very careful experimental study by Becker (1960) illustrates the need to distinguish different types of inhibition. He/..

He tested the hypotheses that (a) individual differences in satiation and reactive inhibition are correlated; (b) individual differences in basal cortical inhibition are related to reactive cortical inhibition; and (c) individual differences in satiation, reactive inhibition, or basal cortical inhibition are related to individual differences in introversion-extraversion. Basal cortical inhibition was assessed by measuring GSR conditioning, aniseikonic distortion (with the hypothesis that extraverts should be less bound to past perceptual habits because of their greater cortical inhibition and therefore shift more rapidly), and critical fusion frequency. Satiation was measured by Archimedes spiral after-effect, and by kinaesthetic figural after-effect. Reactive inhibition was assessed by pursuit rotor reminiscence and speed of alternation of behaviour. The conclusion of this study is that satiation and reactive inhibition do not form unitary traits related to each other or internally consistent. Nor are they significantly related to extraversion, with the exception of pursuit rotor reminiscence, which correlates +.21 to +.22 with extraversion. One unitary factor, basal cortical inhibition, was identified, but it was not related to extraversion.

The study by McEwan and Rodger (1960), which confirmed that there is no unitary process of satiation to cover both visual and kinaesthetic after-effects has already been mentioned.

In a subsequent study, Eysenck and Claridge (1962) reaffirmed that hysterics and psychopaths are characterised by high neuroticism-extraversion, and that obsessives, depressives, compulsives and phobic patients are characterised by neuroticism-introversion. Using these criterion groups, tests of sedation-threshold, reaction speed, and spiral after-effects were conducted. Single-task analysis did not separate extraverts and introverts, but multiple discriminant function did. It is difficult to see why Eysenck continues to use neurotic subjects for his studies, since he wishes to generalise his results to cover non-neurotics.

He deliberately/...............

He deliberately introduces the factor of neuroticism, apparently satisfied that, because extraversion and neuroticism are orthogonal factors, they do not modify each other. The high correlation between neuroticism and extraversion in extreme populations is also ignored.

At this stage, the instrument which Eysenck uses in his classification of extraverts and introverts in normal and neurotic populations should be described. It is the Maudsley Personality Inventory.

9.7 The Maudsley Personality Inventory

There are two forms of the Maudsley Personality Inventory. These are, a short form (Eysenck, 1958) and a long form (Eysenck, 1956). Both have been used in the present experiments.

x The short form consists of the first twelve items of the long form. It has been standardised with a sample of 1,600 normals, equally divided as to age, sex, and class. The long form has been standardised with English and American normal subjects, hospitalised dysthymics, hospitalised hysterics, recidivists, hospitalised psychopaths, and hospitalised psychopaths.

According to Eysenck's theory, hysterics and psychopaths ought to be more extraverted than dysthymics. His standardisation tables show that this is so, by the M.P.I. Hysterics and psychopaths ought also, according to his theory, to be more extraverted than normal subjects, but the M.P.I. does not show this satisfactorily. Psychopaths are more extraverted than normals, but hysterics are not. Dysthymics are more introverted than normals, as demanded by his theory. Sigal, Star and Franks (1958) have argued that the failure to find a significant difference between hysterics and normals on extraversion means that hysterics cannot be used as a criterion group in studies of extraversion.

Since hysterics/..............

Since hysterics were also used as a criterion group in the construction of the scale, but are nevertheless not more extraverted than normals, this means that the whole scale is biassed in the direction of introversion. It may also mean that Eysenck's theory that hysteria is an extraverted neurotic condition is incorrect.

For this reason, as well as for the reason that neuroticism and extraversion may interact, hysterics and dysthymics cannot be accepted as criterion groups in experimental studies of inhibition if the results are going to used in formulating general laws to apply to the population as a whole.

For this reason, too, it is worth repeating Eysenck's work, using normal subjects.

9.8 Hypotheses

Following Eysenck, two hypotheses may be set up which can be tested with our experiment.

The first hypothesis is that extraversion and time reproduced are negatively related. This would be a satiation effect. This has been demonstrated by Eysenck (1957) and Claridge (1960), using hysterics and dysthymics as criterion groups. Lynn (1961), using the method of positive feedback, has shown the relationship with university students. A replication of this would be of value, if only because various experimenters testing Eysenck's hypotheses have arrived at contradictory results.

The second hypothesis set up for testing is that extraverts are more variable in their reproduction of time because of a more rapidly aroused inhibitory process. The evidence that this hypothesis is based on is rather flimsy. Canestrari (1957) found that perceptual rigidity is high in introversion, low in extraversion, but Becker (1960) failed to confirm this. On the other hand, perceptual constancy has been found low among introverts and high among extraverts (Ardis and Fraser, 1957).

Eysenck (1947)/..........

Eysenck (1947) reports more intra-subject variability among extraverts. Extraverts have also been found more inconsistent in such motor activities as car driving (Venables, 1956).

We have shown that inhibition as a general factor related to extraversion cannot be maintained in view of the failure to find evidence for a unitary process of inhibition. It remains important to test whether there are any particular processes of inhibition which can be related to extraversion. It is possible that Eysenck's theory may have no validity at all, or that its validity may be confined to the field of reminiscence effects in motor activity. Careful experimentation must establish the limits of the theory. Perhaps something valuable will remain.

A third hypothesis, not related to Eysenck's work, was also tested. It is the hypothesis that extraverts move further than introverts in reproducing time by linear arm movements. This is based on the demonstration by Wallach and Gahm (1960) that extraverts are more expansive than introverts in their drawings. There is also the general picture of the extravert as more outgoing, more inclined to "let himself go", more expressive in gesture, to justify this hypothesis.

A fourth hypothesis, that extraverts move more quickly than introverts in reproducing time intervals by linear arm movements, is justified by such items in the M.P.I. as

(5) Are you inclined to be quick and sure in your actions?

If the "quick and sure" picture of the extraverts is true, then he ought to move further and faster in reproducing time signals.

9.9 Experiment

9.9.1 Subjects and Method

The data of 54 subjects who filled in the short form of the M.P.I. in Experiment 2, and of the 40 subjects who filled in both the short and the long forms of the M.P.I. in Experiment 3 were analysed.

The description/.........

The description of the 54 former subjects is contained in Chapter 3, Experiment 2. The description of the 40 latter subjects is contained in Chapter 3, Experiment 3.

The 54 subjects of Experiment 2 were tested on the short M.P.I. after they had completed their second session of time judgements. By this time they had judged each length of signal four times by linear arm movements - twice in each session. The short form of the M.P.I. was filled in by each subject in the presence of the experimenter.

The 40 subjects of Experiment 3 were tested on the short form of the M.P.I. after judging 8 seconds in their second session, and on the long form of the M.P.I. after judging 16 seconds in their fourth session. Both forms were filled in by each subject in the presence of the experimenter.

9.9.2 Results

The full results are listed in various Tables in Appendix B . In Table LX and LXI are the linear movement and verbal estimate correlates of extraversion, as measured in Experiment 2. Variability of verbal estimate and linear movement reproduction were also calculated with the results of Experiment 2, and these are listed in Tables XLI and XLII. Controlled linear movement reproduction time, verbal estimate, variability in time judgement by controlled movement and verbal estimate, and error in time judgement by both methods were calculated with the results of Experiment 3 and are listed in Tables XLIII and XLIV.

Product-moment correlations of extraversion and reproduction and verbal estimate variables obtained in Experiment 2 were calculated. This may be designated the correlation of extraversion and time judgements, obtained by free linear arm movements.

The correlations are /..........

The correlations are listed below.

TABLE 45

Time judgement correlates of extraversion in Experiment 2

Signal	Reproduced time	Verbal estimate	Reproduction error	Verbal error	Reproduction variability	Verbal variability
8 sec.	+.207	.000	-.483++	-.117	+.079	+.032
16 sec.	+.102	+.009	-.500++	-.015	-.225	+.029

++ significant at 5% level

The only significant correlations are the two between error in reproduction and extraversion. Both of these show that extraverts make significantly less errors than introverts. It should also be noticed that the correlation between time reproduced and extraversion reverses Eysenck's prediction. The correlation is not statistically secure, but it reverses the direction of the results obtained by Eysenck (1957), Claridge (1960) and Lynn (1961). Verbal estimate, error in verbal estimate, and the variability scores correlate at such a low level with extraversion that we cannot advance them as support for any except the null hypothesis.

The correlations between extraversion and distance, speed of movement and variability in speed of movement were calculated and are shown below. Variability in speed is calculated by using the set of speed scores in the first session, irrespective of the signal length. This is done because speed does not, on the average, vary with signal length. Reference to Table 18, p 89 in the text will show this. The distance score is the distance moved in reproducing 16 seconds.

X

TABLE 46

Extraversion and distance, speed, and variability of speed in reproducing time signals in Experiment 2

Distance	Speed	Variability in speed
-.062	-.161	-.434 ++

++ significant at 5%

This table/........

It is noticeable that the correlation between extraversion and reproduction of time by free linear movement is positive (though statistically insignificant) in both Experiment 2 and 3. But the sign of the correlation between extraversion and reproduction of time by controlled linear movement is negative. The correlation between reproduction by grip in Experiment 3 and extraversion is positive (+.02, .00, +.21 and +.22), resembling the correlation between extraversion and free linear movement. In Experiment 2, the correlation between key-pressing and extraversion is +.225 at a signal length of 16 seconds. From this we can conclude that free linear movement resembles key-pressing and grip more closely than it does controlled linear movement, in its correlation with extraversion. In spite of the fact that free and controlled linear movement reproduction scores correlate more highly than the scores obtained by any other methods of time judgement studied (see tables 20 to 23), the same personality factors may contribute to scores in opposite ways, if our data are significant of anything.

On the other hand, error in controlled linear movement and in free linear movement correlate negatively with extraversion in Experiment 2 (-.483; -.500) and Experiment 3 (-.27; -.12; -.35; -.47). Under conditions of both free and controlled linear movement extraverts appear to be more accurate in time reproduction than introverts.

The results of Experiment 2 and 3 confirm each other in the correlation of reproduction variability with extraversion as well. In both experiments, the correlation is negative, for both free and controlled linear movement.

Verbal extimate, verbal estimate error, and variability of verbal estimate do not correlate significantly or reliably with extraversion in the two experiments. This confirms our view that verbal estimates are not informative about time experience unless special precautions are taken in assessing them.

Another point/...........

Another point of importance is that, as expected of two scales which correlate so highly (+.87), the long and the short M.P.I. extraversion scales give very similar correlations with the time judgement variables.

9.9.3 Discussion

Our first hypothesis, based on the work of Eysenck, was that reproduction time and extraversion are negatively related. In our experiments, none of the correlations between time scores and extraversion is significant, statistically. This makes it dangerous to base any argument firmly on them. Yet we may note that the free linear movement reproduction times of both Experiment I and Experiment 2 correlate positively with extraversion. This could quite possibly be held to be a result of the particular method of time judgement which is adopted. But the time reproductions by key-pressing in Experiment 2 and by gripping the stationary handle in Experiment 3 are also positive. These positive correlations do not only fail to support the Eysenck theory by being too low, they contradict it by being in an opposite direction to that expected.

But the reproduction of 8 seconds and 16 seconds by linear movements of controlled distance does agree with prediction. The correlations with extraversion are negative, but again statistically insignificant. If we take the sign of the correlations as being a true reflection of a tendency among extraverts to reproduce less time than introverts, then we must conclude that controlled and free linear movement draw upon the personality factors of extraversion opposite ways. One is reminded of how, in the Wallach and Gahm experiment, anxious extraverts and non-anxious extraverts behaved in opposite ways. Is it possible that, when the scope of the movement is restricted, the extravert behaves in a way which is the opposite of his normal manner? This depends on the assumption that our third hypothesis is true.

When we/................

When we examine the data pertinent to the third hypothesis - that extraverts move further in reproducing time signals than introverts - the conclusion which we must reach is that only the null hypothesis is supported. In Experiment 2, the correlation between distance moved and extraversion is -.06 at 16 seconds. In Experiment 3, the correlation between extraversion and distance of movement is -.08 and -.03. In all cases, less than 1% of the variance is accounted for. If we conclude that hypothesis number three is not proven, then we must also abandon it as a possible explanation of the reversal effect on the relationship between extraversion and linear movement.

Another possibility is that there is an appreciable amount of reactive inhibition when the subject has to control the natural tempo of his movement. If one assumes that, in moving at natural tempo, over any distance chosen by the subject, the muscular adaptation is easiest and the least amount of reactive inhibition is generated, then it would follow from the Typological Postulate that, in a task in which reactive inhibition is made appreciable, there would be a negative relationship between extraversion and performance. But this explanation is only of the most tentative kind. Though the link between reactive inhibition and extraversion is the best established of the facets of the Typological Postulate, it is usually detected in a very special way - by motor reminiscence effects. It is probably dangerous to extend reactive inhibition to a perceptual or judgemental task as an explanation. Inhibition may easily become an overworked, overgeneralised concept. We shall have to abandon the reversal effect with an acknowledgement that we are unable to explain it.

The second hypothesis, that variability of response is greater among extraverts than among introverts, is contradicted by the consistent negative correlation between variability in reproduction of 8 seconds and 16 seconds and extraversion, in both Experiment 2 and 3. Variability in speed of movement is significantly and negatively associated with extraversion ($-.43$, $p < .01$) and variability of controlled linear movement reproduction of 8 seconds is significantly and negatively correlated with

the short/............

the short extraversion score (-.35; $p < .05$), though not significantly with long extraversion score (-.21). Our findings agree very well with general descriptive portraits of the extravert as sure, confident, inclined to be casual about his work. The correlation between verbal variability and extraversion is so low that, again, only the null hypothesis is supported. It is only in his motor performance that the extravert is less variable than the introvert.

The fourth hypothesis - that extraversion and speed of movement x are positively related - is also contradicted. In Experiment 2 a correlation of -.16 was found between speed and extraversion. Whether one accepts the null hypothesis or whether one attaches importance to the negative sign of the correlation, the hypothesis must be abandoned. When one refers to the M.P.I. questionnaire, items such as the following occur:-

(1) Are you happiest when you get involve in some project that calls for rapid action?

(2) Are you inclined to be quick and sure in your actions?

But they do not predict to the testing situation.

The most significant correlations of the whole set are those between extraversion and error in reproduction of time, in both Experiment 2 and 3. The correlation between free linear movement reproduction error and extraversion in Experiment 2 is -.48 ($p < .01$) at 8 seconds and -.50 ($p < .01$) at 16 seconds. The correlation between controlled linear movement error and extraversion in Experiment 3 is -.27 (short form) and -.12 (long form) at signal 8 seconds, and -.35 ($p < .05$; short form) and -.47 ($p < .01$, long form) at signal 16 seconds. No other relationships in the present study are as consistent or as significant. This discovery, that extraverts are more accurate in reproductions by both controlled and free linear movement, may be interpreted as a consequence of the Jungian distinction between the extrovert as a person who explores the world by using his exteroceptors and skeletal muscles, whereas the introvert explores the world by use of interoceptors and autonomic effectors.

This very/.......

9.10. Summary and Conclusions

Four hypotheses were set up for testing:-

(a) Extraverts under-reproduce time signals as compared to introverts.

(b) Extraverts are more variable in their responses than introverts.

(c) Extraverts move further than introverts in reproducing time signals by linear arm movements.

(d) Extraverts move faster than introverts in reproducing time signals by linear arm movements.

All of the hypotheses had to be rejected. Partial, but statistically insignificant support was found for hypothesis (a) in the negative correlation between extraversion and time reproduced by linear arm movements of controlled distance. But all other correlations between time reproduced (by free linear arm movement, by gripping the stationary handle, and by key-pressing) and extraversion were positive.

Correlation between error in reproduction and extraversion were significant and negative, indicating that extraverts tend to be more accurate than introverts in the reproduction of time signals.

It was concluded that the results as a whole did not favour the hypothesis that extraverts develop inhibition more rapidly than introverts or that extraverts develop less excitation.

CHAPTER 10

SECONDARY FUNCTIONING AND TIME JUDGEMENT

10.1 Introduction

The reason for studying primary-secondary functioning in relation to time judgement is that Eysenck (1957, pp 197-199) has suggested that the introversion-extraversion dimension and the primary-secondary functioning dimension are largely identical. One of his arguments in doing so is that Mundy-Castle (1955) has associated primary-secondary functioning with a "Central nervous excitability characteristic" (largely on the basis of EEG readings). We have seen that Eysenck's Typological Postulate (1957) advances the view that one of the main distinctions between extraverts and introverts is the strength of the processes of excitation aroused by stimulation. Another reason for Eysenck's identification (tentative it must be said, in fairness to Eysenck) is that secondary functioning effects may be described as inhibitory effects (Wiersma, 1932). If, then, primary functioners may be said to display higher excitability than secondary functioners, and if inhibitory processes are stronger among secondary functioners than among primary functioners, there is a clear parallel between the dimensions. Biesheuvel and Pitt (1955) describe one of the factors experimentally isolated by them in a study of primary-secondary functioning as "mobility and plasticity of behaviour at a more discriminative level" (p395). They also describe the factor in terms of flexibility and state that inertia is the "essence of the concept of secondary function" (p.391).

Eysenck's suggestion that extraversion and secondary functioning are identical or closely related immediately leads to two testable hypotheses.

(a) Measures of secondary function correlate with measures of extraversion.

(b) Measures of secondary functioning correlate with time judgements.

The latter hypothesis is in terms of Eysenck's finding, discussed in the previous chapter, that extraversion is negatively correlated with reproduction of time.

The/.........

The concept of primary-secondary functioning, as used in the present chapter, is based largely on Biesheuvel's (1949) account of this dimension and on his (1955) experimental analysis of the concept into the factors of flexibility and unstructured motor speed.

According to the Heymans-Wiersma theory of temperament, each conscious event has a primary function of immediate experience, and a secondary function in mental life which is exerted even after the event has receded from consciousness. As a result of secondary function, a conscious event can inhibit or modify a succeeding conscious event. Secondary function gives continuity and stability to conscious mental activity. Individuals who are characterised by a low degree of secondary function are dominated by immediate stimulation, and have an extensive but shallow conscious field. Individuals who are characterised by a high degree of secondary function have a deeper and possibly narrower conscious field, and show lower flexibility of response, but have richer evocations of past experience.

But if we examine the portraits which emerge, then it seems as though the primary functioner ought to be described as the extravert and the secondary functioner as the introvert. Examination of an earlier publication by Eysenck (1953) shows that he also regarded the matter in this light. He writes that "primary and secondary function denote extraversion and introversion respectively. To illustrate this correspondence we may set down some of the traits found by Heymans and Wiersma to be characteristic of persons in whom primary and secondary functioning predominated. Those with predominantly primary functioning are impulsive, give up easily, are always on the move, jocose, superficial, vain, demonstrative, tending to exaggerate, given to public speaking, to telling jokes and to laghing a lot. On the other hand, the person with predominant secondary function is quiet, persistent, grave, shut-in, reliable, given to introspective thinking, laughs little, has depressive tendencies, and is not given to indulge in pleasures of the body" (p.39). Yet Eysenck (1957) claims that "it will be remembered that the term "secondary function" is equivalent to "extraversion"

in our/......

in our terminology" (p.198).

Clearly, Eysenck is in two minds about the exact equivalence of the sets of terms. The difficulty arises partly from the fact that in Eysenck's system there is a clear distinction between expressive activity and neurone excitability. Thus, in the M.P.I. the extravert is the person who agrees with statements that he is active, quick, sociable, and so on, while in terms of neurone excitability he is at a lower level than the introvert. There is, thus, an inward and an outward face to Eysenck's description of introversion and extroversion, and these two have to be kept distinct. It is not clear how the external behaviour or actions of the individual come to be the reverse of the degree of neurone excitation. Eysenck essays an explanation in terms of learning theory. The introvert acquires, by conditioning, the mores of the society in which he lives more strongly than the extravert. He is, in the social sense, more inhibited. But this view suggests that the prime function of acculturation is inhibition of socially expressive behaviour. Is not the contrary equally true? We shall not enter into this question at this stage, because we wish merely to point out the source of the confusion about the equivalence of the two sets of terms. In the Wiersma-Heymans theory of temperament, on the other hand, the person who is most excitable in expressive behaviour is the person whose neurones are most excitable, too. There is no reversal of the external and internal faces.

In spite of the confusion, we shall accept Eysenck's most recent (1957) solution, rather than his older (1953) solution. The primary functioner will be, for us, the introvert. The secondary functioner will be, for this chapter, the extravert. These are the hypotheses which we shall test.

The tests which we shall use are some of those found by Biesheuvel and Pitt (1955) to be highly saturated with flexibility and unstructured motor speed. These two experimenters had their subjects (all of whom were members of the N.I.P.R.) rated in order of primariness by 25 assessors. The total number of subjects was only slightly over 50, but the fact that they were all well known to each other was though to

contribute/.......

contribute to the validity of the ratings. Subjects were asked to complete a battery of psychomotor tests. These were: voluntary and maximum tapping speed; drawing crosses; walking speed; talking speed; sorting (of discs into compartments according to symbol); formboard; pursuit (of weaving intersecting lines); repeated letters (subjects had to ring every letter which was the same as its predecessor); and identical pictures (subjects had to recognise one of a set of eight pictures). Two factors were identified: unstructured motor speed and flexibility of "behaviour at a more discriminative level". The first factor, unstructured motor speed, had high loadings on alpha rythm, maximum and voluntary tapping speed, speed of crosses, and ratings on primariness. The seconds factor, flexibility, had high loadings on repeated letters, crosses, pursuit, sorting, and ratings on primariness.

Mundy-Castle (1955) suggests that behaviour characterised by the first factor, unstructured motor speed, originates at a thalamic level; but behaviour character ised by the second factor, flexibility, involves high level discriminatory processes and originates at a cortical level. Behaviour characterised by factor one is associated with maximal alpha rhythm, whereas behaviour characterised by factor two is associated with minimal alpha rhythm. Alpha rhythm is known to block when attention and readiness to discriminate are high. Mundy-Castle is extrapolating from known intra-individual changes with changes of set to explain inter-individual differences in discriminative ability.

In our experiment, since several other tests were already being taken by the subjects in addition to the rather extensive time judgement tests, the psychomotor battery had to be pared to a bare minimum. This is unfortunate. No doubt a much more extensive study than the one about to be reported is necessary to settle the issue. But the results obtained here may be taken as indications.

10.2 Hypotheses

The hypotheses set up were as follows:-

(a) Extraversion is positively correlated with secondary functioning. That is, it is negatively correlated with speed of performance/.......

performance in tasks involving flexibility.

(b) Speed in performance of tasks involving "mobility and plasticity of behaviour at a more discriminative level" is positively related to time reproduced.

(c) Speed (in tasks saturated with both flexibility and unstructured motor speed) is related to the speed of linear arm movement in reproducing time. This prediction is made on the basis of Biesheuvel and Pitt's (1955) demonstration of a general speed factor for unstructured motor activity involving (among other things) speed of limb movements (as in gestures and in walking). The flexibility measures are included in the hypothesis because of the possibility that speed of movement in reproducing time by linear movement is a discriminative function and not merely an unstructured motor speed characteristic.

10.3 Experiment

10.3. 1 Subjects and Method

The subjects used in this experiment are those who completed two sessions of testing in Experiment 2. The subjects, and the method of testing their time judgements by free linear arm movements are described in detail in Chapter 3. Results of both sessions were used. Immediately after completing the reproduction series, and after filling in the Maudsley Extraversion Scale, each subject was given two tests of unstructured motor speed and two tests of secondary functioning (flexibility).

Preferred rate of tapping and maximum rate of tapping were used as tests of unstructured motor speed. The subject was asked to tap a key (which was in series with a counter which recorded the number of taps) at a preferred rate. "When I give you the signal, tap the key at any rate which seems natural to you. Continue tapping until I give you the signal to stop". Each subject tapped the key for one minute. After this, the subject was asked to tap the key as fast as possible. "When I give you the signal, tap the key as fast as you possibly can until I tell you to stop". Again, each subject tapped the key for a minute.

Speed of handwriting and rate of making crosses were the two tests of secondary functioning used. Speed of handwriting was measured by asking the subject to take down a passage of 50 words of prose at speed, "as in taking notes from a rapid lecturer". The time taken to write down the passage was recorded. Speed of crossing was measured by asking the subject to make as many crosses as possible in a given period of one minute on a paper divided into 5 mm squares.

10.3. 2 Results

The full results of all the tests of speed are listed in Appendix B, Table LXII.

The first step taken was to correlate all the speed scores

with /.........

with extraversion scores, listed in Table LX. The product-moment correlations are shown below in Table 48.

TABLE 48

Product-moment correlations of speed variables and extraversion

	Tapping preferred speed	Tapping maximum speed	Crosses	Handwriting
Extraversion	-.13	-.07	-.01	-.14

Though the correlations are all in the expected negative direction, not one of them is significant. It is possible that each task would have to be continued for a longer period before significant correlation could be obtained.

The measures of speed were then correlated with free linear movement reproduction of time and with verbal estimates. The product-moment correlations are shown below in Table 49.

TABLE 49

Correlations of secondary functioning (speed of handwriting and making crosses) and time judgements.

Speed measure	Reproduction of 8 secs.	Verbal est. of 8 secs.	Reproduction of 16 secs.	Verbal Est. of 16 secs.
crosses	+.13	+.11	+.20	+.08
handwriting	+.14	+.19	+.03	+.14

The correlations are all in the expected direction, positive, but none of them is significant. They all indicate that subjects who tend to be fast in discriminative tasks also tend to reproduce time at a higher level. The positive correlations between speed of flexibility measures here and the negative correlations between speed of flexibility measures and extraversion are consistent with our hypotheses.

The next step was to correlate speed of linear arm movement in reproducing the time signals and the various measures of unstructured motor speed and of flexibility. These correlations are shown in Table 50 below.

TABLE 50

Correlations of speed of linear arm movement, unstructured motor speed and flexibility.

Linear/........

	Preferred tapping speed	Maximum tapping speed	Crosses speed	Handwriting speed
Linear movement speed	+.02	+.09	.00	.00

These correlations are very low indeed. The only course one can take is to accept the null hypothesis that there is no relationship between speed of arm movement and the other measures of speed used in this experiment. In the discussion it will be shown that this finding is in agreement with the results of many other experimenters. Indeed, Biesheuvel and Pitt are among the very few recent researchers to obtain general speed factors. Their work is exceptional. It was decided to correlate the tempo tests of unstructured motor speed and flexibility to see whether, in our results, correlations of the same order as those obtained by Biesheuvel and Pitts would obtain. In Table 51 are the results of the correlations of the data obtained in the present experiment. Below that, in Table 52, are the results obtained by Biesheuvel and Pitt.

TABLE 51

Correlations of unstructured motor speed and flexibility in the present experiment (Experiment 2)

	1	2	3
1. Preferred tapping speed			
2. Maximum tapping speed	+.01		
3. Crosses	+.20	+.30*	
4. Handwriting speed	-.01	+.05	+.22

*Significant at 5%

TABLE 52

Correlations of unstructured motor speed and flexibility in the experiment of Biesheuvel and Pitt.

	1	2	3
1. Preferred tapping speed			
2. Maximum tapping speed	+.32		
3. Crosses	+.39	+.21	
4. Handwriting speed	+.22	+.12	+.10

The/........

The correlations obtained by Biesheuvel and Pitt are, on the whole, a little higher than those obtained in the present experiment, but not verymuch so. Their factors are drawn from correlations which are in many instances not statistically significant.

10.3.3 Discussion

The first hypothesis set up is that extraversion is negatively correlated with primariness, as measured by speed of, especially, functions involving discrimination and attention. This hypothesis is supported to the extent that the signs of the correlations between speed of crossing and speed of handwriting on the one hand and extraversion on the other hand are negative. The correlations between extraversion and unstructured motor speed are also negative but not statistically significant. Rechtschaffen (1958) has also shown that the correlation between extraversion and performance of a speed task involving discrimination (reversed alphabet writing), is negative but not significant. But it is possible that reactive inhibition takes a longer time to produce significant differences in the expected direction. The tasks which we have used may be far too brief to show up real differences. Eysenck (1962) produces a considerable amount of evidence to show that reactive inhibition generates more rapidly and dissipates more slowly among extraverts, and even Becker (1960) in a series of experiments giving results very unfavourable to Eysenck's views, found significant differences between extraverts and introverts in the amount of reactive inhibition generated.

Though our results do not confirm the first hypothesis, they do not appear to be extensive enough to lead to a rejection of it.

The second hypothesis was that primariness (as measured by flexibility) correlates positively with reproduction of time. The reason for this hypothesis is that Eysenck has identified primariness with introversion. According to his theory, introverts develop stronger excitatory processes and generate inhibition more slowly. In the Heymans-Wiersma theory, primariness is also associated with greater excitability, and Mundy-Castle (1955) advances the view that the primary-secondary function dimension is associated with a "central nervous excitability

characteristic"/.....

characteristic". As with the first hypothesis, the correlations are in the expected direction but are not significant. Again, it is possible that significant positive correlations would be found if the testing had been more protracted. It is possible that testing must last for a certain time before the reactive inhibition generated is sufficient to discriminate between extraverts and introverts.

The third hypothesis was that speed of linear movement in reproducing time is related to primariness (either as measured by flexibility or as measured by unstructured motor speed). The reason for the doubt was that it is not certain whether speed of linear arm movement during reproduction of time reflects speed at a "more discriminative level" or whether it reflects only habitual lower level tempo. Again, the correlations were in the expected direction, but statistically not significant. Again, we can only reiterate our point that more protracted testing might reveal differences in time judgement related to differences in primariness. All the speed variables in our experiment, except speed of handwriting and preferred tapping speed, were positively related. The correlation between speed of handwriting and preferred tapping speed was close to zero (-.01). When the correlations obtained in the present experiment were compared with those obtained by Biesheuvel and Pitt, they were found to be slightly lower.

It may be pointed out here that the isolation of two general speed factors by Biesheuvel and Pitt is rather exceptional, as a review of the literature shows. Most authors have found rather limited speed factors, confined to certain classes of activity.

One of the most thorough studies of speed of expressive movement was conducted by All port and Vernon (1933). They studied 45 original measures of speed, but reduced the number to 14 in the course of the experiment. These were reading, counting, handwriting, blackboard writing, drawing on paper, foot drawing, finger and hand tapping, leg tapping, stylus compression, walking, strolling, estimating distances with hands, arranging cubes, and ratings by others on speed.

These/.....

These movements were measured at three separate sessions taken four weeks apart. From the results it appears that there is no general speed factor, though there are three fairly broad factors covering verbal speed, drawing speed, and rhythmic speed. The average intercorrelation of all speed items was .05, which the authors take to show that it is very doubtful whether we can speak of a general speed factor. If we consider the six correlations of speed in Tables 51 and 52, then the average for the present experiment is found to be .13 and the average for the Biesheuvel and Pitt experiment is found to be .22. These are higher than the Allport and Vernon average, but they are still so low (considering that they cover a rather limited number of speed functions) that they support the conclusion that it is unlikely that there is a general speed factor. But, Allport and Vernon found, when the speed functions were grouped very high average intercorrelations were found. The average intercorrelation of verbal speed was +.77; drawing speed was also +.77; and rhythmic speed was +.90. Further analysis of the data enabled the authors to detect three factors which they identified as an areal (or expansive) factor, a centrifugal factor, and a factor of emphasis in movement. Nine variable were attributed to the areal factor. They were area of writing, total area of figures, area of blackboard figures, slowness of drawing, area of foor squares, overestimation of angles, ratings on movement during idleness (restlessness length of self-rating checks, and length of walking strides. The average correlation of each item with the sum of the other eight is +.51. The centrifugal factor was made up of overestimation of distance from body with legs, overestimation of distance from body with hands, extent of cubes, underestimation of weights, verbal speed, underestimation of distance towards body with hands, and ratings of speech fluency. The average correlation of each item with the sum of the other six is +.47. The third factor, that of emphasis, was made up of ratings of voice intensity, fewness of parallel lines drawn, ratings of movements during speech, writing pressure, overestimation of weights, finger pressure on stylus, tapping pressure, underestimation of distance between hands, verbal slowness, ratings on forcefulness/.....

forcefulness, overestimation of angles, pressure of resting hand, and unoccupied space in drawing figures. The average correlation of each component with the sum of the other twelve is +.45. By this analysis, some speed measures are placed in a broad context of expressive style. Slowness of drawing is found to relate to the areal factor, verbal speed is found to relate to the centrifugal factor, and verbal slowness to the factor of emphasis. The other speed items are not relevant to the expressive factors. Allport and Vernon show that many of the speed measures correlate more highly with non-speed measures than with each other. In short, they conclude, physical categories of movement are unsuitable models for the psychological study of expression.

This valuable study by Allport and Vernon is confirmed in some of its details (no other study of such a broad and informative scope has been conducted). Harrison (1941), studying the relationship between maximum and voluntary rates of movement in a variety of tasks, found no indication of a general speed trait at either preferred or maximal rates of behaviour. Pierson and Rasch (1960) found that subjects ranking high for reaction time and movement time in one part of the body also tended to rank high for other parts. Arm extension, arm flexion, and overall body speed were measured. It was found that there is a general factor in reaction time and movement time and that there is a low, statistically significant relationship between reaction time and movement time. Pemberton (1952) did not find a decisive relationship between perceptual speed and temperament, as demanded by the Heymans-Wiersma theory of temperament. But she formed the impression that those who scored high on the factor were unsystematic and reacted immediately to outside stimuli, liked variety and contrast, often acted without considering the consequences, and had changeable moods. If these impressions may be accepted as evidence, then they confirm Wiersma's (1906) contention that the temperamental component of perceptual speed is freedom from inertia. The last two studies mentioned are too limited in scope to give any indications as to the generality of the speed factors which they represent.

Adams (1935), in a more extensive study of speed in various

activities/.....

activities (preferred and maximum tapping speed, card sorting, preferred and maximum handwriting speed, maximum cancellation speed and speed of arithmetic addition) found that each speed was reliable, but that there was no general speed factor. Rimoldi (1951) in a study of 59 tests of tempo, ranging from simple motor skills to mental activities, found that each test was reliable, but that there was no general factor of tempo. ~~They~~ He found nine speed factors: (a) large movements of the trunk and limbs; (b) small movements; (c) verbal speed and speed of perception; (d) motor activity; (e) drawing with the foot; (f) metronome test; (g) reaction time; (h) performance with the hands; and (i) space and reasoning. Four second-order factors were extracted. These were (i) speed of all motor activities; (ii) speed of perception; (iii) speed of cognition; and (iv) reaction time.

It is possible that factor (i) corresponds to the Biesheuvel and Pitt factor of unstructured motor speed and that factor (iii) corresponds to the Biesheuvel and Pitt factor of flexibility. But these more extensive experiments caution one against too expansive a concept of primary-secondary functioning. It is clear that the factors entering into this concept must still be analysed in considerable detail.

SUMMARY AND CONCLUSIONS

All subjects who had completed two sessions of time judging in Experiment 2 were also asked to take tests of handwriting speed and speed of filling in crosses on squared paper, which are thought to be related to secondary functioning; and preferred and maximum tapping speed, which are thought to be measures of unstructured motor speed. In the discussion of results, some doubt was expressed about the generality of these two factors.

Three hypotheses were tested with these results.

(a) That secondary functioning is positively related to extraversion.

(b) That secondary functioning is negatively related to time reproduced, since it has been identified (by Eysenck, 1957) with extraversion.

(c) That speed of linear movement in reproducing time is positively related to other measures of speed.

The correlations were all in the expected directions, but none were significant. The null hypothesis has to be accepted in each case, but it is suggested that more protracted testing might produce significant results. It is borne in mind that reactive inhibition takes some time to develop to the level when it will lead to discrimination between extraverts and introverts.

CHAPTER 11

MANIFEST ANXIETY AND TIME JUDGEMENTS

11.1 Introduction

The argument in this chapter will fall under three main divisions. Firstly, an attempt will be made to show that drive variables affect time judgements. Secondly, by reference to the literature, the merits of treating Manifest Anxiety as a drive variable will be considered. Thirdly, the results of an experiment in which Manifest Anxiety and time judgement are related will be discussed.

11.2 Drive Variables and Time Judgement.

The drive variable "need-tension" was studied in relationship to estimation of time by Rosenzweig and Koht (1935). It was argued by them that need-tension was greater when subjects were working at an insoluble problem presented to them as an intelligence test than when it was presented to them as a practice task. It was found that time estimates under the former conditions - when need-tension was presumably high - were lower than under the latter conditions. The authors explained this as an effect of wanting time to pass more slowly under test conditions and wanting time to pass more rapidly under practice conditions. These results have been questioned by Meade (1960), who found no difference between the time estimates of high and low need-tension groups. He found that the first trial was always estimated longer than the second, and attributed the results of Rosezweig and Koht to neglect of this factor. Reference to the results obtained in the present experiment (Experiment 2) shows that this is not invariably so. First and second session verbal estimates of 8 seconds were 10.9 seconds and 10.1 seconds, respectively. First and second session verbal estimates of 16 seconds were 19.7 and 20.2 seconds, respectively. In neither case is the difference significant. Of course, it is possible that in the judgement of much longer intervals, such as those used in the above experiments, there may be substantial increases from the first to the second session. But our results do make it clear that the statement by Meade that this is invariably so needs to be

limited/......

limited. Schonbach (1959) has tested and confirmed the hypothesis that, in a barrier situation, the greater the force acting on the subject to reach a goal, the greater the estimation of the time spent within the barrier situation. This is very much the situation of the subjects in Rosenzweig and Koht's experiment. Those who were performing the practice task and those who were performing the intelligence test were both in barrier situations, since the task was insoluble. But in the latter case the force to reach to goal was presumably much greater. Schonbach went further and argued that the force acting on a person in a barrier situation in an increasing function of the person's need for the goal and the relevance of his ideation with respect to the goal. In the main part of his experiment, Schonbach deprived subjects of food to increase their need, and insured relevant ideation by providing magazines and cookery books lavishly illustrated with food pictures while the subjects were waiting. His conclusions may be regarded as an addition to, and an affirmation of, the conclusions of Rosenzweig and Koht.

Closely related to the perception of time under motivation in a barrier situation is the perception of time as a function of perceived rate of progress towards a goal. Filer and Meals (1949) found that subjects motivated by an attractive reward to complete the task estimated the task as taking a longer time than subjects without a definite goal. Meade (1959) found that subjects not motivated to complete the task perceived duration as unrelated to either rate of locomotion or to distance from the end of the task. The task used was a stylus maze. Subjects who were motivated to complete the task perceived duration as inversely related to rate of progress and distance from the goal. This result was confirmed when a puzzle was used instead of a stylus maze (Meade, 1960). If one interpreted rate of progress as the barrier in this task (low rate of progress corresponding to firm barrier, high rate of progress corresponding to weak barrier) then the results are in accord with those of Schonbach. The greater the rate of progress, the weaker the barrier, the lower the estimate of time. Hindle (1950) investigated time estimates as a function of the

relative/........

relative clarity of the goal and of the distance travelled. During the latter part of the task, when it leads to a clearly defined goal, estimates of time spent increase more slowly relative to actual time spent than when there is no clear goal. This appears at first sight to disagree with the result of Filer and Meals (1949) who found that there was greater overestimation among those approaching the goal. But there are important differences. In Hindle's experiment the variable was the clarity of the goal, in Filer and Meals' experiment the variable was the attractiveness of the goal. In the former case, the clarity of the goal was a weakening of the barrier. In the latter case, it is possible that the nearer the subject gets to an attractive goal, the stronger his fear that he will lose it. The barrier of fear may get stronger as the subject approaches a very attractive goal. N.E. Miller (1944) has shown in a number of illuminating studies that the motive increases in strength as the goal is approached. If we assume that fear of failure acts as a barrier, and that fear of failure is (at least in part) determined by the strength of the motive (Fear of failure = f (D)), then the subject approaching an attractive goal may be compared to a person placed in a barrier situation which grows firmer as motivation rises. Another experiment of some relevance to these comments on perceived rate of progress in relation to perceived duration, is that of Langer and others (1961), who found that approach to danger produced overestimation. In their experiment, estimates were not conveyed verbally, but by the method of production which is, as we have seen, negatively correlated with verbal estimates. Subjects were placed in a chair moving towards a fall, and were required to stop the chair, by pushing a button, when 5 seconds had passed. The average subject pushed the button too soon. This experiment is complicated by the simple fact that pushing the button may express the subject's desire to stop the movement, rather than his judgement of time.

Estimation of length of a time interval may obey the same rule as estimation of size and brightness. An early experiment in this field found that children who were asked to adjust the size of a disc of light to equal the sizes of coins and cardboard discs, made the circle of light too large when they were judging coins, but not

when/........

when they were judging cardboard discs (Bruner and Goodman, 1947). It was also found that, the greater the value of the coin, the greater the degree of overestimation. Children from poor homes overestimated more than children from well-to-do homes. It may be remarked here that the same results have not always been obtained by other experimenters. Beams (1954) found that children estimated the sizes of foods they liked as relatively larger than those they disliked. Gilchrist and Nesberg (1952), working with adults, found that hungry and thirsty observers perceived pictures of food and drink as being relatively brighter than unrelated pictures. The estimates of brightness increased steadily in size until the observers had been eight hours without drinking. After being allowed to drink all they wanted, the level of brightness estimated fell to the level found at the commencement of the experiment. These situations are very much like the barrier situation employed by Schonbach. The subjects are judging qualities of things they would like to have. In none of these situations is the judgement directed to an essential attribute of the thing judged, and in none of these situations is the judgement instrumental in securing release from the barrier situation. An experimenter who asks "How long (bright, heavy, bit) did it <u>seem</u> to you" will probably get different results from one who stresses "How long do you think it actually was. Be as accurate as you can." An experimenter who carries this stress further by rewarding accuracy will probably get rather different results from the free situation in which the perception (or judgement) carries no penalties or serves no essential instrumental purpose.

Most of the work reviewed has been done with verbal estimates of time. We have shown in detail what common understanding clearly leads one to suspect: that verbal estimates are not good indicators of the time experience of the subjects. For this reason, the work reviewed can be accepted as an indication of what may happen, but it cannot be accepted as conclusive in any sense. But, making do with what we have, what general principle, if any, can be derived? We may hazard the suggestion that when the attention of the subject is focussed on the time interval (time which no instrumental act can abbreviate) which he spends in a barrier situation, for example, estimation is likely to be

high/.........

high. On the other hand, when the subject's attention is focussed entirely on a task, estimation of time is likely to be low. There must be, as Fraisse has remarked in a statement which has already been quoted, an activity which exactly satisfies the motivation present for the subject to be unaware of the passage of time.

There is a difficulty that, where the subject is unaware of the flow of time, in the sense that he is unoppressed by it, or occupied by some task, he may still be relatively accurate in his time judgements. One would expect that the more educated the subject is, the less subject he would be to errors of this kind. Time judgement of this kind is an abstract operation. Cohen and Mezey (1961) have observed rate of tapping, reproduction of time, verbal estimate of a signal, and verbal estimate of time more actively employed, under two conditions. The subjects were 24 doctors. Under the first condition, they were about to address a critical audience, and under the second condition, they were engaged in the normal routine of duty. Though the subjects reported subjective distortion of awareness of time, none of the measured variables was affected. This illustrates the difficulty that might be encountered among intelligent subjects. Another factor which might be of importance is the cognitive style predominating. These were discussed in the previous chapter.

But, bearing these difficulties in mind, the hypothesis is set up that where the subject's attention is directed to the judgement of the time interval (and not to some task occupying that interval), an increase in drive level will bring about an increase in the judged duration of that interval.

11.3 Manifest Anxiety as a Drive Variable

It has been stated quite emphatically by Janet Taylor that "the construction of the test (M.A.S.) was not aimed at developing a clinically useful test which would diagnose anxiety, but rather was designed solely to select Ss differing in general drive level" (1956, p. 303). The selection of subjects differing in general drive level is important in testing various aspects of Hull's (1943) system. According to Hull, the effect of an increase in drive level is to increase the

excitatory /........

excitatory potential, since drive and habit strength combine multiplicatively.

$$E = f\ (HxD).$$

The total effective drive is, according to Hull, determined by both relevant and irrelevant drives present. Excitatory potential determines, to a large extent, the response strength. Therefore, an increase in drive should increase the strength of the response.

$$R = f\ (E)$$

where E is the value of excitatory potential after the inhibitory effects of oscillation O and threshold L have been subtracted from E.

Another function of a rise in drive may be that several competing reaction potentials are raised above threshold. This might result in an increase in variability of response which will occur only in the early stages of an experiment in which one particular response is consistently reinforced, but throughout an experiment in which no particular response is reinforced. In Hull's behavioural system it is proposed that the range of behavioural oscillation is not affected by the level of habit strength, but other evidence suggests that "the range of oscillation is a diminishing function of habit strength" (J.G. Taylor, 1949). J.G. Taylor proposes that oscillation is positively related to drive and that it remains unaffected by practice in a task in which there is no primary reinforcement; but that oscillation is reduced when primary reinforcement is introduced.

How does all this apply to the experiments on time judgement? The first application is that an increase in drive might be expected to raise the level of the response, by increasing reaction potential. The second application is that an increase in drive can be expected to result in an increase in oscillation, or variability of response. Janet Taylor has stated that the anxiety scale which she has developed is a measure of drive. If this is true, then subjects who have high M.A.S. scores ought to be more variable in their responses and ought to have higher time reproduction scores. We may consider some of the evidence for accepting the Taylor Manifest Anxiety Scale as a measure of drive.

There is some difference of opinion as to whether the Taylor M.A.S. Measures chronic drive or differences in emotional reaction. On the basis of electromyographic studies, which show that high M.A.S.

jects exhibit greater muscular tension, even at rest, Rossi (1959) has concluded that chronic drive is measured by the M.A.S. This was the original opinion of Taylor as well (1951), though on no very clear grounds. On the basis of defensive conditioning experiments, Spence and others (1954) have advanced the view that high and low scorers may differ in readiness with which emotional response is aroused.

A number of studies of eyelid conditioning tend to show that high M.A.S. scorers condition more rapidly than low scorers (Spence and Farber, 1954; Spence, Farber and Taylor, 1954; Spence and Taylor, 1951; Spence and Taylor, 1953). In these experiments extremely high and extremely low scorers were contrasted. Hilgard, Jones and Kaplan (1951), using small groups of only 10 subjects, found differences in eyelid conditioning in the expected direction, but the correlations were insignificant. They found differential conditioning to be negatively related to M.A.S. score, which is contrary to prediction from the Hullian theory. But Spence and Beecroft (1954) and Spence and Farber (1954), using rather larger groups, have found evidence which is in the predicted direction and is not in agreement with the results of Hilgard, Jones and Kaplan. They found that excitatory potential aroused by the positive conditioned stimulus during both simple and differential conditioning was greater for the high M.A.S. scorers. Furthermore, they found that high M.A.S. scorers showed greater discrimination between positive and negative stimuli.

Bitterman and Holzman (1952) divided 37 university students into upper and lower 50% according to their scores on various anxiety indices derived from Rorschach data, 5-point rating, and performance under stress. They studied the rate of PGR conditioning in the two groups. The PGR conditioned to shock more readily and extinguished less readily in the high anxiety group than in the low. This shows that anxiety rating on other indices tends to give the same results as rating on the M.A.S., thus strengthening our faith in the M.A.S. as a measure of drive.

Learning of verbal and stylus mazes has also shown expected differences (in terms of Hullian learning theory) between low and high M.A.S. scorers, according to Taylor and Spence (1952). Anxious subjects tend to show greater oscillation of response and take more trials in

learning/..........

learning a verbal maze. Spence and Farber (1953) have shown the same effects on a stylus maze. It may be added that the study of stylus maze learning by Axelrod, Cowen and Heilizer (1956) has produced contradictory evidence. The data on verbal and stylus mazes, if one accepts them, seem to show that M.A.S. may be treated as a chronic difference in drive. The study by Spence and Farber (1953) shows that the difference between high and low M.A.S. scorers remains the same under three intensities of unconditioned stimulus in eyelid conditioning. This is interpreted as demonstrating that drive arousal does not depend on situation. Deese, Lazarus and Keenan (1953) found that low M.A.S. subjects performed worse in an avoidance conditioning experiment than in a non-avoidance conditioning experiment, but that high M.A.S. subjects performed slightly better. They explain the observed differences between high and low M.A.S. subjects in eyelid conditioning as due to the fall in performance by low M.A.S. scorers rather than a rise in performance by high M.A.S. scorers.

It appears that high M.A.S. scorers are superior in paired learning of nonsense syllables to low scorers (Taylor and Chapman, 1955). This is thought to be because of the greater excitatory potential in a non-competitional response situation aroused in high M.A.S. scorers.

Quite a different explanation of some learning effects might be made in terms of the finding by Voas (1956) that more intelligent subjects tend to have lower M.A.S. scores. Where the subjects are drawn from a heterogeneous population subjects with high intelligence scores tend to concentrate in the lower 50% of the M.A.S. scores. This could account for the low verbal and stylus maze learning scores of high M.A.S. subjects in some experiments. Taylor states, though, that this is not a danger when the population is relatively homogenous, and the experiment by Taylor and Chapman (1955) quoted above appears to affirm this.

Eysenck (1957) has criticised the Taylor M.A.S. on the grounds that it includes two orthogonal dimensions, since it correlates with both neuroticism (+.77) and extraversion (-.35). He advances the argument that the superior conditionability of high M.A.S. scorers may be due to the presence of the extraversion dimension in their scores. Taylor and Rechtschaffen (1959) report a correlation of only -.188 in their sample, between the Guilford R scale and the Taylor M.A.S., which makes Eysenck's explanation rather improbable. Furthermore, in a reversed alphabet writing task, performance correlated negatively with M.A.S. score and not positively, as would be expected if extraversion played a significant part in determining performance (Taylor and Rechtschaffen, 1959). Extraversion (low M.A.S.) would be associated with high reactive inhibition and low score, but introversion (high M.A.S.) would be associated with low reactive inhibition and high score, if Eysenck's objections were valid. These experiments are somewhat tangential. The main point appears to be that the correlation between M.P.I. extraversion and M.A.S. is not high enough to account for the effects produced by differences in M.A.S. scores.

A factor analysis of the 50-item Taylor M.A.S. by O'Connor, Lorr, and Stafford (1956) has identified 5 factors: (a) chronic anxiety; (b) physiological reactivity to emotional stimuli; (c) inner strain associated with sleep difficulty; (d) sense of personal inadequacy; and (e) motor tension. Taylor and Rechtscchaffen have replied to criticisms citing the test's multidimensionality with the argument that all the sub-scale correlate negatively with performance and may be assumed to have drive properties. It may be pointed out here that a justification of the negative correlation between performance and drive is sought in the Yerkes-Dodson (1908) law that an increase in drive in a complex task has a deleterious effect on performance.

These arguments for treating manifest anxiety as a drive variable have all been derived from learning theory. No attempt has been made to evaluate score on the scale as a drive variable in perceptual-motor tasks. One reason for this is, of course, that predictions based on a fairly well-developed theory may be made within the field of learning, and the Iowa school has been largely concerned with the exploration and confirmation of Hullian postulates. But there is no reason why M.A.S. score should not be used in other situations.

x A review of the literature leaves one with the impression that Spence, Taylor, Rechtschaffen and Farber seldom fail to confirm their hypotheses, using M.A.S. scores as drive variables. But there is a mixed voice from other experimenters. This is a puzzling and unfortunate

situation./......

situation. But there is no remedy except to set up hypotheses on the assumption that the Iowa School is right. These can then be proved or disproved, providing affirmation or infirmation of their views.

11.4 Hypotheses

The first hypothesis which will be set up is that M.A.S. score is positively related to time reproduced by linear movement. The first reason for this is that an increase in drive might be expected, in terms of Hull's (1943) theory, to result in an increase in reaction potential and an increase in the strength of response. A second reason for this hypothesis may be couched in more general terms. When the attention of the subject is focussed on the time interval and not on a task occupying that interval, an increase in drive might be expected to lead to an increased judgement of the duration of the interval.

The second hypothesis is that an increase in drive will lead to an increase in the variability of the response. Again, in terms of Hullian theory, oscillation of response (variability) is held to be an increasing function of drive. In an experiment such as ours, in which no particular response is reinforced, oscillation might be expected to continue at the same strength throughout the experiment, in terms of the explanation put forward by J.G. Taylor (1949).

11.5 Experiment

11.5. 1 Subjects and Method

The subjects used in this experiment were 38 of the subjects of Experiment 2 who had completed two sessions in which their time judgements were tested. Full descriptions of the time judgement testing may be found in Chapter 3, Experiment 2. These subjects were also asked to fill in Taylor Manifest Anxiety questionnaires during their normal psychology laboratory periods.

Very briefly, the subjects were 38 men and women first-year students of psychology. They attended two sessions in which their judgements of time were tested by free linear movement and verbal

estimation/.....

tion. During a normal psychology laboratory session, some time before the time judgement experiments began, they were asked by their laboratory instructor to fill in the Taylor Manifest Anxiety questionnaire, which consists of 50 items phrased in such a way that the testee merely responds "yes" or "no". A copy of the scale is included in Appendix A.

In addition, all 40 subjects participating in Experiment 3 filled in the Taylor Manifest Anxiety questionnaire in the presence of the experimenter at the end of the second time testing session, in which they had reproduced 8 seconds. The details of the time judging experiments are found in Chapter 3, Experiment 3.

The subjects were 40 men and women drawn from various courses and various levels of seniority. Their time judgement was tested in four separate sessions by the methods of controlled linear movement and verbal estimation.

Thus, the 38 subjects of Experiment 2 filled in the scale under group conditions and the 40 subjects of Experiment 3 filled in the scale under conditions of individual testing; but it is not expected that this affected results.

11.5. 2 Results

The results of Experiment 2 are tabled in Appendix B, Tables XLI and XLII. The results of Experiment 3 are tabled in Appendix B, Tables XLIII and XLIV.

Product-moment correlations of Manifest Anxiety score and reproduced time, verbally estimated time, error in time judgement, and variability in time judgement were calculated and are shown below.

TABLE 53

Time judgement correlates of Manifest Anxiety in Experiment 2.

Signal	Free linear movement reproduction	Verbal estimate	Error in reproduction	Error in verbal estimate
8 sec.	-.20	-.11	+.14	-.07
16 sec.	-.23	-.10	+.21	-.04

TABLE 53 (contd.)

Signal	Variability in reproduction	Variability in verbal estimate
8 sec.	+.06	+.01
16 sec.	+.23	+.13

None of the correlations listed above is statistically significant. The

Manifest Anxiety and free linear movement reproduction of time signals, error in reproduction, variability in reproduction, verbal estimate, error in verbal estimate, and variability in verbal estimate must be accepted. Furthermore, the correlations between time judgement and Manifest Anxiety are in the opposite direction to that expected. They are negative instead of positive. The correlations between variability and Manifest Anxiety are in the expected direction. They are positive, but are so low that they cannot be taken as reliable evidence.

Correlations between speed of movement, variability in speed, and Manifest Anxiety were also calculated and are shown below.

TABLE 54

Correlations of speed, variability in speed, and Manifest Anxiety in Experiment 2.

Speed	Variability in speed
-.08	+.39+

+ significant at 5% level of confidence

Speed and variability of speed are calculated from all responses in the first session. Since speed remains constant for all distances of movement and lengths of signal, each subject can be represented by one score for speed and variability in speed.

The negative correlation between speed and Manifest Anxiety, though in an opposite direction to that predicted by the first hypothesis, is so close to Zero that it cannot be taken as indicative of a direction. The only significant correlate of Manifest Anxiety is variability in speed. The correlation of +.39 is in the expected direction (in terms of the second hypothesis) and is significant at the 5% level. As we have already noted, all the correlations between variability scores and Manifest Anxiety scores are in the expected direction, but this is the only significant correlation.

The correlates of Manifest Anxiety in Experiment 3 were also calculated and are shown below.

Table 55/.........

TABLE 55

Time judgement correlates of Manifest Anxiety in Experiment 3

Signal	Controlled l.m reproduction	Verbal est.	Error in reproduc.	Error in verbal est.	Variability reproduction	Variab. verb. est.
8 sec.	+.10	+.15	+.13	+.11	+.24	+.13
16 sec.	+.07	+.49**	+.25	+.22	+.14	+.33*

**significant at 1%
*significant at 5%

The data in Table 55 support both hypotheses, though not conclusively. The correlation between time judgement and Manifest Anxiety is positive, as predicted, but only the correlation of +.49 between Manifest Anxiety and verbal estimate is statistically significant. And we have noted several times that verbal estimates are not, on the whole, informative. The correlation between variability and Manifest Anxiety is also positive, as demanded by the second hypothesis, but only the correlation of +.33 between Manifest Anxiety and variability in the verbal estimate is statistically significant.

It will be noticed that the correlations between verbal estimate, reproduced time, and Manifest Anxiety reverse those obtained in Experiment 2, under conditions of free movement. A reference to Tables 47 and 45 in the previous chapter, will show that the same reversal of correlation occurred when extraversion was studied in relation to time judgement. Free linear movement correlated +.21 and +.10 (at 8 and 16 seconds, respectively) with extraversion. Controlled linear movement correlated -.20 and -.18 (at 8 and 16 seconds, respectively) with extraversion. Unfortunately, in neither the experiment with Manifest Anxiety, nor the experiment with extraversion, do the correlations achieve the level of significance required for us to draw conclusions from the reversal.

11.5.3 Discussion

The main point of interest to us is the extent to which our hypotheses are supported.

The first hypothesis, that the level of time judgement will correlate positively with Manifest Anxiety is supported by the results of the third experiment, but not by the results of the second. But in neither case are the correlations high enough to be more than indicative. The only significant correlation (.49, $p < .01$) is that between verbal estimate of 16 seconds and Manifest Anxiety, but great reliance cannot be placed on any interpretation of the significance of verbal estimates. It seems best to accept the null hypothesis, that there is no relationship between Manifest Anxiety and the reproduction of time by linear movement or by verbal estimation.

The second hypothesis, that there is a positive relation between Manifest Anxiety and variability in performance, is supported by the fact that there are, throughout the two experiments, positive correlations between all variability scores and Manifest Anxiety. The only two of these correlations (out of a total of 9) to reach significance are those between Manifest Anxiety and variability in speed (+.39), and Manifest Anxiety ~~(+.39)~~ and variability in verbal estimate of 16 seconds in Experiment 3 (+.33). Both of these correlations are significant at the 5% level. Because of these two significant correlations, it seems wise not to accept the null hypothesis, but at the same time we cannot too firmly assert that the hypothesis is confirmed.

The positive correlation between anxiety score and variability is congruent with what is known about the effects of anxiety on behaviour, and also with what is known about the results of increasing drive strength in a situation in which no single response or strength of response is consistently reinforced.

When one examines the Taylor Manifest Anxiety questionnaire various items seem to explain the relationship of the scale to variability in motor performance without reference to drive. Consider:-

Q 8. I frequently notice my hand shakes when I try to do something.

Q 34. I have periods of such great restlessness that I cannot sit long in a chair.

But these two items are not sufficient in a 50-item inventory to produce a positive correlation between variability in motor performance and the anxiety scale as a whole.

To account/......

To account for the variability in verbal performance attention may be drawn to the following item:-

Q 41. I find it hard to keep my mind on a task or job.

But again, a single item can hardly account for the positive correlation between verbal estimate variability and the scale taken as a whole. It must be admitted, though, that the scale does contain some items which favour explanation of the observed phenomena without recourse to a drive variable.

Attention may be drawn to the argument advanced by Taylor and Rechtschaffen (1959) in reply to criticism of the scale. They maintain that all the items reflect drive properties. By their argument, the hand tremor and the restlessness and the inability to keep the mind on the job reflect drive, It is logically a questionable precedure to use hypotheses about the origin of predictor variables to explain the appearance of predicted variables. In other words, it is an unverified hypothesis, itself subject to verification, that agreement with the above items reflects drive only, or mainly drive, or even partly drive. But this hypothesis, without further verification, is used to explain results. The scale as a whole has been subjected to testing in learning experiments which do, at least, show that it has a certain construct validity. That is, the test as a whole may be interpreted as a measure of drive because it satisfies the requirements of such a measure in a theoretical network or system.

Eysenck (1957) has criticised the experiments of the Iowa group on the grounds that it would be much simpler to manipulate a drive variable such as hunger or thirst. Franks (1957) has tested rate of eyeblink conditioning as a function of hunger and thirst (18 hour deprivation), and found no difference between satiated and deprived subjects. This is an admirable technique for those who are able to persuade sufficient numbers of subjects to deprive themselves of food and water for so long a period. And there is the added problem of the reliability of the subjects' reports on their deprivation. The truthfulness of the subject is, of course, always a problem in psychological experiments, but it is more likely to be found where the burden imposed is not too heavy.

It also/.......

It also appears that Manifest Anxiety measures chronic drive differences. Subjects at high chronic drive level may differ from subjects in whom an irrelevant drive is aroused momentarily. In Hull's theory any irrelevant drive should have the effect of accelerating conditioning, and it is fair criticism to produce evidence that a particular irrelevant drive does not have that effect. But we must be clear that a chronic irrelevant drive, such as measured by Manifest Anxiety may operate in a different way to an ephemeral drive. Furthermore, when the irrelevant drive becomes too strong, it may have a distracting effect. The subject, under strong drive, may no longer be interested in the experiment which is being performed. By shifting the whole area of the subject's interest, by focussing his attention on a new area, an irrelevant drive may retard learning. Instead of being an irrelevant drive, the drive may become <u>the</u> drive, and the other drives concomitant may become the irrelevant drives. In this way, a scale which measures drive disposition may have an advantage.

There is an unsatisfactory ambiguity in the interpretation of the results. We do not know whether we can attribute the positive correlations between variability and Manifest Anxiety purely to the drive properties measured.

Some reference to other literature should be made, to show that the results obtained here are not singular. Robertson (1958) found high-anxiety subjects to be more variable in their speed of turning a crank. Venables (1957) found neurotic drivers to be more inconsistent. Taylor and Spence (1952) found greater variability of response in learning a verbal maze to be associated with high anxiety score. These results are adduced merely to show that the correlations obtained between M.A.S. and variability in the present experiment are not exceptional. It appears that our first hypothesis must be rejected, but that our second hypothesis may be accepted with caution. There remains an ambiguity in interpretation of the results. The greater degree of error among anxious subjects (as indicated by positive though insignificant correlations between anxiety scores and error) is consistent with their greater variability of response.

SUMMARY AND CONCLUSIONS

11.6

Hypotheses were set up that (a) Taylor Manifest Anxiety scores (as measures of drive) would correlate positively with time judgement; and that (b) Taylor Manifest Anxiety scores (again as measures of drive) would correlate positively with variability of response.

The time judgement scores drawn from two free linear movement reproduction sessions in Experiment 2 (38 subjects) and four controlled distance linear movement sessions in Experiment 3 (40 subjects) were used. Manifest Anxiety scores were correlated with linear movement reproduction time, error in reproduction time, variability in reproduction time, speed of linear movement in reproduction, variability of speed, verbal estimate of duration of time signals, error in verbal estimate, and variability of verbal estimate.

The relationship between Manifest Anxiety and time judgement was inconsistent and not statistically significant. The null hypothesis was accepted that there is no relationship between time judgement and Manifest Anxiety.

All correlations between variability of response and Manifest Anxiety were positive, and two were significant at 5%. These were the correlation between Manifest Anxiety and variability of speed of movement (+.39) and between Manifest Anxiety and variability of verbal estimate of 16 seconds in Experiment 3 (+.33). It was decided that these facts tentatively support hypothesis (b) that there is a positive correlation between Manifest Anxiety and variability of time judgement.

The problem of deciding whether variability can properly be attributed to drive in general or to Manifest Anxiety score in particular was discussed, but no firm conclusion is possible.

CHAPTER 12

ACHIEVEMENT MOTIVATION, TIME IMAGERY AND TIME JUDGEMENT

12. 1 Introduction

Some attempts have been made to relate both Achievement and preference for certain classes of time imagery to a "puritan pragmatic character syndrome" (Knapp, 1962) which finds expression in characteristic ways of judging, among other things, time. This statement divides rather well into four questions. These are, the nature of achievement motivation, the nature of the time metaphor test, the relationship between/Achievement scores and metaphor scores, and the /n/ relationship of both to time judgement. The evidence under each heading will be reviewed and considered below.

12. 2 The nature of n Achievement

Achievement motivation is thought to be a relatively stable result of the manner of ego involvement (Mcclelland and others, 1949) which is measured by its perceptual and expressive consequences. The perceptual effects of n Achievement, especially after failure, are similar to those produced by hunger, according to McClelland and others (1949). There is an increase in imagery associated with the particular need aroused.

These perceptual consequences of n Achievement are demonstrated each time that protocols procured under neutral and under failure conditions are compared, since more themes mentioning mastery, failure, acts to overcome failure, statements of the need for mastery, press hostile to mastery, wishes for mastery by hero in story, anxiety over mastery of hero, and mastery images in the story appear (McClelland, 1953). There is some doubt about whether all these themes covary (McArthur, 1953), as the hypothesis on which testing n Achievement is based, demands. McArthur has also produced evidence which seems to show that contrary to expectation subjects low on n Achievement show a high incidence of

failure themes /...

failure themes after experience of failure. But his method of selecting subjects low on n Achievement is open to dispute. Low n Achievers were those subjects whose college grades fell one full grade below the grade expected of them on the basis of their school performance. High n Achievers were those who did better than expectation. This procedure leads us to examine the interesting problem of the relationship between achievement imagery and achievement behaviour.

Kagan and Moss (1959), using 44 boys and 42 girls in the Fels research population, found that achievement fantasy is in fact an index of a tendency to actually seek achievement goals. Broverman and others (1960) argue that fantasy is a substitute for action, and that the measurement of n Achievement by use of imagery does not tell us about the achievement-directed behaviour of the individual. From a study of 37 adult males representing a wide range of age and socio-economic position, they derive evidence that there is an inverse relationship between behavioural striving for advancement and fantasy measures of n Achievement. The finding in the original McClelland and others (1949) paper that failure arouses achievement fantasy is not inconsistent with this. But French (1955) has found that performance is related to n Achievement, and that it is more closely related to n Achievement than to a change in test conditions (from a relaxed to a competitive situation). Even under relaxed conditions, the subject high in n Achievement tries to perform well.

McClelland (1958) points out that measuring motivation by various methods very seldom produces agreement. When self-ratings, ratings by others, ratings of observation, and scores based on imaginative productions are correlated, significant intercorrelations are rarely obtained. Each of these measures is affected by a number of factors which does not enter into the others. Self-rating is affected by differences in candor and insight, ratings of others are affected by projection, halo effects and lack of knowledge, observation of conduct often fails to reveal the private motivation of the observed subject, and imaginative productions have peculiar difficulties of

interpretation. /...

interpretation. To a varying degree all these measures are multi-dimensional. Though they may overlap slightly, they have different central tendencies. McClelland argues that we must choose among these methods the one to suit our particular purpose; but we cannot regard them as interchangeable.

Fortunately, for the present purpose, it is not necessary to identify achievement imagery with achievement behaviour. It is sufficient for our purpose that the test chosen have relational fertility, and this criterion is satisfied by the n Achievement measure.

An important issue is the reliability of the n Achievement assessments. Interscorer reliability appears to be about .87 (Feld and Smith, 1958), but repeat reliability appears to vary between .64 (Morgan, 1953) and .03 to .56 (Birney, 1959). Birney attributes the wide range in reliability to the susceptibility of imaginative productions to setting.

In spite of this difficulty, it was thought worth while to include a study of the relationship between n Achievement and time judgement because of the theoretical richness of the measure. A large body of experimental and conceptual study has grown round the concept of n Achievement. Any new experiment may thus draw on this background for interpretation. The fact that many meaningful relations have been found between the measure of n Achievement and other variables is taken by McClelland to be the surest indicator of its validity.

12. 3 The Metaphor Test and Its Relation to n Achievement

High n Achievement appears to be related to a preference for swift, directional metaphors (Knapp and Garbutt, 1958). Subjects were assessed for n Achievement by the McClelland (1953) technique and asked to rate 25 time metaphors on a 5-point scale of preference in such a way that 5 metaphors were assigned to each ranking on the scale. That made five categories of five metaphors each, in order of preference from one to five. A factor analysis of the results yielded three clusters, which were characterised as (a) dynamic-hasty,

(b) naturalistic-passive /...

(b) naturalistic-passive, and (c) humanistic. Cluster (a) was related to high n Achievement, and was further defined by the authors as relating to a "Newtonian sense of time". Clusters (b) and (c) were further defined as, respectively, oriental-mystical and classical mediterranean. Examples of dynamic-hasty metaphors are:-

a dashing waterfall

a space ship in flight.

Examples of naturalistic-passive metaphors of time are:-

a road leading over a hill

a quiet, motionless ocean.

Examples of humanistic metaphors are:-

a tedious song

an old woman spinning.

A full list of all the metaphors may be consulted in Appendix A.

Knapp (1962), in a further study of attitudes to time and n Achievement, found two factors - the first identified as "time servant-master" which is characterised by emotional concern and harassment over management of time; and the second identified as obliviousness of time (at one pole) and efficient, unharassed management of time (at the other pole). High n Achievement, which was measured by the Tartan Test (Knapp, 1958) was positively related to the first factor. Low n Achievement was associated with the second factor.

Though the relations between time imagery and attitudes towards time have not been experimentally studied, they both separately reveal relations with n Achievement. Knapp puts forward the hypothesis that these connotations of time are dynamically integrated in a "puritan-pragmatic character syndrome in which achievement motivation, acute time awareness, asceticism, interest in science and technology and the preferred use of repression as a defense are positively related". This is a far-reaching and interesting hypothesis. It was possible to break down one small aspect of it for experimental study in the present programme. The problem with which we are concerned here is the relationship between judgement of short intervals of time, time

imagery, and /...

imagery, and need Achievement. The conjecture that there might be a link between time imagery and judgement of time is not a systematic prediction. It is arrived at as a fairly probable hypothesis on the basis that (a) differences in attitude to time might result in differences in the accuracy with which time is abstracted from experience; and (b) differences in time imagery might reflect subjective differences in the flow of time experience. Statement (a), that time is an abstraction from experience, simply reiterates the fact that we do not perceive time intervals (above a certain length, according to Fraisse, 1957) in the same way that we perceive objects or colours, or space. There are special sensory receptors for all these, but there is no sensory receptor for time. Duration, or time, is an attribute of all phenomena, but it is not directly perceived. As Pavlov remarked, there is no special cortical analyser for time because all cortical analysers are capable of analysing time. It is possible that persons with habitually different attitudes to time perform this abstraction rather differently.

Hypotheses were set up for testing with the data made available by the experiments described in Chapter 3. These were:-

(a) Subjects with a preference for dynamic-hasty metaphors are more accurate in their judgements of time.

The reason for this hypothesis is that subjects who prefer dynamic-hasty metaphors of time may be more acutely aware of time and hence more accurate. This is a deduction which one might make from Knapp's concept of the "puritan-pragmatic character syndrome".

(b) Subjects with a preference for dynamic-hasty metaphors have higher reproduction times than subjects with a preference for less active metaphors of time.

The reason for setting up this hypothesis is that subjects with a preference for swift metaphors may be more aware of the flow of time, or may be more concerned about the passage of time. This consciousness of time might be associated with a heightened judgement of the amount of time consumed.

In addition /...

In addition to these hypotheses about the relationship between time imagery and time judgement, further hypotheses about the relationship between n Achievement and time judgement were set up. But before we detail these additional hypotheses, the evidence that there is some relationship between n Achievement and time judgement ought to be considered.

12. 4. Time Judgement and n Achievement

High n Achievement has been found to relate to the tendency to recall past events as near to the present, and to anticipate future events (Knapp and Green, 1959). In one part of their experiment, subjects were asked to date six events in recent history. It was found that high n Achievement scorers tended to assign more recent dates to these events than low n Achievement subjects. In the second part of their experiment, subjects had to estimate the time taken by a moving point to reach a mark. High n Achievement was found to be associated with an underestimation of this time.

The authors maintain that the dynamic triad of aesthetic asceticism (measured in this experiment by the Tartan Test of Knapp (1958)), anticipation of the future and recall of the past as close to the present is characteristically associated with puritanism, which they identify with high n Achievement. But puritanism is certainly not the only, and may not even be the most descriptive, label to apply to the high n Achiever. Studies have shown that social classes as a whole may differ in n Achievement (Douvan, 1956), but it may be dangerous to describe these subcultures in terms of puritanism.

Another study by Knapp and Green (1961) shows that high n Achievement is associated with resistance to increasing judgement of a period of time which is presented on four successive occasions in a row. Subjects were asked to listen four times to a one-minute recording (played loudly, as the authors note) of Strauss' Blue Danube waltz. Those with high n Achievement scores resisted the impulse to increase their estimate of the duration of the fourth as compared to the first playing.

The authors suggest that subjects with high n Achievement scores have greater ego-executive control than those with low scores, and are more resistant to the "special qualities of music as a distractive influence".

Perhaps another study of ego-involved motive - but this time level of aspiration - and the judgement of time may be included. It has been found that subjects with a less accurate level of aspiration in time-based tasks (who tend to be less accurate, that is, in their estimation of their rate of doing work), also tend to be less accurate in their estimate of the duration of one second (Baer, Wukasch and Goldstone, 1963). But, according to the same authors, underestimators and accurate estimators of the duration of one second do not differ from each other in time-based aspiration level. The significance of this finding is hard to appraise without a more exhaustive study of the role of level of aspiration in time judgements under other conditions. As it is, no reason is advanced by the authors to explain the effect.

These studies, limited as they are, do suggest the plausibility of setting up hypotheses about the relationship between n Achievement and time judgements. The hypotheses set up for investigation with our data were:-

(c) Accuracy in the judgement of time and n Achievement are positively related.

The reason for setting up this hypothesis is that n Achievement is, in Knapp's concept of the "puritan-pragmatic character syndrome", positively associated with harassment and concern over time.

(d) High n Achievement and high time reproduction scores are positively related.

The first reason for setting up this hypothesis was outlined in a previous chapter, when it was shown that an increase in motive, when attention was focussed on the time interval, might be expected to lead to an increase in judgement of the length of the time interval. The second reason for setting

up this /...

up this hypothesis is that high n Achievement is, as has been mentioned, positively associated with a preference for swift metaphors, which may in turn reflect an increase in the rate of flow of subjective time.

12. 5 Hypotheses

The four hypotheses for testing will be stated together here for convenience. It must be pointed out that these hypotheses are not systematic predictions. They do not follow from some well-knit and carefully elaborated theory. They are merely conjectures about what the most probable relations are, after a oonsideration of such evidence as exists. If they test any unified concept at all, it is the concept of the puritan-pragmatic character syndrome, and then only one detail of that concept - the reference to "acute time awareness". But this is not a disadvantage, because the concept is extremely broad, and it would require a protracted experimental programme to study all its implications. The four hypotheses may now be stated.

(a) Subjects with a preference for dynamic-hasty time metaphors are more accurate in their judgements of time.

(b) Subjects with a preference for dynamic-hasty time metaphors have higher time reproduction scores than subjects with a preference for less active time metaphors.

(c) Subjects who have high n Achievement scores are more accurate than subjects with low n Achievement scores.

(d) .Subjects who have high n Achievement scores have higher time reproduction scores than subjects with low n Achievement scores.

12. 6 Experiment

12. 6. 1 Subjects and Method

The subjects were forty of the men and women first-year students described in Experiment 2, who, during normal psychology laboratory sessions, completed the Metaphor Preference Sdale and produced imaginative protocols for n Achievement scoring; and all

forty subjects /...

forty subjects described in Experiment 3, who completed the Metaphor Preference Scale only.

The sample for the Metaphor Preference Scale consisted, therefore, of a total of eighty subjects, forty of whom reproduced time intervals by free-distance linear movements and verbal estimates, and forty of whom reproduced time intervals by controlled-distance linear movements and verbal estimates.

The sample for studying the relationship between n Achievement and time judgement consisted only of forty subjects who reproduced time intervals by free linear arm movements and verbal estimates in Experiment 2.

The method of testing time judgements by free linear movements has been described in Experiment 2 (Chapter 3). Briefly, subjects who reproduced time signals by the method of free linear arm movements moved for any distance preferred and at a preferred rate in reproducing the time signal, and made a verbal estimate immediately after reproduction. Subjects who reproduced time signals by the method of controlled linear arm movements were asked to move a prescribed distance at such a speed as to equalise the duration of the movement of reproduction and the length of the signal. Verbal estimates were made after reproduction. A difference in procedure between between the two experiments is that, in Experiment 2, a number of signals of different duration were reproduced in each session, but in Experiment 3, only one length of signal was reproduced by movements of different distances in each session.

The forty free-movement subjects were tested for metaphor preference and time judgement in separate sessions. The forty controlled-movement subjects were tested for metaphor preference and time judgement in the same session. Subjects were asked to rank metaphors in groups of five on a five-point scale of preference. The scale was scored for preference for swift, directional metaphors. The Metaphor Preference Scale is shown in Appendix A.

Subjects were tested for n Achievement in the following way. During normal laboratory periods forty of the subjects tested in Experiment 2 wrote imaginative stories in response to three pictures: a) Two men in a workshop; (b) a boy with a book; and (c) a girl against the background of a farm scene. The entire experiment was conducted by a postgraduate researcher and the protocols were independently scored according to McClelland's (1953)

technique by / ...

technique by two postgraduate research students, working on a programme entirely divorced from the time judgement study.

12. 6 2 Results

The full Metaphor Preference scores obtained in Experiment 2 are listed in Appendix B, Table LXIII. The Metaphor Preference scores obtained in Experiment 3 are listed in Appendix B, Tables XLIII and XLIV.

Product-moment correlations of Metaphor Preference and time judgement variables were calculated and are shown below in Table 56.

TABLE 56

Product-moment correlations of Metaphor Preference and time judgement variables in Experiment 2.

Signal	Linear movement reproduction	Verbal estimate	Linear movement error	Verbal estimate
8 sec.	+.01	+.05	-.13	+.12
16 sec.	-.08	+.11	-.07	+.15

The correlations in the table above are in several instances in the expected direction, but they are so low that we must accept the null hypothesis. We may point out, though, that there is a positive correlation between a preference for swift metaphors and verbal estimate of both 8 and 16 seconds, and a positive correlation between reproduction of 8 seconds and preference for swift metaphors. Linear movement error correlates in the expected negative direction with a preference for swift metaphors, but error in verbal estimate correlates positively with preference for swift metaphors.

Metaphor Preference scores were also correlated with key-pressing scores, which were available for 21 of the subjects. The correlation of +.27 is in the expected direction, but is based on such a small sample that it is not statistically significant.

Correlations between speed of linear movement, variability in speed, and Metaphor Preference were also calculated, tp see whether a

preference for / ...

preference for swift metaphors was correlated with swift action. The correlations are shown below.

TABLE 57

Product-moment correlations of speed of linear movement reproduction, variability in speed, and preference for swift metaphors in Experiment 2.

Speed	Variability in speed
+.27	+.07

The correlation of +.27 between speed of linear arm movement and preference for swift metaphors is not statistically significant, but it does seem to indicate a slight degree of positive association between time imagery and action. The correlation of +.07 between variability in speed and Metaphor Preference is so low that we accept the null hypothesis. It has been thought that subjects high on preference for swift metaphor might display what Knapp and Green called greater "ego-executive control" and hence lower variability.

The correlations between Metaphor Preference and controlled linear movement reproductions were also calculated, and are shown below in the text.

TABLE 58

Product-moment correlations of Metaphor Preference and time judgement variables in Experiment 3.

Signal	Linear movement Reproduction	Verbal Estimate	Reproduction Error	Verbal error	Reproduction variability	Verbal variab
8 sec.	-.06	+.05	-.08	+.07	+.02	-.05
16 sec.	-.08	-.29	-.08	+.06	+.03	-.03

The first hypothesis, that time judgement and preference for swift metaphor are positively associated, is not supported by the correlations obtained, since they are largely negative. The exception is that verbal estimate correlates +.05 with Metaphor Preference. But the correlations are so low that the null hypothesis must be accepted in each case. The second hypothesis, that error in time judgement is

negatively associated /...

negatively associated with a preference for swift metaphors, is supported by the negative correlations between linear movement reproduction error and metaphor preference, but is contradicted by the positive correlations between Metaphor Preference and error in verbal estimate. In Experiment 2 the correlations went the same way. But in both Experiment 2 and 3 all the correlations are so low that the best course is to accept the null hypothesis.

Product-moment correlations of n Achievement scores and time judgement variables were also calculated. The full list of n Achievement scores and the associated time scores is given in Appendix B, Table LXIV. The correlations are shown below in the text.

TABLE 59

Product-moment correlations of n Achievement and time judgement variables in Experiment 2.

Signal	Linear movement reproduction	Verbal estimate	Reproduction error	Verbal error
8 seconds	-.04	-.07	+.01	-.02
16 seconds	-.06	+.05	+.01	+.19

The correlations are so low that the null hypothesis is accepted and the hypotheses about the relationship between time judgement and n Achievement are rejected. Not even the signs of the correlations are in the expected direction. Time judgement scores are positively rather than negatively associated with n Achievement, as was predicted; and error in time judgement is positively rather than negatively associated with n Achievement. But the signs are probably not indicative of anything where the correlations are so low.

Key-pressing scores were available for a small number of subjects (N=21). A calculation of the correlation between key-pressing reproduction of 16 seconds and n Achievement yields a figure of +.20, which is in the direction (though also not statistically significant) predicted in the hypothesis set up for testing.

Correlations between speed of movement in linear reproduction, variability in speed, and n Achievement were also calculated. It was thought that subjects with high n Achievement scores might be more energetic in their expressive movements, and that their acute awareness of time might find expression in swifter movements. It was also thought that subjects with high n Achievement scores would have lower variability in speed scores, since they are supposed to exercise greater control. This is a very broad statement, and it has to be experimentally limited. The present experiment may be regarded as, in some details, limiting the very broad concept of "puritan-pragmatic" character advanced by Knapp.

TABLE 60

Product-moment correlations of speed of linear movement, variability in speed, and n Achievement in Experiment 2.

Speed	Variability in speed
$+.32^{+}$	$+.34^{+}$

The significant positive correlation between speed of linear arm movement in reproducing time signals and n Achievement is congruent with the positive correlation of +.27 between preference for swift metaphors and speed of linear arm movement, since preference for swift metaphors is in turn associated with high n Achievement. This seems to show that there may be a personality constellation in which n Achievement, swift and energetic movement, and dynamic time imagery are associated, and that time awareness or time judgement may be secondary to this. The finding that high n Achievement is significantly and positively correlated with variability in speed is one instance of the fact that Knapp's concept of greater "ego-executive" control is too broad to be useful. The correlation is the reverse of expectation. Variability in speed has already been found to be positively and significantly associated with Manifest Anxiety (+.39). It is possible, therefore, that the positive correlation in both instances is the result of drive. We have discussed Hull's (1943) postulate that an increase in drive brings about an increase in variability. If high n Achievement score

does/........

x score does in fact reflect a higher drive condition then this correlation is psychologically meaningful. Another interesting possibility is suggested. It has been shown that the correlation between speed and variability in speed of linear reproduction movement is +.25 (N=54). This correlation borders on significance at the 5% level. It may be that this positive correlation is explained by both speed and variability in speed being, partly, indicators of drive.

12. 6. 3 Discussion: Metaphor Preference and Time Judgement

The two hypotheses set up for testing are both unsupported by the results, which favour the null hypothesis. The two hypotheses are:-

(a) That subjects with a preference for dynamic-hasty time metaphors are more accurate in their judgements of time.

(b) That subjects with a preference for dynamic-hasty time metaphors have high time reproduction scores.

These results suggest that a considerable amount of experimental evidence must be found to give Knapp's (1962) concept of the "puritan-pragmatic character syndrome" some substance. Furthermore, the obvious fact that "acute time awareness" is far too broad a concept to be meaningful or testable is brought into sharp focus. The fact that time imagery does not appear to be associated with the judgement of short intervals of time does not mean that there may not be long-term differences. Subjects who prefer time images of a certain kind may have different time perspectives from subjects who prefer time images of another kind. It is still possible that "acute time awareness" may be reflected in the way a person budgets or manages his time, rather than in his judgement of short intervals. Experience of any given interval of time is probably an extremely complex relationship among momentary, transitory conditions such as present physiological state (hot-cold, restless-relaxed, alert-tired, healthy-ill, etc.), present level of activity and absorption in activity, present motivational state, and among more enduring dispositions, such as images and attitudes referring to time, personality differences, differences in temperament, and long-term intentions. Some of these factors may be

relevant to /...

relevant to the way an individual locates himself in large time-perspectives, to the coherence and structure of his view of the past and the future; but other factors may be relevant to judgement of × short intervals. We ought certainly to distinguish very carefully among a number of different experiences of time, which probably have very little in common.

Even in short intervals of time, different facets of the experience may be isolated. Abe (1933) has distinguished between flow and structure, and has attempted to demonstrate their relationships. He asked subjects to represent their experience of time by means of drawings, and found that subjects portrayed the flow of time as hererogeneous when time intervals were experienced as long. Two structural effects found by him were, the dominance of the terminals portrayed in experiencing the duration as a short duration, and also a tendency to incorporate the terminals in the time-gestalt when the duration was experienced as a short duration.

But it has not been shown that the structure of the individual's impression of short time intervals is related to the structure of his conception of long time intervals. Nor has it been shown that individuals consistently experience time as long or short, fast-flowing or slow either when judging short intervals or in thinking about longer perspectives of time.

With these distinctions in mind, we may accept the null hypothesis for the relationship between the judgement of short intervals of time and swift metaphor preference. But we note that the problem of swift metaphor preference and its relation to the conception of longer time perspectives and time scheduling may be well worth the study, if Knapp's hypothesis of acute time awareness has any substance.

12. 6. 4 Discussion: n Achievement and Time Judgement

Both the hypotheses set up about the relationship between n Achievement and Time Judgement are unsupported. The results favour the null hypothesis in both cases.

The first /...

The first hypothesis was that subjects with high n Achievement scores are more accurate in their time judgements than subjects with low n Achievement scores. The correlations obtained between error by verbal estimate and n Achievement (-.02; +.19) and between error by linear movement reproduction and n Achievement (+.01; +.01) oppose this hypothesis.

The second hypothesis was that subjects with high n Achievement scores tend to make higher time judgements than subjects with low n Achievement scores. The correlations obtained between verbal estimate and n Achievement (-.07; +.05) and between linear movement reproduction and n Achievement (-.04= -.06) are in the opposite direction to that expected, but are so low that they cannot be held to indicate anything.

Again, we must emphasise the distinction made in the previous section. Though there is no support in our results for the hypothesis that acute time awareness is associated with the puritan pragmatic character syndrome, an acute time awareness may be expressed rather in conceptualisation of larger periods of time and in time scheduling. The greater the level of abstraction, the more possible it is that personality dispositions influence time experience. The subject with a high n Achievement score may, characteristically, be pressed for time, know what he is going to do at a certain hour a day or two ahead, and rationalise his time; but he does not appear to have a more accurate impression of shorter time intervals. To this extent our results do not lend any support to those of Knapp and Green (1959) who found that subjects with high n Achievement scores tend to underestimate a short interval of time.

But, though the more deliberate hypotheses framed at the commencement of the experiment failed to find support, an incidental observation of the relationships between speed of movement, variability in speed, and need Achievement found significant associations. It was found that n Achievement and speed of linear arm movement in reproducing time signals correlated significantly (+.32; $p<.05$). And again, variability in speed of movement and n Achievement correlate significantly

(+.34; /...

(a) A preference for swift metaphors is positively associated with accuracy in time judgement.

(b) A preference for swift metaphors is positively associated with high time judgement.

In both cases, after a study of the evidence, the hypotheses were rejected and the null hypothesis was accepted.

The relationship between n Achievement and time judgement was also studied, using the results of 40 subjects who reproduced time signals by free linear movement in Experiment 2. The hypotheses set up for testing were:-

(c) High n Achievement is positively associated with accuracy in time judgement.

(d) High n Achievement is positively associated with high time judgement.

In both cases, after a study of the evidence, the hypotheses were rejected and the null hypothesis was accepted.

It was found that speed of linear arm movement in reproducing time signals is positively and significantly associated with n Achievement. Variability in speed is also positively and significantly associated with n Achievement. It is concluded that the positive X. correlation between speed and n Achievement is consistent with Aronson's (1958) finding that high n Achievement is associated with spatial extension and mobility in graphic expression. The significant positive correlation between variability and n Achievement conforms with the prediction that high motivation is associated with high variability (Hull, 1943).

CHAPTER 13

CONCLUSIONS

13. 1 A Reliable Method of Time Judgement

Different methods of time judgement give different results. The method of verbal estimation reveals the accuracy with which the subject conceptualises time experience. The method of production reveals the accuracy with which a subject can convert a conceived duration into an acted duration. The method of reproduction reveals the accuracy with which a subject can convert a non-verbal, received duration into an acted duration. It is tempting to believe that there are three methods of time judgement, and that each of these methods reveals high internal consistency. In fact, different methods of reproduction do not relate more closely to each other than they do to the method of verbal estimation. Therefore, the logical distinctions which we make among broad categories of method do not correspond to psychological distinctions and may not have any psychological value.

Different methods of time judgement tend to show different degrees of accuracy and reliability. It has been found, in the past, that verbal estimates are reliable but that reproductions of time are not. For this reason, results obtained by the method of reproduction cannot be related to persistent differences in personality or temperament. They may reveal quite ephemeral status in time judgement. But if we wish to discover individual differences in time experience, non-verbal methods, such as the methods of reproduction, have special advantages. They do not rely on differences in conception of time and they reveal much finer distinctions of judgement. Most studies of individual differences in time judgement have been confined to individual differences in verbal estimation of time. In view of the high reliability of verbal estimates, this is wise. But it means, since time judgements by different methods are very slightly related to each other, that our knowledge of individual differences in time judgement must remain very restricted by the use of one method only. When verbal estimates of time are taken, it is not known whether they

reveal / ...

reveal (a) accuracy of conceptualisation; (b) perception of the presented time interval; or (c) ability to relate a non-verbal experience of time to a symbolic, verbal process. There are too many variables which the experimenter does not control. A precaution which might be taken to eliminate most of the objections is to deal only in intra-individual ratios. By this method, a separate standard is set up for each individual based on his verbal estimates of a set of signals. All judgements in the experimental situation are then converted into ratios of the standard. This method is not very often adopted. Furthermore, if a subject is tested in different sessions, he may radically alter his verbal estimates by checking his concept of clock time. This would alter his whole frame of references and invalidate the standard.

The problem is to find a reliable non-verbal method of obtaining time judgements. A method based on the known reliability of speed of movements of the limbs was designed by Professor K. Danziger, of the University of Cape Town, and was found to be a very reliable way of obtaining time judgements by the method of reproduction. Another advantage of this method is that the standard deviation of scores obtained by using it is high, so that individuals differ very widely in their reproduction scores by this method. Inter-subject deviation is high, and intra-subject deviation is low. Both of these are desirable in studying individual differences.

The first conclusion of the present study is that the method of reproduction of time signals by either free or controlled linear movement is more reliable than the method of reproduction by key-pressing, and is of the same order of reliability as verbal estimation of time (average reliability coefficient +.71). The level of reliability is suitable for detecting individual differences.

13.2 <u>Relations Among Different Methods of Time Judgement</u>.

The relations among three different methods of time judgement have been examined in the preceding chapters. These are:
(a) reproduction of time signals by key-pressing; (b) reproduction of time signals by horizontal linear arm movements of free and controlled

distance /...

distance; and (c) verbal estimation. Judgements obtained by the methods of key-pressing and linear arm movement do not relate more closely to each other than to verbal estimates. It would seem that each method of reproduction has special factors entering into it which must be considered. Judgement cannot be separated from the method of expression. An attempt was made, by using intra-individual ratios of scores, to show that a common core of time experience underlies each method. To put it in other words, changes in scores were correlated because, though subjects may have different frames of reference for judgements according to each method, changes in judgement might occur at the same rate within each frame of reference when the time experience is altered. In concrete terms this means that a Subject A may reproduce a signal of 8 seconds' duration with a response lasting 12 seconds and Subject B may reproduce the same signal with a response lasting 15 seconds. But their verbal estimates are not made according to the same frame of reference. They may be 21 seconds and 30 seconds (to take an example). In each case the verbal estimate is different from the reproduction time and does not bear the same relation to it. But, if the experience of time on which both verbal and reproduction time is altered, both may change proportionately. For example, if Subject A reproduces 16 seconds, in the second trial (the signal being held constant), then he might verbally estimate the signal as 28 seconds, increasing both his estimates by a third. If Subject B reproduces 10 seconds in the second trial (the signal being held constant), then he might verbally estimate the interval as 20 seconds, decreasing both his estimates by one third. Provided that changes in judgement by each method bear the same proportion to each other, they should reveal whether there is a common core of time experience on which they are all based. But what justification have we for assuming that they do change at the same rate? Reference to Table 19 in the text shows that, irrespective of method, the average ratios of change in judgement as signal length is doubled are very similar (verbal estimate 1.8; key-pressing 1.9; linear movement 1.8). The method of ratios seems, therefore, to have a reasonable basis. But the findings were equivocal. Correlations of ratios were found to be statistically significant when the signal was 16 seconds, but not when the signal was 8 seconds. This would lead us to

conclude /...

conclude, if we accept the result, that integration of judgements by different methods is greater at 16 seconds than at 8. This is understandable if we set up the hypothesis that, at 8 seconds, the individual is able to perceive the time signal as a unit without symbolic aid (this interval would correspond to the specious present, or the perceived present), but that at 16 seconds the common factor underlying all methods is a conversion of the time experienced into symbolic units.

Two main conclusions were drawn from the evidence.

i. Methods of reproduction of time by key-pressing and by linear movement are not more closely related to each other than they are to verbal estimates. The commonly accepted idea that the classification of method of time judgement into verbal estimates, reproductions and production is psychologically significant does not seem to be true. This is a logical, not a psychological division of methods.

ii. For all methods of time judgement, the relationship between time judged and length of signal may be satisfactorily fitted to Stevens' (1957) power law,

sensation = kS^n (where k is a constant; S is the stimulus; and n is the log. Sensation ratio/log. stimulus ratio).

Different k values have to be substituted in the equation, but the power n is almost identical for all methods.

13.3 Proprioceptive Time-Space Relations.

Time judgements based on exteroceptively received stimuli are affected by the speed at which these stimuli move and by their spatial distribution. Brown (1931) showed that when a subject has to reproduce the duration of a stationary visual signal by adjusting the speed of a figure moving across a screen (so that the time taken for a figure to move across the screen is equal to time for which the light was previously inspected), he adjusts the speed so that the moving figure is visible for a longer time than the light. Unfortunately he did not reverse the procedure and ask subjects to reproduce the duration of a moving figure by switching on a stationary light, but his results do suggest that movement reduces

phenomenal /...

phenomenal time. The work of Piaget (1946) leads to the same conclusion. Piaget states that "while it is being experienced, a rapid or accelerated action brings about a contraction of time (by virtue of the inverse relation of time and speed)" (Piaget, 1946, p. 266) once the child has reached the stage at which he can intuit transformations and is not dependent purely upon final results for his judgement of time.

This would lead us to suspect that when the subject is required to reproduce time intervals by some action which requires extensive bodily movement, the duration of the reproduction should be affected by speed. In Experiment 2 subjects were asked to reproduce auditory signals by linear arm movements at a preferred speed, but in Experiment 3 subjects were compelled to alter the speed of their arm movements by experimentally varying the distance which had to be covered in reproducing each signal. In neither case was speed found to be correlated with time reproduced.

The spatial effect on time judgement was also not found. When unequally spaced exteroceptive stimuli are presented, the impression which the subject receives is that the stimuli separated by a larger distance are also separated by a larger time interval (the kappa and suto effects). But in Experiment 3 of the present study, subjects asked to reproduce time intervals by movements of varying distance were able to maintain constancy. Reproduction of a given time interval over larger or smaller distances did not effect the impression of time which the subject received.

There is one effect which does seem to show that distance moved and time experience may be related. The verbal estimate of the auditory signal is more highly correlated with distance moved in reproducing that signal (average +.51) than with the time reproduced by the movement (average +.33). To put it another way: the two time judgements are not as closely associated as time judgement by verbal estimate and the distance of the movement of reproduction. This effect is found consistently in Experiment 2 and 3. It is reminiscent of the effect found by Jaensch (1905) : estimates of the extent of an arm movement are at least partly determined by the duration of that movement. Similarly, estimates of the duration of an arm movement may be at least partly determined by the extent of that movement.

The /...

The close relationship between psychological space and psychological time, which has been shown in discussion of the tau, kappa and suto effects, as well as in Piaget's studies of the confusion between "further" and "longer" in the time judgements of children, was also examined by Bergson in his treatise on "Time and Free Will" (1910). Bergson distinguishes between pure duration and time. The former is a qualitative change, but the latter is a spatial concept. Bergson states that "pure duration might well be nothing but a series of qualitative changes ... "; but "when you attribute the least homogeneity to duration, you surreptitiously introduce space" (ibid., p. 104). Bergson enlarges on the difference between duration and measured time with the example of the cumulative psychological effect of a repeated sound. "We must admit that the sounds combined with one another and acted, not by their quantity as quantity, but by the quality which their quantity exhibited ... If we assert that it was always the same sensation, the reason is that we are thinking, not of the sensation itself, but of the objective cause situated in space. We then set it out in space in its turn, and in place of an organism which develops, in place of changes which permeate one another, we perceive one and the same sensation stretching itself out lengthwise, so to speak, and setting itself out in juxtaposition without limit" (ibid., p. 106). If we follow Bergson's argument and repeat an example which has been used earlier (section 6.1.2.); the adult's ability to equate a duration spent looking at an amusing picture and a duration spent standing with his arms folded is the result of a geometrical externalisation of duration. He has converted duration into space (that is, time).

The spatial representation of time perspectives and of short time intervals presents no difficulties to subjects in psychological experiments. Guilford (1924), Abe (1933), and Cohen, Hansel and Sylvester (1954) have asked subjects to represent time by means of spatial figures. This spatial representation of time, becoming increasingly detached from the first experiences which gave rise to it, "ends in a conception in which time is assimilated to a Euclidean type of space" (Fraisse, 1963, p. 283).

In /...

In the experiments of the present study, subjects were able to reproduce time intervals by movements of varying length with reliabilities which are considerably higher than those reported in other experiments. Is this not, perhaps, because once the subject has converted duration into space he is able to form a stable image of that duration? He has externalised his experience in a form which is readily retained and repeated.

The problem of the way in which duration and space are linked has not yet been mentioned. Bergson (ibid., p. 110) describes the relationship in the following manner: "There is a real space, without duration, in which phenomena appear and disappear simultaneously with our states of consciousness. There is a real duration, the heterogeneous moments of which permeate one another; each moment, however, can be brought into relation with a state of the external world which is contemporaneous with it, and can be separated from the other moments in consequence of this very process. The comparison of these two realities gives rise to a symbolical representation of duration derived from space. Duration thus assumes the illusory form of a homogeneous medium, and the connecting link between these two terms, space and duration, is simultaneity, which might be defined as the intersection of time and space".

The work of Piaget (1946) has shown that the concept of a uniform, homogeneous, and continuous time is an achievement of operational thought. At first, the child judges duration purely by results, or work accomplished. When he becomes capable of introspection, he judges by his experience of duration (which varies with motivation and affect), but only at the stage of formal operational thought is time detached from duration. In the words of Bergson, "time, conceived under the form of an unbounded and homogeneous medium, is nothing but the ghost of space haunting the reflective consciousness" (ibid., p.99).

The hypothesis advanced here is that it is nothing but this "ghost of space" which makes the judgement of duration by movement in space so reliable (though inaccurate) compared to other methods. The subject fastens onto the image of space, which he uses throughout his life, in externalising his experience of duration.

The less tentative conclusions about the time-space relations of linear arm movements are stated below.

i. Time reproduced by free linear movement, and speed of free linear movements, are not significantly related. This is found when either raw scores (average correlation, regardless of direction, -.18), or intra-subject changes in scores (average correlation +.03) are correlated.

ii. Time reproduced and distance of free linear movement in reproducing time are significantly correlated. This applies both to raw scores and to changes in scores (average correlations are +.39 and +.46, respectively). This means that subjects who move further tend to move for a longer time (the alternative is that they might move faster and keep duration constant) and that, when a subject increases his distance of movement, he increases the time taken for the movement (the alternative is that he might increase his speed sufficiently to compensate).

iii. Speed and distance of linear movement are positively related to each other, as might be expected. The alternative is that a subject might move faster, but for a shorter time, and so keep the distance constant. The positive correlation between distance and speed of movement is found among both raw scores (average correlation +.78) ~~and intra-individual changes in scores (average correlation +.78)~~ and intra-individual changes in scores (average correlation +.71).

iv. The correlation between distance of free linear arm movement and verbal estimate of the length of signal is greater than that between time reproduced by free linear arm movement and verbal estimate of the length of the signal (average coefficients are +.51 and +.33, respectively). This leads to the conclusion that time estimate and distance of movement are more closely associated than time estimate and duration of movement. Jaensch's (1906) conclusion that estimates of the spatial extent of a limb movement are

partly /...

partly determined by the time take for that movement may be true in the reverse as well: estimates of the duration of a movement are partly determined by the spatial extent of that movement.

v. When the distance of the linear arm movement by which the subject reproduces time signals is experimentally varied, no significant differences in time judgements occur. This means that the subject can reproduce the same time interval by movements of varying speed and distance.

vi. All linear movement reproductions, whether free- or controlled-distance, differ significantly from key-pressing reproductions, but free- and controlled-distance linear movement reproductions do not differ from each other. This suggests that the method of linear movement requires a different adaptive timing system from key-pressing.

13.4 Delayed Reproduction of Time Intervals.

Delayed reproduction of time signals might seem to offer a sensitive technique for measuring the strength of the trace of a time signal - and thus giving information about the immediate history of traces caused by stimulation. Satiation and inhibition theory seem to predict a rise in the strength of the trace - for a limited period - since both satiation and inhibition are thought to dissipate more rapidly than excitation. The classical perseveration theory also predicts an initial increase in the strength of the trace. This initial increase is more protracted than the effect reported by Köhler (1923), who found an increase in the strength of the excitation process lasting approximately 3 seconds.

Theory based on the assumption that recurrent circuits carry the trace would seem to predict that there is no loss over a short period of time, but an important modification of circuit theory has been introduced by Broadbent (1957), who suggests a circuit with a limited capacity for units of information to act as a vehicle for immediate memory. If, in the time between input and rehearsal, the limits of the circuit are exceeded, information is lost. The amount of information lost varies with conditions, but it is generally not merely the amount by which input

exceeds /...

exceeds capacity. Presumably, with rehearsal there is a transfer to other circuits for more permanent storage. There is direct evidence that recent and older memories are stored at different loci (e.g. Penfield, 1959), so that this hypothesis is not untenable. The fading trace theory of memory has been applied to explain effects obtained in time judgement. Frankenhaeuser (1959) has explained the fact that past-time estimates obtained by her from subjects are lower than present-time estimates, on the basis of a fading trace. Present-time estimates were measured in the following way: A subject is instructed to produce (say) 20 seconds by reading randomised digits at a rate of one digit per second. Randomised digits are used to prevent counting. Past-time estimates are then given by the subject's verbal estimate of the time produced. Frankenhaeuser explained the fact that past-time estimates are lower than present-time estimates by means of the fading trace theory, but overlooked the fact that two different methods of time judgement have been used for the comparison. It has been shown that different methods of time judgement have different means and standard deviations. But, even if one accepts her result, it seems that the most appropriate model to explain it is Broadbent's (1957) recurrent circuit model. The time estimate must, in this experiment, be based on a large number of units of information, in order to be correct. Probably, other cues are used in addition to the remembered digits for the assessment of time. These may be analogous to the work of attention proposed by Mach (quoted by James, 1890, p.635). A trace theory is more appropriate to reproduction of a continuous single stimulus. If this is so, then the data obtained by us suggest that there is no change in the strength of the trace over a period of 60 seconds, the upper limit of the observations in the experiment.

The conclusion is stated formally below.

Where the time interval to be judged is presented in the form of a continuous auditory signal, short delay has no effect on time judgement. This may be understood in terms of Broadbent's (1957) model to show that where the information stored is within the capacity of a recurrent system, no delay effects may be expected as long as the system is kept active.

13. 5 Extraversion /...

13.5 Extraversion and Time Judgement.

On the basis of work by Eysenck (1957) and Claridge (1960), using hysterics and dysthymics as criterion groups for, respectively, extraverts and introverts, it was predicted that extraversion would be negatively correlated with time judgements. The use of neurotics as criterion groups may be criticised on the grounds that, whereas extraversion and neuroticism are orthogonal dimensions in normal samples (r= -.1), they correlate very highly in extreme populations (-.3 to -.4). In terms of Eysenck's own strictures on other writers, a test should not be used if it does not isolate a dimension. Besides the fact that in these neurotic samples extraversion and neuroticism are not independent factors, there is the possibility that extraversion and neuroticism may interact in such a way as to reverse results. That this can happen is shown in an experiment by Wallach and Gahm (1960). They found that extraversion is normally associated with large drawings, and introversion with small drawings, but that these associations may be completely reversed when anxious introverts and extraverts are used.

In support of Eysenck's work on neurotic populations there is the evidence of Lynn (1960), obtained with normal subjects, that extraversion is associated with lower reproduction score.

This would seem to settle the issue. But, there is a great deal of disagreement among various experimenters who have tested predictions from Eysenck's Typological Postulate. Another difficulty is that we cannot speak of time judgement as though there is one absolute scale according to which all responses are made.

Several interesting results were obtained and are described in detail in Chapter 9. None of the time judgements correlated significantly with extraversion. Furthermore, there was not complete consistency in the direction of the correlations. Reproduction by controlled linear movements correlated in the expected negative direction with extraversion, but all other time judgements (free linear arm movement, verbal estimate, key-pressing) correlated in a positive direction with extraversion, which contradicts expectations.

One score /...

One score which correlates significantly - and consistently - with extraversion is error in reproduction of time by both free and controlled linear movement. The correlation is negative. This seems to be psychologically meaningful. Extraverts, who tend to use the skeletal muscular system to a greater extent than introverts (if the questionnaires indicate anything) might be expected to be more accurate in a task requiring motor co-ordination.

Consistent with this result is the finding, also in the present experiment, that extraversion is negatively correlated with variability in linear movement reproduction. Since variability has been found to correlate positively and significantly with error ($r = +.52$ at 8 seconds and +.56 at 16 seconds), the results seem to provide a consistent pattern.

Though the hypotheses based on the work of Eysenck are not confirmed, the picture which we get of extraverts as less variable and more accurate in their performance of a perceptual-motor task is psychologically meaningful.

The conclusions of the present study are stated formally below.

i. Eysenck's conclusion that level of time judgement is negatively related to extraversion is contradicted by positive (though statistically insignificant) correlations between reproduction by key-pressing and by free linear movement, and verbal estimation of time signals, and extraversion. But it is supported by the negative (though statistically insignificant) correlations between reproduction by controlled linear movement and extraversion. The results show that time judgements cannot be thought of as distinct from the method used to obtain them. On the whole, they do not favour his Typological Postulate.

ii. Extraverts tend to be less variable in their performance than introverts. The correlation between extraversion and variability in speed of free linear movement is statistically significant (-.43; $p < .01$). All other correlations between extraversion and variability scores are negative, though not statistically significant.

iii. There is no difference between extraverts and introverts in the speed of linear arm movement, nor in the distance moved. Both of these

were /...

were expected of extraverts (rather tentatively) on the basis of the finding that extraverts tend to be rather more expansive than introverts in graphic expression (Wallach and Gahm, 1960).

iv. Extraverts are more accurate than introverts in their reproduction of time signals by both free- and controlled-distance linear arm movement. In Experiment 2 the correlations between extraversion and error are -.48 at 8 second signal and -.50 at 16 second signal, (both significant at less than 1%). In Experiment 3 the correlations between extraversion and error are -.12 at 8 second signal and -.47 at 16 second signal. The latter correlation is significant at less than 1%.

13.6 Secondary Functioning and Time Judgement.

The view that a general factor of inhibition might affect speed of function in a large variety of activities is fundamental to Eysenck's concept of extraversion-introversion. The view that there are temperamental differences in speed of function in a large variety of activities - caused by mental inertia - is fundamental to the Heymans-Wiersma concept of primary-secondary functioning. If we identify inhibition with mental inertia, then Eysenck's tentative proposal (1953, 1957) that the two dimensions are to a large extent identical is not unreasonable. Using some of the tests of secondary functioning described by Biesheuvel and Pitts (1955), an attempt was made to see whether there is any correlation between extraversion and secondary functioning. At the same time, an attempt was made to discover whether there is a relation between secondary functioning and time judgement. The argument is simply that if there is an overlap between extraversion and secondary functioning, then the predictions of the Typological Postulate might hold good for the relation between secondary functioning and time judgement.

It was predicted that secondary functioners would have lower reproduction scores than primary functioners.

The correlations between extraversion and measures of secondary functioning are in the expected direction, but not significant. The correlations between time judgement and measures of secondary functioning are also in the expected direction, but not significant.

Since /...

Since the measures of speed used were very brief, and since the inertia, or inhibition, associated with secondary functioning might well take some time to develop to a detectable level, it is recognised that the fact that the correlations are in the expected direction, though statistically significant, invites further experimental study.

The conclusion is stated below.

i. The hypothesis that secondary functioning is related to extraversion and to reproduction of time by linear movement is supported by the direction of the correlations. But none of the correlations are statistically significant.

13.7 Manifest Anxiety and Time Judgement.

With a considerable degree of success, Janet Taylor, Spence and Farber have shown that the Manifest Anxiety Scale has construct validity as a measure of drive. The evidence for and against this view is discussed in Chapter 11. Their experiments were designed very largely to test predictions from Hull's (1943) learning theory. If we accept that Manifest Anxiety does measure drive, several predictions in connection with time judgements become possible.

Evidence drawn from experiments on visual perception indicate that an increase in drive brings about an increase in judgements of size and brightness. In addition, evidence drawn from experiments on time judgement indicate that an increase in drive brings about an increase in the judgement of a time interval, where attention is directed to the duration of the time interval and not to a task occupying that interval. In both types of experiment, the judgement is of an inessential attribute. It is not instrumental in securing a reward. This may be important in affecting the ease with which distortions are brought about. On these grounds, an increase in Manifest Anxiety Score, as an index of drive, should bring about an increase in judgement of the length of the time signal. Another effect which is likely to occur (in terms of Hull's theory) is that variability of response is increased by heightened drive.

But results showed that the relationship between Manifest Anxiety and time judgements by various methods is inconsistent and not statistically significant. The null hypothesis is accepted that there is no relationship between time judgement and Manifest Anxiety.

On the other hand, all correlations between Manifest Anxiety and variability in response are in the expected (positive) direction, and two of these correlations are significant at the 5% level of confidence. These are the correlation between Manifest Anxiety and variability of speed of movement (+.39) and between Manifest Anxiety and variability of verbal estimate of 16 seconds (+.33). It is concluded that Manifest Anxiety is related to variability in performance.

The conclusions are formally stated below.

i. There is no relationship between Manifest Anxiety and time judgement by any of the methods in the experiments described.

ii. Manifest Anxiety seems to be positively related to variability of response. All correlations between Manifest Anxiety and measure of variability are positive, and two of them are statistically significant. These are: (a) between Manifest Anxiety and variability in speed of free linear movement ($r = +.39$; $p < .05$); and (b) between Manifest Anxiety and variability in verbal estimate of 16 seconds ($r = +.33$; $p < .05$).

13.8 <u>n Achievement and Time Judgement.</u>

Knapp (1962) has described a "puritan-pragmatic character syndrome in which achievement motivation, acute time awareness, asceticism, interest in science and technology, and the preferred use of repression as a defense are positively related". There is some evidence that high n Achievement is related to underestimation of time separating events from the present (Knapp and Green, 1959), but there is not a great deal of evidence to substantiate the view that time awareness is significantly related to n Achievement. Nor can we be sure exactly what kind of time awareness is implied. Knapp and Garbutt (1958) do refer to the association between n Achievement and a "Newtonian sense of time", but much remains to be done to define the time awareness involved. Does it refer to tight scheduling and long-term planning, or to accuracy in the judgement of short time intervals? With the data available it was possible to test the second possibility.

Among the problems studied were: (a) what is the relation between n Achievement and the time judgement score by various methods; (b) what is the relation between n Achievement and accuracy of time judgement; and (c) what is the relation between n Achievement and speed of linear arm movement as an expressive characteristic? The null hypothesis had to be accepted for both (a) and (b), but it was concluded that n Achievement is positively and significantly associated with speed of linear arm movement ($r = +.32$; $p < .05$). High n Achievers appear to be more energetic in their expressive behaviour. This is in agreement with the finding of Aronson (1958) that n Achievement can be measured by spatial extension and mobility in graphic expression. An incidental observation, which agrees very well with the prediction that variability is associated with drive, is that variability in speed of linear arm movement is also significantly and positively associated with n Achievement. ($r = +.34$; $p < .05$).

The conclusions are formally stated below.

i. n Achievement is not related to the judgement of time by any of the methods described.

ii. n Achievement is significantly related to speed of free linear arm movement in reproducing time signals. This confirms Aronson's (1958) discovery that n Achievement is related to spatial extension and mobility in graphic expression.

iii. n Achievement is significantly related to variability in speed of movement. This may be expected in terms of the prediction that ascillation of response is positively related to strength of motive.

13.9 <u>Metaphor Preference and Time Judgement</u>.

A relation has been found between a preference for swift, directional metaphors, and n Achievement (Knapp and Garbutt, 1958). Although there is no direct evidence, it is possible that a preference for swift metaphors of time reflects, or is related to, other aspects of time awareness. For this reason, the time judgement data at our disposal were related to metaphor preference scores. Several problems were studied. These were: (a) the relationship between a preference for swift metaphors and time judgement; (b) the relationship between a

preference /...

preference for swift metaphors and speed of linear arm movement, as an expressive characteristic.

None of the correlations is significant. The highest correlation (+.27) is between speed of linear arm movement and a preference for swift, directional metaphors of time. This corre - lation does seem to show that a preference for swift images may have other expressive correlates.

The conclusions are formally stated below:

i. Metaphor Preference is not related to time judgement by any of the methods described.

ii. The relationship between a preference for swift, directional metaphors and speed of linear arm movement approaches statistical significance ($r = +.27$) and may indicate that there is a general expressive preference guiding imagery and gesture.

13. 10 Suggestions for Further Research.

13.10. 1 Primary and Secondary Illusions.

The distinction between primary perception and perceptual activity which has been made by Piaget (quoted by Flavell, 1963, p.p. 234 - 236) might form a valuable guide in studying some temporal illusions. Primary perception usually depends on isolated centrations. It is perception relatively unaffected by operational thought. Such field effects, or primary illusions, as the Müller-Lyer, are the result of primary perception. Perceptual activity, on the other hand, tends to reduce the magnitude of the field effects which occur in primary perception. Perceptual activity is characterised by decentration, spatial and temporal transports of elements during comparisons, active reconfiguration, memories and other processes which merge with the operations of intelligence. Though perceptual activity reduces the primary illusions produced by primary perception, it is the source of secondary illusions, such as overconstancy in the visual judgement of size. Thus, primary illusions tend to decrease with age and secondary illusions tend to increase.

There are several illusions in the judgement of time which might

be studied /...

be studied genetically to determine whether they are primary illusions (field effects) or the result of perceptual activity. The kappa effect (Cohen and others, 1955) has been explained by appealing to the subject's experience of moving bodies. This is clearly a perceptual activity and not a primary perception. The tau effect (Helson and King, 1931) has also been explained as a result of the experience of movement, and the suto effect (Suto, 1952) has been explained as an effect which is dependent on visual experience. Genetic studies to determine whether these effects increase or decrease with age and experience would help to make clear whether these explanations are likely to be true.

The effect of velocity on the judgement of time might also be the result of perceptual activity rather than of primary perception. Piaget has shown that the ability to compare different velocities occurs only after the operational stage of development has been reached. We might, therefore, find the young child impervious to velocity effects on time judgement. An experimental difficulty would be to secure comparisons of duration from young children, since judgements of duration are usually based on the results of action, as we have seen in an earlier section (6.1.2). The young child will base his judgement of duration on the spatial position of the figure, or on the amount of work accomplished.

13.10. 2 <u>Cognitive Variables and Time Judgement.</u>

If the distinction between perceived time intervals of a duration up to a maximum of about 5 seconds (Fraisse, 1963, p.92) and longer, conceived time intervals which require an operation of intelligence for their reconstruction and judgement is valid, then children should be found to judge short intervals relatively inaccurately. Genetic studies have used longer intervals ranging from 14 seconds to 117 seconds (Axel, 1924; Gilliland and Humphries, 1943) and have shown, as expected, that children are much more variable and inaccurate in their estimations of time. But these studies do not enable one to compare judgements of perceived and conceived time intervals. But research by Orsini (quoted by Fraisse, 1963, p. 238) has at least answered the question of whether 7-year-old children are capable of judging an interval of 30 seconds as

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well as adults. She found that after a training period of three weeks the judgements of the children were as accurate as those of adults before training. From this it appears that the experience rather than the capacity is lacking.

Adults as well as children may be affected to different degrees by the nature of the task, and the evidence seems to show that the ability to overcome errors in judgement which are a direct result of the nature of the task may be related to the growth of operational thought. Both children and adults experience the same illusions (that time seems longer when we are labouring up a hill or doing a boring task or waiting for something to happen), but adults can usually correct the illusion on the basis of a variety of criteria, whereas children are dominated by one particular aspect of the situation in forming their judgement. Axel (1924) found that children are much more susceptible to the effects of qualitative differences in forming time judgements than adults are. The contrast between filled and unfilled time intervals is more important in influencing time judgement at 9 years of age than at 14 years of age. At both ages, verbal estimates of empty time intervals are higher than estimates of intervals spent at some task, but the difference is much smaller at 14 than at 9 years of age. At the age of 9 years an empty interval of 20 seconds is judged 4.4. times as long as the same time interval spent doing mental arithmetic. At 14 years the ratio is 2.3. At 9 years the task of writing I's is judged 2.5 times as long as the task of doing mental arithmetic; but at 14 the ratio is 1.4. The growth of formal operational thought may explain the decreasing effect of qualitative differences on time judgement.

The relationship between cognitive variables and ability to overcome qualitative differences in making a time estimate might be a field worth exploring. Even at the adult level, the differences may be very great. To take an example, the intra-subject ratio of time judgement by linear movement and time judgement by key-pressing may vary from nearly 7 to almost 1. Subjects who are able to judge equally well by the two methods have a ratio approximating 1. They are able to overcome the large qualitative differences between the two methods of judgement.

The relation /...

The relation between an active-passive cognitive style and time judgement has been demonstrated by Loehlin (1959). Active subjects appeared to be less subject to time illusions - such as errors in comparison of intervals filled with accelerating or decelerating auditory pulse. Spivack and others (1959) have shown that relative delay in telling the experimenter when a period of time has elapsed is positively related to intelligence. These are somewhat fragmentary findings, but they do suggest that cognitive variables and time judgement might be related.

But the work of Gardner and others (1960) on the relationship of four methods of cognitive control to perceptual tasks might be profitably pursued in the field of time judgement. The first method of cognitive control is that of levelling versus sharpening, which may be defined as the readiness of the subject to accurately judge a change in stimulus. The second cognitive style is field articulation, or the degree of field dependence versus independence. It may be defined as the selectiveness of the subject in actively directing his attention to significant features of the field. The field-dependent subject, in comparison with the field-independent subject, shows little selectivity. The third method of cognitive control is scanning control, or the degree of deployment of attention of which the subject is capable. The fourth cognitive control is the ability to tolerate unrealistic experiences.

The relationship between these methods of cognitive control and time judgement might be studied.

13.10. 3 Individual Differences in Integration of Time Judgements.

Considerable differences exist in the degree to which individuals are able to integrate their time judgements. This problem exists both where qualitatively different time intervals must be judged by the same method and where an identical time interval is judged by different methods. Since the former problem was rather more extensively dealt with in the preceding section than the latter problem, the present section will be largely confined to a discussion of the latter. In the former case, the problem is the extent to which subjects are able to reduce different afferent stimuli to a common denominator. In the latter, the problem is the extent to which subjects are able to make different efferent impulses

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equivalent, according to some objective criteria by which the resultant behaviours are judged.

We may study the extent to which the different actions yield judgements which are objectively equal, or we may attempt to measure differences in the extent to which different judgements, though not equal, are functionally related. We may differentiate between subjects who are able to give the same judgement by different methods, and those who are less able; or we may accept that judgements by different methods are different, but maintain that they form (to an extent which differs from individual to individual) a system. In the former case, if a subject verbally estimates an interval as 8 seconds, then his judgements are referred to as integrated if he reproduces it as 8 seconds. In other words, integration is defined by equal time judgements, when the method is changed. This is perhaps the ideal case. But we may accept that judgements which are objectively unequal (8 seconds by verbal estimation, 5 seconds by reproduction, for example) may be subjectively equivalent, and may be related, provided that they change at some uniform rate in relation to each other. If that occurs, then we can say that the time judgements of the person form a system. Obviously, the case in which all methods yield the same objectively equal time judgement is the paragon, the pure and ideal example of systematic relationship. But even where methods yield objectively unequal time judgements they may form a tightly integrated system, preserving uniform rates of change in relationship to each other. The rate of change of time judgements by each method may be sampled by asking the subject to judge a number of time intervals of varying length and determining the averate ratio of increase of the judgement in relation to a fixed ratio of increase of the stimulus (see Chapter 5).

The extent to which the subject's judgements of time by different methods form a system is likely to vary with age, which brings about a growing systematisation of the subject's cognitive operations. In addition, the extent of this systematisation at any given age may be related to other cognitive variables.

To the extent that the subject achieves a state of cognitive

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equilibrium, such functional relations could be expected to occur. A state of equilibrium is described by Piaget (quoted by Flavell, 1963, pp. 242 - 244) by means of the dimensions of field of application, mobility, permanence and stability. The field of application of a psychological state of equilibrium will vary from a single centration (such as on the final position of the moving figures when the preoperational child is asked to judge durations) to consideration of the relations between order of stopping and starting, velocity, or other facts which might be relevent. The more developed the system, the wider the range of application. The mobility of the system increases as the actions are internalised, since representation is more mobile than overt behaviour. The permanence and stability of the system in equilibrium are defined by the resistance of that system to changes of state as input changes. On the one hand, perceptual equilibria have low permanence (are unstable) and may be altered by changes in the field; but on the other, the relations in cognitive systems retain their structure even when the momentary stimulus-input is altered. As an example of this, one might take the extended impression of time which the subject has when he is bored, or the contracted impression which he has when he is interested. If he bases his time judgements on these affective states alone, then he is likely to vary considerably. But cognitive systems, once developed, are not so easily upset. The subject may look (to take the simplest case) at his watch and assure himself that the two periods are identical. He may use other cues, such as counting, rhythmic breathing, the feeling of muscular strain, changes in light, the position of the sun, to correct conclusions based on less stable systems.

It is our contention here that the extent to which subjects fail to integrate their time judgements is at least partly determined by their failure to use more stable cognitive systems. The converse is that the extent to which subjects do integrate their judgements is at least partly determined by the extent to which they use more stable cognitive systems. The more the subject's judgements are affected by qualitative differences in the period judged or the method of judging,

the less /...

the less the extent to which he corrects his judgements by using rational clues.

The results of Experiments 2 and 3 show that time judgements by different methods are more closely related to each other when a longer (16 second) interval is judged than when a shorter (8 second) interval is judged. It was suggested, in the Chapter in which this was considered (Chapter 5), that one factor underlying the closer integration of judgements of the longer time interval might be that the longer interval must be judged by a process which demands more consideration, a greater use of symbols, whereas the shorter period may be directly perceived. In other words, where the interval is longer, the greater integration depends on the greater systematisation of cognitive systems. Where the interval is shorter, the lower integration reflects the lack of use of the more integrated cognitive systems.

An extended study of the degree of integration of judgements of shorter or longer intervals might help to strengthen the distinction (or prove it invalid) between perceived and conceived time.

An extensive study of the relationship between cognitive variables and the systematisation of time judgements might be illuminating.

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BRIEF PERSONALITY INVENTORY

NAME OR CODE: .... SEX: ....

The following brief personality inventory has been used a great deal for making rapid assessments of certain aspects of personality. It is now planned to subject it to further statistical analysis.

Please answer the following questions frankly by putting a ring around either YES or NO for each question. It is important that you should not leave out any questions, so please decide in each case whether on the whole the answer should be YES or NO in your case.

1.	Do you have dizzy turns?	YES	NO
2.	Do you get palpitations or thumping in your heart?	YES	NO
3.	Do you worry too long over humiliating experiences?	YES	NO
4.	Do you consider yourself rather a nervous person?	YES	NO
5.	Are your feelings easily hurt?	YES	NO
6.	Are you subject to attacks of shaking or trembling?	YES	NO
7.	Are you an irritable person?	YES	NO
8.	Do you worry over possible misfortunes?	YES	NO
9.	Do you have nightmares?	YES	NO
10.	Do you suffer from sleeplessness?	YES	NO
11.	Did you ever get short of breath without having done heavy work?	YES	NO
12.	Do you suffer from 'nerves'?	YES	NO
13.	Are you troubled by aches and pains?	YES	NO
14.	Do you get nervous in places such as lifts, trains or tunnels?	YES	NO
15.	Do you lack self-confidence?	YES	NO
16.	Are you troubled with feelings of inferiority?	YES	NO
17.	Do you prefer action to planning for action?	YES	NO
18.	Are you happiest when you get involved in some project that calls for rapid action?	YES	NO
19.	Do you usually take the initiative in making new friends?	YES	NO
20.	Are you inclined to be quick and sure in your actions?	YES	NO
21.	Would you rate yourself as a lively individual?	YES	NO
22.	Would you be very unhappy if you were prevented from making numerous social contacts?	YES	NO

METAPHOR TEST

NAME or CODE .... SEX ....

It is psychologically interesting to investigate the effectiveness of metaphors. There are certain metaphors which have a universal appeal for everyone, others which appeal to some people but not to all, and finally those which appeal to hardly anyone.

Below are listed 25 metaphors which a poet or a writer might use to symbolize his sense of <u>time</u>. Please read through this list and then indicate before each metaphor how appropriate it is in evoking a satisfactory image of time.

First select the five metaphors that seem to you most appropriate as images of time and before each place the number "1". Then pick out the next most appropriate metaphors and before them place the number "2". Continue this process until you have placed the number "5" before what are in your opinion the five least appropriate metaphors.

Number	Assessment	Metaphor
1.		A large revolving wheel.
2.		A whirligig.
3.		A road leading over a hill.
4.		Budding leaves.
5.		An old man with a staff.
6.		A bird in flight.
7.		A fast-moving shuttle.
8.		A winding spool.
9.		A speeding train.
10.		A quiet, motionless ocean.
11.		A burning candle.
12.		A stairway leading upward.
13.		A dashing waterfall.
14.		A space ship in flight.
15.		Wind-driven sand.
16.		An old woman spinning.
17.		Drifting clouds.
18.		Marching feet.
19.		A vast expanse of sky.
20.		The Rock of Gibraltar.
21.		A fleeing thief.
22.		A devouring monster.
23.		A tedious song.
24.		A string of beads.
25.		A galloping horseman.

26.	I am more sensitive than most other people.	TRUE	FALSE
27.	I frequently find myself worrying about something.	TRUE	FALSE
28.	I wish I could be as happy as others seem to be.	TRUE	FALSE
29.	I am usually calm and not easily upset.	TRUE	FALSE
30.	I cry easily.	TRUE	FALSE
31.	I feel anxiety about something or someone almost all the time	TRUE	FALSE
32.	I am happy most of the time.	TRUE	FALSE
33.	It makes me nervous to have to wait.	TRUE	FALSE
34.	I have periods of such great restlessness that I cannot sit long in a chair.	TRUE	FALSE
35.	Sometimes I become so excited that I find it hard to get to sleep.	TRUE	FALSE
36.	I have sometimes felt that difficulties were piling up so high that I could not overcome them.	TRUE	FALSE
37.	I must admit that I have at times been worried beyond reason over something that really did not matter	TRUE	FALSE
38.	I have very few fears compared to my friends.	TRUE	FALSE
39.	I have been afraid of things or people that I know could not hurt me.	TRUE	FALSE
40.	I certainly feel useless at times.	TRUE	FALSE
41.	I find it hard to keep my mind on a task or job.	TRUE	FALSE
42.	I am unusually self-conscious.	TRUE	FALSE
43.	I am inclined to take things hard.	TRUE	FALSE
44.	I am a high-strung person.	TRUE	FALSE
45.	Life is a strain for me much of the time.	TRUE	FALSE
46.	At time I think I am no good at all.	TRUE	FALSE
47.	I am certainly lacking in self-confidence.	TRUE	FALSE
48.	I sometimes feel that I am about to go to pieces.	TRUE	FALSE
49.	I shrink from facing a crisis or difficulty.	TRUE	FALSE
50.	I am entirely self-confident.	TRUE	FALSE

BIOGRAPHICAL INVENTORY I

Name or Code .... Sex ....

The following inventory is being investigated for research purposes.

Please indicate, to the best of your ability, which of the following statements apply in your case and which do not. Put a ring around the word TRUE if you feel that, on the whole, the statement applies to you; put a ring around the word FALSE if you feel that, on the whole, the statement does not apply to you.

1.	I do not tire quickly.	TRUE	FALSE
2.	I am troubled by attacks of nausea.	TRUE	FALSE
3.	I believe I am no more nervous than most others.	TRUE	FALSE
4.	I have very few headaches.	TRUE	FALSE
5.	I work under a great deal of tension.	TRUE	FALSE
6.	I cannot keep my mind on one thing.	TRUE	FALSE
7.	I worry over money.	TRUE	FALSE
8.	I frequently notice my hand shakes when I try to do something.	TRUE	FALSE
9.	I blush no more often than others.	TRUE	FALSE
10.	I have diarrhoea once a month or more.	TRUE	FALSE
11.	I worry quite a bit over possible misfortunes.	TRUE	FALSE
12.	I practically never blush.	TRUE	FALSE
13.	I am often afraid that I am going to blush.	TRUE	FALSE
14.	I have nightmares every few nights.	TRUE	FALSE
15.	My hands and feet are usually warm enough.	TRUE	FALSE
16.	I sweat very easily even on cool days.	TRUE	FALSE
17.	Sometimes when embarrased, I break out in a sweat which annoys me greatly.	TRUE	FALSE
18.	I hardly ever notice my heart pounding and I am seldom short of breath.	TRUE	FALSE
19.	I feel hungry almost all the time.	TRUE	FALSE
20.	I am very seldom troubled by constipation.	TRUE	FALSE
21.	I have a great deal of stomach trouble.	TRUE	FALSE
22.	I have had periods in which I lost sleep over worry.	TRUE	FALSE
23.	My sleep is fitful and disturbed.	TRUE	FALSE
24.	I dream frequently about things that are best kept to myself.	TRUE	FALSE
25.	I am easily embarrassed.	TRUE	FALSE

PLEASE TURN OVER

13.	Are your daydreams frequently about things that can never come true ?	Yes	?	No
14.	Are you inclined to keep in the background on social occasions ?	Yes	?	No
15.	Are you inclined to ponder over your past ?	Yes	?	No
16.	Is it difficult to " lose yourself " even at a lively party ?	Yes	?	No
17.	Do you ever feel " just miserable " for no good reason at all ?	Yes	?	No
18.	Are you inclined to be overconscientious ?	Yes	?	No
19.	Do you often find that you have made up your mind too late ?	Yes	?	No
20.	Do you like to mix socially with people ?	Yes	?	No
21.	Have you often lost sleep over your worries ?	Yes	?	No
22.	Are you inclined to limit your acquaintances to a select few ?	Yes	?	No
23.	Are you often troubled about feelings of guilt ?	Yes	?	No
24.	Do you ever take your work as if it were a matter of life or death ?	Yes	?	No
25.	Are your feelings rather easily hurt ?	Yes	?	No
26.	Do you like to have many social engagements ?	Yes	?	No
27.	Would you rate yourself as a tense or " highly-strung " individual ?	Yes	?	No
28.	Do you generally prefer to take the lead in group activities ?	Yes	?	No
29.	Do you often experience periods of loneliness ?	Yes	?	No
30.	Are you inclined to be shy in the presence of the opposite sex ?	Yes	?	No
31.	Do you like to indulge in a reverie (daydreaming) ?	Yes	?	No
32.	Do you nearly always have a " ready answer " for remarks directed at you ?	Yes	?	No
33.	Do you spend much time in thinking over good times you have had in the past ?	Yes	?	No
34.	Would you rate yourself as a happy-go-lucky individual ?	Yes	?	No
35.	Have you often felt listless and tired for no good reason ?	Yes	?	No
36.	Are you inclined to keep quiet when out in a social group ?	Yes	?	No
37.	After a critical moment is over, do you usually think of something you should have done but failed to do ?	Yes	?	No
38.	Can you usually let yourself go and have a hilariously good time at a gay party ?	Yes	?	No
39.	Do ideas run through your head so that you cannot sleep ?	Yes	?	No
40.	Do you like work that requires considerable attention ?	Yes	?	No
41.	Have you ever been bothered by having a useless thought come into your mind repeatedly ?	Yes	?	No
42.	Are you inclined to take your work casually, that is as a matter of course ?	Yes	?	No
43.	Are you touchy on various subjects ?	Yes	?	No
44.	Do other people regard you as a lively individual ?	Yes	?	No
45.	Do you often feel disgruntled ?	Yes	?	No
46.	Would you rate yourself as a talkative individual ?	Yes	?	No
47.	Do you have periods of such great restlessness that you cannot sit long in a chair ?	Yes	?	No
48.	Do you like to play pranks upon others ?	Yes	?	No

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MAUDSLEY PERSONALITY INVENTORY

NAME .... CHRISTIAN NAMES ....

AGE .... SEX .... OCCUPATION ....

N = E = ? =

Instructions

Here are some questions regarding the way you behave, feel and act. After each question there is a " Yes," a " ? " and a " No ".

Try and decide whether " Yes " or " No " represents your usual way of acting or feeling ; then put a circle round the " Yes " or " No." If you find it absolutely impossible to decide, put a circle round the " ? ", but do not use this answer except very occasionally. Work quickly, and don't spend too much time over any question ; we want your first reaction, not a long drawn-out thought process ! The whole questionnaire shouldn't take more than a few minutes. Be sure not to omit any questions. Now go ahead, work quickly, and remember to answer *every* question. There are no right or wrong answers, and this isn't a test of intelligence or ability, but simply a measure of the way you behave.

1.	Are you happiest when you get involved in some project that calls for rapid action ?	Yes	?	No
2.	Do you sometimes feel happy, sometimes depressed, without any apparent reason ?	Yes	?	No
3.	Does your mind often wander while you are trying to concentrate ?	Yes	?	No
4.	Do you usually take the initiative in making new friends ? ..	Yes	?	No
5.	Are you inclined to be quick and sure in your actions ? ..	Yes	?	No
6.	Are you frequently " lost in thought " even when supposed to be taking part in a conversation ?	Yes	?	No
7.	Are you sometimes bubbling over with energy and sometimes very sluggish ?	Yes	?	No
8.	Would you rate yourself as a lively individual ?	Yes	?	No
9.	Would you be very unhappy if you were prevented from making numerous social contacts ?	Yes	?	No
10.	Are you inclined to be moody ?	Yes	?	No
11.	Do you have frequent ups and downs in mood, either with or without apparent cause ?	Yes	?	No
12.	Do you prefer action to planning for action ?	Yes	?	No

APPENDIX A

QUESTIONNAIRES

1. Maudsley Personality Inventory
2. Taylor Manifest Anxiety Scale
3. Metaphor Preference Test

APPENDIX B

TABLES OF SCORES

T A B L E   I

EXPERIMENT 1

Average first and second session free linear movement reproduction of time signals (N = 31). <u>All scores are seconds.</u>

	0.9 Sec Signal		2.0 Sec Signal		3.7 Sec Signal	
	1st Session	2nd Session	1st Session	2nd Session	1st Session	2nd Session
	0.5 sec	0.8 sec	0.6 sec	0.8 sec	0.9 sec	0.7 sec
	0.7	0.6	1.0	1.0	2.0	1.8
	0.6	1.0	1.3	1.2	0.6	1.9
	0.8	0.7	1.5	1.3	2.5	1.8
	0.3	0.4	1.5	0.5	1.8	1.5
	0.6	0.8	1.4	1.1	2.5	2.8
	0.8	1.3	2.0	1.9	2.5	2.8
	0.9	0.7	1.9	2.2	2.2	3.7
	0.6	0.7	1.8	1.4	3.1	2.8
	1.2	1.0	2.3	2.0	3.5	3.7
	0.9	0.9	2.5	1.9	3.8	1.9
	1.3	1.0	1.6	1.8	2.0	2.7
	1.4	1.3	2.2	1.2	4.0	4.0
	0.8	0.9	2.1	1.4	3.3	3.8
	0.8	1.0	1.0	2.2	2.7	3.1
	1.0	0.8	1.8	1.6	2.3	2.5
	0.9	0.8	1.6	2.5	3.0	2.7
	0.8	0.6	2.1	1.6	3.3	3.2
	1.0	1.2	2.0	1.8	3.1	3.9
	0.8	0.5	1.4	1.1	3.1	3.2
	1.1	1.0	2.7	1.4	2.4	2.0
	2.4	1.6	3.3	4.4	6.5	8.0
	1.8	1.0	2.8	2.0	6.0	3.1
	1.1	1.5	2.5	3.1	3.8	4.1
	0.8	0.7	3.4	1.0	3.7	2.3
	1.3	0.8	3.2	2.1	4.0	5.0
	0.9	0.8	2.2	2.3	4.4	3.6
	0.8	0.7	2.2	1.8	3.8	3.0
	1.5	1.0	2.6	2.0	3.5	3.3
	0.9	0.6	2.7	2.7	3.8	4.3
	0.8	0.6	2.8	3.1	2.7	3.3
TOTAL	30.1 sec	27.3 sec	64.0 sec	55.4 sec	96.8 sec	96.5 sec
MEAN	0.97	0.88	2.06	1.79	3.12	3.11
STD. DEV.*	0.399	0.252	0.680	0.744	1.198	1.278

* STANDARD DEVIATION

TABLE I (Continued)

EXPERIMENT 1

Average first and second session free linear movement reproduction of time signals (N = 31). All scores are seconds.

	4.3 Sec Signal		6.1 Sec Signal	
	1st Session	2nd Session	1st Session	2nd Session
	0.9 sec	1.4 sec	1.4 sec	1.3 sec
	1.3	1.2	1.9	2.8
	2.6	1.9	2.3	2.0
	2.1	2.3	4.2	2.9
	3.2	1.5	3.0	2.9
	3.5	4.2	5.0	4.5
	3.5	3.6	3.8	4.7
	3.5	3.6	4.9	5.5
	2.6	3.3	4.7	4.8
	3.5	4.8	6.4	4.9
	3.2	2.8	5.4	2.8
	3.2	3.0	3.6	3.5
	4.4	3.5	5.0	4.8
	4.4	4.7	6.2	6.7
	4.7	3.6	5.3	4.1
	3.8	4.0	5.0	5.1
	2.5	3.3	4.7	5.2
	3.7	3.8	5.9	6.3
	3.3	4.2	5.0	4.6
	3.8	3.6	5.1	3.9
	4.9	3.4	4.7	3.5
	8.6	8.1	13.2	10.0
	8.4	3.9	12.6	4.0
	4.6	3.5	7.0	6.8
	6.8	7.5	6.2	4.6
	4.5	4.0	6.4	5.7
	4.5	5.2	6.0	4.4
	4.4	3.2	6.5	5.3
	5.3	3.9	6.1	4.2
	4.9	4.5	6.1	5.8
	7.8	6.7	7.5	5.9
TOTAL	128.4 sec	118.2 sec	171.1 sec	143.5 sec
MEAN	4.14	3.81	5.62	4.63
STD. DEV.*	1.774	1.523	2.159	1.622

* STANDARD DEVIATION

TABLE II

EXPERIMENT 1

Average first and second session speed of free linear movement in reproducing time signals (N = 31). All scores are inches per second.

	0.9 Sec Signal		2.0 Sec Signal		3.7 Sec Signal	
	1st Session	2nd Session	1st Session	2nd Session	1st Session	2nd Session
	8.0	4.7	13.3	10.0	21.1	22.8
	8.6	15.0	15.0	19.0	12.0	18.7
	21.7	19.0	17.7	15.0	18.3	11.6
	7.5	10.0	8.0	13.8	8.8	13.3
	3.3	2.5	2.7	6.0	5.0	5.3
	15.0	16.2	15.0	11.8	10.0	7.5
	7.5	4.6	5.0	5.8	5.2	6.4
	3.3	4.3	7.9	5.4	10.0	6.0
	5.0	8.6	6.7	6.4	6.1	6.8
	7.5	9.0	5.2	7.0	7.1	6.8
	10.0	14.4	6.8	17.4	8.2	17.4
	9.2	9.0	7.5	8.3	12.5	8.1
	7.1	13.1	5.5	15.8	5.8	7.5
	17.5	14.4	16.7	16.4	15.5	15.0
	37.5	20.0	30.0	16.8	41.1	15.2
	5.0	8.7	7.2	4.4	4.3	4.0
	4.4	6.2	2.5	3.6	4.0	5.6
	5.0	6.7	4.8	6.2	4.5	4.7
	10.0	8.3	8.0	8.3	8.1	7.7
	22.5	42.0	20.0	33.6	21.3	43.7
	17.3	12.0	14.1	20.7	19.6	18.5
	6.3	5.6	6.7	4.5	5.7	3.5
	11.1	6.0	10.7	7.5	8.0	7.4
	11.8	5.3	14.4	4.8	12.9	5.1
	7.5	11.0	5.0	7.5	5.7	11.7
	4.6	8.7	4.7	6.7	5.8	6.0
	8.7	7.5	6.4	8.3	6.4	8.9
	5.0	4.3	5.5	3.9	6.3	3.3
	6.0	8.0	4.2	8.5	5.4	7.6
	6.7	10.0	4.1	5.1	5.5	3.9
	27.5	36.7	21.1	42.9	36.7	37.8
TOTAL	328.1	351.8	302.4	351.4	346.9	348.0
MEAN	10.58	11.35	9.75	11.33	11.19	11.23
STD.DEV.*	7.66	8.54	6.33	8.65	8.84	9.25

* STD.DEV. = STANDARD DEVIATION

TABLE II (Continued)

EXPERIMENT 1

Average first and second session speed of free linear movement in reproducing time signals (N = 31). All scores are inches per second.

	4.3 Sec Signal		6.1 Sec Signal	
	1st Session	2nd Session	1st Session	2nd Session
	14.4	20.0	21.4	17.7
	28.4	30.8	15.4	17.9
	13.1	14.7	15.7	17.5
	15.2	15.2	11.2	15.5
	2.5	4.0	8.0	4.5
	8.0	7.4	6.0	7.6
	8.6	5.8	6.1	6.0
	7.3	5.0	6.7	5.4
	7.3	7.3	7.0	6.7
	6.6	7.7	5.6	7.3
	11.6	13.0	7.0	13.9
	9.7	9.3	9.4	8.3
	6.8	8.0	5.2	6.7
	11.6	16.8	12.6	19.4
	30.9	16.4	34.9	18.1
	5.5	4.0	6.0	4.3
	5.2	3.9	3.2	3.3
	4.3	3.9	3.6	3.8
	8.2	7.4	8.8	8.0
	13.7	37.5	21.8	46.1
	14.1	16.5	19.6	21.1
	8.6	4.6	5.6	5.0
	8.5	5.9	7.5	7.0
	12.4	5.9	14.9	4.7
	8.1	6.1	8.7	8.8
	5.6	6.0	4.7	5.8
	6.2	6.5	5.3	10.6
	6.4	4.4	6.0	4.0
	4.5	7.4	5.1	8.3
	4.0	3.9	4.1	3.6
	26.0	31.2	26.7	35.6
TOTAL	323.3	336.5	325.8	352.5
MEAN	10.43	10.85	10.51	11.37
STD.DEV.*	6.77	8.63	7.48	9.48

* STD.DEV. = STANDARD DEVIATION

TABLE III

EXPERIMENT 2

Average first and second session free linear movement reproduction of 8 seconds and 16 seconds. (N = 56). All scores are seconds.

	8.0 Second Signal		16.0 Second Signal	
	1st Session	2nd Session	1st Session	2nd Session
	8.3 sec*	6.2 sec*	11.4 sec*	11.7 sec*
	6.0	6.9	11.9	9.2
	6.1	6.2	14.6	13.6
	7.0	5.2	15.3	12.5
	5.3	4.2	11.5	8.4
	5.4	6.1	11.9	11.8
	4.8	6.3	13.0	12.2
	7.2	6.3	15.2	12.8
	5.7	6.0	13.1	10.2
	5.8	6.2	11.6	12.7
	1.3	1.5	4.3	3.5
	3.9	4.6	10.4	10.5
	3.5	2.5	6.8	4.6
	3.5	4.8	8.2	8.4
	7.8	7.7	12.4	13.3
	2.3	2.2	3.7	4.5
	6.2	5.5	14.0	14.0
	6.5	7.0	12.0	14.8
	5.7	6.8	10.8	14.3
	6.9	7.5	12.5	14.9
	7.3	7.2	13.8	14.9
	5.9	3.2	10.5	8.5
	6.0	2.9	16.9	6.1
	4.7	2.5	9.8	5.1
	7.1	6.7	18.6	12.2
	4.1	2.8	7.0	5.1
	6.0	7.1	18.0	14.2
	8.9	7.1	16.1	14.6
	7.9	8.3	13.7	14.6
	4.7	5.5	9.0	13.3
	3.8	3.5	8.0	5.4
	7.5	4.6	13.9	8.5
	6.5	4.4	12.5	10.0
	3.3	2.7	2.2	2.9
	7.4	7.6	14.7	14.7
	6.4	4.4	10.4	7.9
	7.5	7.5	19.0	16.3
	8.8	5.6	17.8	10.7
	6.2	4.3	11.9	9.0
	10.0	5.6	10.5	14.0
	9.0	8.2	16.9	16.1
	5.5	8.4	9.6	16.8
	4.3	4.6	9.1	7.7
	1.6	1.4	0.7	1.0
	6.1	6.8	12.0	10.5
	7.3	5.4	14.3	10.0
	8.9	8.3	12.0	16.0
	7.3	6.3	18.3	10.6
	8.2	6.4	14.5	12.0
	8.4	8.9	15.6	18.2
	7.8	6.0	14.0	13.3
	5.9	6.0	14.9	8.6
	4.7	6.5	12.9	12.0
	2.8	1.6	2.3	3.9
	8.0	5.6	13.3	15.0
	2.7	5.7	8.0	6.0
TOTAL	337.7	309.3	667.3	603.6
MEAN	6.03	5.52	11.92	10.78
STANDARD DEVIATION	2.44	1.90	4.09	4.02

* sec = seconds

TABLE IV

EXPERIMENT 2

Average first and second session speed of free linear movement in reproducing 8 and 16 seconds (N = 56). All scores are inches per second.

	8 Second Signal		16 Second Signal	
	1st Session	2nd Session	1st Session	2nd Session
	4.6 ins/sec*	7.6 ins/sec*	4.1 ins/sec*	8.0 ins/sec*
	11.7	6.8	11.5	8.6
	8.3	11.3	10.3	8.1
	7.1	7.1	7.2	6.4
	13.2	13.1	13.9	12.5
	6.5	2.3	8.1	4.1
	7.5	9.2	7.7	8.6
	5.1	4.8	4.3	5.3
	9.6	7.8	5.3	8.2
	5.7	9.5	5.9	7.6
	16.1	22.7	16.3	21.4
	4.9	4.6	4.6	4.5
	5.7	3.6	5.1	3.7
	13.4	9.8	13.7	10.7
	6.7	3.1	7.1	7.9
	13.0	18.2	11.9	23.3
	8.1	6.9	9.3	7.5
	6.3	8.6	5.8	9.0
	4.6	4.7	4.3	4.9
	2.7	4.0	4.2	3.4
	12.0	16.0	15.2	14.8
	7.6	8.7	7.6	7.9
	10.8	15.2	12.7	13.1
	36.2	50.4	38.1	52.9
	6.3	5.7	5.6	1.4
	7.6	14.3	10.7	15.7
	9.2	7.7	8.9	9.1
	5.4	11.3	7.4	10.9
	25.3	31.3	28.2	37.9
	2.8	6.4	7.1	5.4
	5.0	3.1	3.0	3.5
	3.1	3.7	2.6	3.4
	5.2	5.9	4.4	5.0
	10.3	11.1	3.6	5.5
	6.3	8.5	6.1	8.5
	8.3	4.1	7.2	4.3
	2.9	2.4	1.6	1.6
	9.4	13.2	10.6	9.8
	7.6	5.1	7.1	5.4
	3.7	5.2	4.5	5.0
	7.8	6.1	6.2	7.3
	10.0	25.0	9.9	26.4
	8.1	7.6	7.7	7.7
	18.1	15.7	11.4	35.0
	3.4	4.1	4.7	4.8
	6.6	6.8	6.1	7.4
	3.4	3.4	4.9	3.1
	7.1	7.3	7.4	8.0
	8.5	6.2	7.9	7.0
	7.4	10.0	11.5	8.8
	6.3	5.3	5.7	4.4
	11.5	8.7	9.4	8.4
	9.8	11.4	9.5	7.8
	3.9	6.3	12.2	4.4
	3.5	3.4	2.6	2.0
	5.9	6.1	6.0	6.7
TOTAL	467.1	529.3	475.9	544.0
MEAN	8.34	9.45	8.50	9.71
STANDARD DEVIATION	5.52	7.70	5.85	9.23

* sec = seconds

TABLE V

EXPERIMENT 2

First and second session verbal estimate and key-pressing reproduction of 8 seconds and 16 seconds (N = 32). Scores are seconds.

	Key-pressing				Verbal Estimate			
	8 Seconds		16 Seconds		8 Seconds		16 Seconds	
	1st Session	2nd Session	1st Session	2nd Session	1st Session	2nd Session	1st Session	2nd Session
	9.2	7.3	17.2	15.5	7.0	7.0	13.0	15.0
	8.3	7.6	15.0	14.6	8.0	9.0	14.0	16.0
	7.7	7.7	16.3	11.7	8.0	8.0	16.0	15.0
	8.2	7.0	16.0	14.4	14.0	10.0	25.0	21.0
	8.5	7.2	16.0	16.3	8.0	6.0	16.0	12.0
	7.4	7.0	14.4	14.3	6.0	7.0	13.0	15.0
	8.1	6.8	14.5	16.0	9.0	8.0	15.0	17.0
	7.3	7.7	17.2	15.3	8.0	7.0	17.0	11.0
	7.0	6.4	14.2	14.7	8.0	8.0	18.0	17.0
	7.4	8.8	15.9	16.6	12.0	11.0	25.0	23.0
	6.9	6.9	14.7	12.3	8.0	8.0	15.0	15.0
	8.4	8.5	16.6	16.7	12.0	15.0	20.0	28.0
	7.2	7.7	15.5	16.0	6.0	6.0	12.0	12.0
	8.3	6.7	14.6	15.0	4.0	6.0	10.0	12.0
	7.1	6.4	16.8	15.9	14.0	17.0	24.0	35.0
	7.8	7.3	17.8	15.9	15.0	11.0	35.0	20.0
	8.6	7.4	16.2	16.0	15.0	13.0	24.0	28.0
	8.0	6.7	17.9	17.0	8.0	7.0	18.0	16.0
	11.4	8.9	19.4	17.7	7.0	6.0	11.0	11.0
	7.6	6.6	18.2	15.6	7.0	8.0	14.0	15.0
	6.1	4.5	11.8	11.3	7.0	3.0	20.0	7.0
	8.5	8.5	11.0	16.2	24.0	18.0	25.0	34.0
	8.7	9.2	15.6	15.3	11.0	8.0	20.0	20.0
	6.7	7.0	9.7	13.0	7.0	6.0	10.0	11.0
	7.0	6.4	14.2	13.7	10.0	7.0	19.0	16.0
	8.3	9.5	13.9	18.1	10.0	25.0	13.0	50.0
	6.5	7.6	15.8	14.5	15.0	8.0	30.0	14.0
	7.2	7.0	16.1	14.5	6.0	6.0	12.0	11.0
	8.6	8.6	14.7	18.8	33.0	27.0	52.0	54.0
	6.3	6.7	13.6	13.5	8.0	8.0	14.0	13.0
	7.8	7.9	15.5	16.8	20.0	18.0	35.0	48.0
	11.7	8.8	21.4	18.9	15.0	12.0	25.0	16.0
TOTAL	253.4	238.3	497.7	492.1	350.0	324.0	630.0	648.0
MEAN	7.9	7.4	15.55	15.38	10.9	10.1	19.7	20.2
STANDARD DEVIATION	1.20	1.02	2.26	1.79	5.86	5.46	8.77	11.69

TABLE VI

EXPERIMENT 3

Average 1st and 2nd session reproduction of 8 seconds and 3rd and 4th session reproduction of 16 seconds, by controlled linear movement (N = 40). All scores are seconds.

	Signal 8.0 Seconds		Signal 16.0 Seconds	
	1st Session	2nd Session	3rd Session	4th Session
	6.8	8.9	15.8	15.7
	14.2	13.5	21.6	18.7
	11.7	11.1	16.5	14.1
	7.3	9.6	12.3	14.2
	6.1	10.5	17.5	18.2
	8.7	7.7	17.3	17.2
	7.1	10.7	19.3	18.7
	9.8	11.0	14.9	12.9
	7.3	7.6	15.6	16.9
	12.1	14.6	9.9	11.8
	7.5	14.3	22.7	18.4
	4.2	3.4	21.9	16.6
	12.1	11.3	22.5	22.8
	5.1	7.4	19.7	17.0
	9.0	10.5	13.9	12.9
	13.7	17.4	16.3	17.7
	8.1	7.9	15.8	14.7
	7.7	7.7	15.3	15.1
	8.7	10.3	10.9	16.0
	7.7	7.7	16.4	16.9
	14.4	12.5	10.5	10.8
	9.8	10.0	18.3	19.8
	8.1	7.1	18.1	14.4
	11.0	13.2	25.6	32.3
	18.0	18.5	22.8	26.1
	8.0	8.7	25.7	16.8
	11.9	9.9	15.6	12.2
	6.4	10.5	13.9	15.7
	13.8	20.9	17.9	16.4
	10.1	11.7	15.7	17.2
	3.8	4.3	18.8	16.2
	9.5	8.7	13.6	12.3
	6.8	8.5	13.9	12.9
	8.0	10.4	25.7	16.8
	7.8	8.5	12.3	14.2
	8.0	8.7	15.8	15.7
	7.7	7.7	25.6	31.0
	8.0	8.7	15.7	17.2
	8.7	7.7	15.6	16.9
	6.8	8.5	12.8	14.2
TOTAL	361.5	407.8	690.0	675.6
MEAN	9.04	10.20	17.25	16.89
STANDARD DEVIATION	2.93	3.40	4.22	4.41

TABLE VII

EXPERIMENT 3

Average 1st and 2nd session reproduction of 8 seconds, and 3rd and 4th session reproduction of 16 seconds, by free linear movement (N = 40). All scores are seconds.

	8.0 Seconds		16.0 Seconds	
	1st Session	2nd Session	3rd Session	4th Session
	7.2	7.8	18.6	16.1
	13.8	11.3	16.4	21.2
	8.9	7.9	17.0	14.7
	7.6	7.9	16.9	15.7
	24.0	11.8	26.2	30.3
	9.7	8.7	18.9	14.0
	8.8	8.2	16.2	14.6
	9.1	8.4	17.3	16.8
	11.1	12.1	18.3	24.2
	8.1	11.2	13.6	20.8
	18.4	23.5	25.2	31.8
	11.7	8.2	20.6	16.5
	6.8	6.5	14.4	14.8
	8.5	9.9	18.9	17.8
	9.9	8.3	14.2	14.0
	11.0	11.5	29.9	25.4
	8.8	7.4	16.3	13.5
	7.4	10.0	14.4	19.0
	7.8	8.2	15.7	15.9
	13.6	12.1	22.9	15.8
	7.4	4.9	10.4	11.1
	6.1	6.4	12.2	11.6
	9.5	10.3	19.8	15.9
	10.9	13.3	19.0	19.4
	12.0	13.2	36.7	20.1
	8.8	10.1	11.6	11.1
	9.9	8.5	19.2	14.8
	10.3	9.8	22.2	19.1
	11.3	9.4	19.8	16.4
	12.6	11.1	21.0	17.5
	3.6	5.3	8.2	8.6
	8.1	9.9	16.0	16.9
	10.6	9.8	18.6	19.6
	10.6	12.1	23.0	25.2
	8.9	6.4	14.1	16.0
	17.3	11.0	34.5	18.0
	14.8	9.9	20.6	15.5
	10.6	7.9	18.8	16.6
	8.4	8.8	16.6	16.6
	9.6	9.3	16.0	19.9
TOTAL	413.5	388.3	750.2	702.8
MEAN	10.34	9.71	18.75	17.57
STANDARD DEVIATION	3.55	2.99	5.68	4.69

T A B L E VIII

EXPERIMENT 2

Immediate and delayed reproduction of 1 second by free linear arm movement (N = 77). All scores are seconds. Delay is in seconds.

	0		5		10		15	
	Imm.*	Delay**	Imm.*	Delay**	Imm.*	Delay**	Imm.*	Delay**
	0.9	1.1	0.8	0.8	1.0	1.2	1.3	2.0
	0.9	0.6	0.4	1.0	0.5	0.8	0.8	0.7
	0.9	0.9	1.1	0.7	0.6	1.1	0.9	0.7
	2.0	1.0	0.9	0.8	1.1	0.6	1.1	1.0
	0.6	0.9	0.5	1.2	1.0	1.0	0.8	0.8
	0.9	1.3	1.0	1.1	1.0	1.4	1.3	1.4
	1.3	1.5	0.5	0.7	0.8	0.7	1.3	1.0
	0.4	0.6	0.8	0.7	0.9	1.6	0.4	0.8
	1.1	1.2	0.8	1.0	1.2	0.8	1.4	0.7
	0.5	0.5	1.4	1.1	1.4	1.1	1.3	0.8
	1.0	1.3	0.9	0.8	1.3	1.2	1.0	0.7
TOTAL	10.5	10.9	9.1	9.9	10.8	11.5	11.6	10.6
MEAN	0.95	0.99	0.83	0.9	0.98	1.04	1.05	0.96
STD.DEV.ø	.4123	.4123	.2757	.1761	.2627	.2898	.2933	.3873

	20		30		60	
	Imm.*	Delay**	Imm.*	Delay**	Imm.*	Delay**
	1.5	1.7	1.0	1.1	1.0	1.0
	0.8	1.2	1.0	1.5	1.1	1.0
	1.5	0.7	1.1	0.9	0.9	1.4
	0.6	0.5	1.2	0.5	1.3	1.2
	0.9	0.8	0.9	1.2	0.6	1.7
	0.9	1.2	1.3	1.3	0.9	1.3
	2.3	2.1	1.0	1.3	0.8	1.4
	0.5	1.3	1.4	2.1	0.6	0.7
	0.5	0.6	1.0	0.5	1.1	1.3
	1.9	2.2	0.5	0.9	1.3	1.2
	0.7	0.8	1.0	1.9	0.9	1.4
TOTAL	12.1	13.1	11.4	13.2	10.5	13.6
MEAN	1.10	1.19	10.4	1.2	0.95	1.24
STD. DEV.ø	.5831	.5657	.2236	.4796	.2280	.2530

	Immediate Totals	Delay Totals
GRAND TOTAL	76.0	82.8
MEAN	0.99	1.08
STD.DEV.ø	.3564	.3937

* Imm. = Immediate Reproduction

** 0 Delay = 0 Seconds Delay

ø STD.DEV. = STANDARD DEVIATION

TABLE IX

EXPERIMENT 2

Immediate and delayed reproduction of 2 seconds by free linear arm movement (N = 77). All scores are seconds. Delay is in seconds.

	Imm.*	0 Delay**	Imm.*	5 Delay**	Imm.*	10 Delay**	Imm.*	15 Delay**
	1.6	1.8	1.9	1.5	1.8	1.9	2.0	2.4
	2.0	1.8	1.5	1.9	0.7	1.6	1.3	1.4
	2.3	2.0	1.8	1.1	2.2	2.3	2.5	2.5
	3.0	2.9	1.8	1.6	2.8	1.4	2.0	2.3
	2.5	1.3	1.9	1.6	2.6	2.1	1.8	1.7
	1.7	1.6	1.9	1.3	2.5	2.0	1.2	2.8
	2.6	2.2	2.1	1.2	1.3	1.2	2.5	1.2
	1.6	1.9	1.8	1.9	1.7	1.5	1.5	1.1
	1.7	1.7	1.9	1.3	2.1	1.6	2.4	1.1
	1.5	1.3	2.0	2.1	2.3	2.2	2.1	1.5
	2.0	2.0	1.0	1.2	2.1	1.7	2.0	1.6
TOTAL	22.5	20.5	19.6	16.7	22.1	19.5	21.3	19.6
MEAN	2.05	1.86	1.78	1.52	2.01	1.77	1.94	1.78
STD.DEV.ø	.447	.438	.286	.310	.270	.350	.447	.588

	Imm.*	20 Delay**	Imm.*	30 Delay**	Imm.*	60 Delay**
	2.2	3.0	2.8	3.8	2.1	4.1
	2.6	3.0	2.4	1.9	2.2	2.5
	2.4	1.6	1.6	0.7	2.0	1.5
	2.2	1.7	2.8	1.4	2.6	2.2
	3.3	2.0	1.5	1.5	1.0	3.0
	2.4	2.2	2.3	2.6	1.8	2.2
	2.9	3.3	3.5	2.3	1.7	2.1
	1.4	2.8	1.9	1.3	0.8	1.9
	1.6	1.5	1.5	3.2	2.3	2.3
	3.0	3.0	2.0	2.1	2.0	1.5
	1.9	2.6	2.6	1.7	1.6	1.8
TOTAL	26.5	26.7	24.9	22.5	20.1	25.1
MEAN	2.41	2.43	2.26	2.045	1.83	2.28
STD.DEV.ø	.656	.609	.600	.848	.510	.714

	Immediate Totals	Delay Totals
GRAND TOTAL	157.0	150.6
MEAN	2.04	1.95
STD.DEV.ø	.7453	.6488

* Imm. = Immediate Reproduction

** 0 Delay = 0 Seconds Delay

ø STD.DEV. = STANDARD DEVIATION

TABLE X

EXPERIMENT 2

Immediate and delayed reproduction of 4 seconds by free linear arm movement (N = 77). All scores are seconds. Delay is in seconds.

		0		5		10		15
	Imm.*	Delay**	Imm.*	Delay**	Imm.*	Delay**	Imm.*	Delay**
	4.5	3.6	3.7	3.3	3.4	3.0	3.0	3.7
	3.3	3.5	3.2	4.3	2.7	3.6	1.7	2.7
	3.2	2.5	2.3	1.9	3.5	3.6	4.8	4.4
	5.3	3.7	2.8	3.1	3.7	3.5	4.5	4.3
	2.3	2.4	1.5	1.5	3.5	3.3	3.2	3.9
	3.2	4.3	2.3	3.0	3.1	2.5	3.4	3.9
	3.7	2.9	2.2	1.6	2.9	3.3	2.7	2.4
	5.1	3.9	3.7	2.9	3.1	2.5	3.1	2.2
	3.6	3.4	4.3	1.7	2.5	2.0	2.8	1.3
	3.0	2.6	4.7	4.3	3.8	4.3	4.3	2.8
	3.5	3.7	1.3	1.3	2.4	2.6	4.0	4.0
TOTAL	40.7	36.5	32.0	28.9	34.6	34.2	37.5	35.6
MEAN	3.70	3.32	2.91	2.63	3.15	3.11	3.41	3.24
STD.DEV.ø	.900	.587	1.058	1.035	.316	.623	.854	.300

		20		30		60
	Imm.*	Delay**	Imm.*	Delay**	Imm.*	Delay**
	3.2	4.3	2.6	3.4	3.3	4.4
	6.0	5.0	4.2	4.5	4.8	3.4
	1.8	1.7	3.4	2.5	2.9	6.1
	3.4	3.7	1.4	1.2	4.4	3.5
	4.8	3.7	3.7	3.2	3.5	2.8
	3.5	4.1	2.0	1.8	2.2	3.0
	7.1	4.5	3.9	3.3	2.5	2.8
	3.8	3.9	4.6	3.8	1.6	1.5
	2.4	2.4	4.1	2.5	6.0	3.7
	5.1	4.1	3.9	4.7	3.7	1.5
	4.6	4.6	4.7	4.9	3.4	3.8
TOTAL	45.7	42.0	38.5	35.8	38.3	36.5
MEAN	4.15	3.818	3.50	3.25	3.48	3.32
STD.DEV.ø	1.732	.828	1.020	1.182	1.183	1.223

	Immediate Totals	Delay Totals
GRAND TOTAL	267.3	249.5
MEAN	3.47	3.184
STD.DEV.ø	1.097	.9935

* Imm. = Immediate Reproduction

** 0 Delay = 0 Seconds Delay

ø STD.DEV. = STANDARD DEVIATION

TABLE XI

EXPERIMENT 2

Immediate and delayed reproduction of 8 seconds by free linear arm movement (N = 77). All scores are seconds. Delay is in seconds.

	0		5		10		15	
	Imm.*	Delay**	Imm.*	Delay**	Imm.*	Delay**	Imm.*	Delay**
	6.1	6.9	7.2	5.7	6.8	6.2	6.6	6.0
	5.6	8.3	4.5	5.7	6.5	6.5	3.5	5.3
	5.1	6.0	6.1	5.4	7.1	5.7	8.0	8.9
	10.7	7.1	6.0	5.8	8.1	6.9	7.0	7.9
	7.5	6.1	3.7	1.3	6.6	7.3	7.5	4.0
	7.7	7.0	6.3	3.9	5.1	5.9	6.4	7.8
	5.7	5.3	3.3	3.5	6.0	6.0	7.8	4.7
	7.3	7.0	7.3	6.5	6.0	4.7	4.8	3.8
	5.2	5.4	6.2	3.5	4.6	2.9	7.4	2.6
	4.6	4.8	7.6	7.8	8.2	7.1	7.8	4.4
	7.7	7.2	7.3	2.3	4.7	4.1	6.0	7.5
TOTAL	73.2	71.1	65.5	51.4	69.7	63.3	72.8	62.9
MEAN	6.65	6.46	5.95	4.67	6.34	5.75	6.62	5.72
STD.DEV.ϕ	1.673	1.009	1.414	1.850	1.183	1.311	1.342	1.426

	20		30		60	
	Imm.*	Delay**	Imm.*	Delay**	Imm.*	Delay**
	7.5	7.5	7.2	5.5	6.1	8.2
	9.5	7.4	7.0	8.8	8.3	8.4
	6.1	3.3	5.4	4.3	6.4	7.1
	8.2	7.4	1.1	1.6	4.9	7.8
	11.8	6.4	8.8	6.1	4.2	8.4
	6.5	7.7	4.1	2.0	5.0	5.9
	8.3	8.8	5.5	7.5	5.6	4.7
	7.0	6.2	14.4	7.3	2.1	2.8
	5.5	4.3	6.2	5.5	8.9	8.0
	10.3	10.0	7.3	8.9	5.7	5.3
	8.3	9.0	7.5	7.3	6.3	3.7
TOTAL	89.0	78.0	74.5	64.8	63.5	69.3
MEAN	8.09	7.09	6.77	5.89	5.77	6.30
STD.DEV.ϕ	1.789	1.890	3.114	2.347	1.761	2.063

	Immediate Totals	Delay Totals
GRAND TOTAL	508.2	460.8
MEAN	6.60	5.99
STD.DEV.ϕ	3.415	1.949

* Imm. = Immediate Reproduction

** 0 Delay = 0 Seconds Delay

ϕ STD.DEV. = STANDARD DEVIATION

T A B L E XIII

EXPERIMENT 2

Average verbal estimates of 1 second, and error in verbal estimate of 1 second, made after free linear movement (N = 77). All scores are seconds.

	Estimate	Error	Estimate	Error
	2 sec.	1 sec.	2 sec.	1 sec.
	1	0	1	0
	1	0	2	1
	2	1	1	0
	2	1	1	0
	3	2	1	0
	2	1	1	0
	2	1	1	0
	1	0	3	2
	1	0	2	1
	2	1	3	2
	1	0	6	5
	1	0	2	1
	1	0	2	1
	1	0	1	0
	2	1	1	0
	2	1	1	0
	2	1	2	1
	2	1	2	1
	1	0	2	1
	4	3	2	1
	1	0	2	1
	2	1	2	1
	2	1	1	0
	1	0	1	0
	2	1	2	1
	1	0	1	0
	1	0	4	3
	1	0	1	0
	2	1	2	1
	1	0	2	1
	2	1	3	2
	2	1	1	0
	2	1	1	0
	2	1	1	0
	2	1	1	0
	3	2	1	0
	1	0		
	2	1		
	2	1		
TOTAL			133 sec.	56 sec.
MEAN			1.73	0.7
STANDARD DEVIATION			.86	.69

TABLE XIV

EXPERIMENT 2

Average verbal estimates of 2 seconds, and error in verbal estimate of 2 seconds, made after free linear movement (N = 77). All scores are seconds.

Estimate	Error	Estimate	Error
3 sec.	1 sec.	3 sec.	1 sec.
2	0	2	0
3	1	2	0
3	1	3	1
3	1	4	2
4	2	3	1
3	1	3	1
6	4	2	0
3	1	3	1
2	0	2	0
3	1	3	1
2	0	5	3
3	1	18	16
3	1	4	2
3	1	3	1
3	1	3	1
3	1	2	0
2	0	3	1
3	1	3	1
1	1	3	1
6	4	3	1
2	0	3	1
3	1	4	2
3	1	2	0
3	1	2	0
2	0	3	1
2	0	2	0
2	0	4	2
2	0	8	6
2	0	1	1
3	1	3	1
3	1	2	0
3	1	7	5
4	2	2	0
4	2	2	0
5	3	3	1
6	4	2	0
3	1	3	1
4	2		

	Estimate	Error
TOTAL	250	100
MEAN	3.25	1.3
STANDARD DEVIATION	2.07	2.05

TABLE XV

EXPERIMENT 2

Average verbal estimate of 4 seconds, and error in verbal estimate of 4 seconds, made after free linear movement (N = 77). All scores are seconds.

Estimate	Error	Estimate	Error
4 sec.	0 sec.	5 sec.	1 sec.
4	0	5	1
4	0	6	2
6	2	4	0
5	1	5	1
8	4	3	1
5	1	4	0
8	4	6	2
5	1	4	0
4	0	5	1
6	2	7	3
4	0	40	36
6	2	8	4
3	1	5	1
3	1	5	1
6	2	4	0
5	1	4	0
7	3	5	1
4	0	6	2
3	1	7	3
11	7	7	3
3	1	4	0
5	1	4	0
6	2	3	1
4	0	5	1
5	1	5	1
3	1	4	0
3	1	15	11
5	1	3	1
3	1	5	1
5	1	3	1
6	2	9	5
5	1	3	1
6	2	3	1
7	3	6	2
8	4	4	0
10	6	3	1
4	0		
5	1		
5	1		

	Estimate	Error
TOTAL	433	153
MEAN	5.62	1.90
STANDARD DEVIATION	4.43	4.28

TABLE XVI

EXPERIMENT 2

Average verbal estimate of 8 seconds, and error in verbal estimate of 8 seconds, made after free linear movement (N = 77). All scores are seconds.

Estimate	Error	Estimate	Error
7 sec.	1 sec.	10 sec.	2 sec.
7	1	8	0
7	1	8	0
14	6	8	0
8	0	10	2
14	6	7	1
10	2	7	1
20	12	13	5
10	2	7	1
8	0	10	2
13	5	12	4
8	0	60	52
10	2	14	6
6	2	10	2
7	1	10	2
11	3	7	1
8	0	7	1
11	3	10	2
7	1	8	0
6	2	14	6
21	13	8	0
7	1	11	3
9	1	9	1
13	5	6	2
10	2	8	0
9	1	8	0
6	2	7	1
6	2	27	19
9	1	5	3
6	2	10	2
12	4	17	9
10	2	20	12
8	0	6	2
10	2	5	3
12	4	11	3
15	7	8	0
18	10	5	3
5	3		
11	3		
9	1		

	Estimate	Error
TOTAL	809	268
MEAN	10.51	3.5
STANDARD DEVIATION	6.94	6.50

TABLE XVII

EXPERIMENT 2

Average verbal estimates of 16 seconds, and error in verbal estimate of 16 seconds, made after linear movement (N = 77). All scores are seconds.

Estimate	Error	Estimate	Error
16 sec.	0 sec.	14 sec.	2 sec.
11	5	15	1
15	1	14	2
26	10	16	0
17	1	20	4
20	4	9	7
20	4	13	3
35	19	18	2
18	2	30	14
15	1	19	3
22	6	25	9
15	1	80	64
22	6	24	8
10	6	18	2
13	3	20	4
20	4	14	2
18	2	19	3
16	0	19	3
15	1	13	3
11	5	28	12
44	28	20	4
14	2	35	19
18	2	15	1
23	7	12	4
17	1	15	1
20	4	23	7
12	4	15	1
14	2	55	39
22	6	12	4
11	5	17	1
20	4	33	17
23	7	40	24
22	6	14	2
27	11	11	5
20	4	20	4
35	19	16	0
25	9	17	1
18	2		
18	2		
19	3		

	Estimate	Error
TOTAL	1,575	497
MEAN	20.45	6.5
STANDARD DEVIATION	10.4	9.1

TABLE XIX

EXPERIMENT 2

Distance of free linear arm movement in first session reproduction of 1 second and 2 seconds (N = 77). All scores are inches.

	1 Second Signal	(Continued)	2 Seconds Signal	(Continued)
	8 inches	2 inches	13 inches	3 inches
	3	4	8	7
	10	4	28	9
	5	3	18	7
	10	19	15	40
	11	3	15	15
	21	5	31	11
	4	5	18	10
	8	12	11	21
	3	8	7	15
	5	19	8	30
	6	7	11	18
	3	3	7	12
	3	9	6	11
	7	8	14	18
	5	10	13	18
	6	19	8	47
	3	11	5	16
	8	3	17	8
	12	4	20	5
	6	8	14	13
	6	10	8	16
	15	18	20	16
	8	6	13	18
	6	5	8	15
	1	10	4	16
	20	4	25	35
	10	5	26	17
	3	8	7	7
	52	7	59	15
	8	11	16	31
	9	7	10	27
	6	9	10	14
	12	2	22	4
	6	10	15	13
	7	9	19	11
	29	8	65	11
	5		14	
	20		24	
	2		4	
TOTAL		668		1,256
MEAN		8.67		16.31
STD. DEV. *		7.25		11.18

* STD. DEV. = STANDARD DEVIATION

TABLE XX

EXPERIMENT 2

Distance of free linear arm movement in first session reproduction of 4 seconds and 8 seconds (N = 77). All scores are inches.

4 Seconds Signal	(Continued)	8 Seconds Signal	(Continued)
4 inches	11 inches	29 inches	19 inches
17	17	38	30
32	25	70	35
17	17	36	23
30	68	53	120
35	14	50	34
35	27	70	47
28	31	42	53
28	21	35	22
22	23	36	15
15	34	37	83
19	25	45	47
21	21	22	30
7	18	19	37
26	25	33	70
22	34	21	55
12	35	19	70
8	23	20	35
33	26	68	29
21	12	47	21
31	18	52	27
14	23	30	40
24	23	50	48
21	28	41	80
16	18	26	30
11	35	19	52
55	35	88	70
25	35	45	62
35	28	65	27
87	26	170	49
15	23	26	90
29	27	45	68
23	20	31	46
32	7	55	11
24	19	54	28
46	10	48	28
125	16	200	16
24		32	
27		64	
7		13	
TOTAL	2,012		3,591
MEAN	26.13		46.64
STD. DEV. *	17.49		30.59

* STD. DEV. = STANDARD DEVIATION

T A B L E XXI

EXPERIMENT 2

Distance of free linear arm movement in first session reproduction of 16 seconds (N = 77). All scores are inches.

Signal 16 Seconds	(Continued)
40 inches	24 inches
47	57
137	55
70	36
150	240
110	44
160	90
105	75
96	31
100	62
65	189
70	85
35	63
24	47
68	105
70	95
48	175
35	70
128	8
112	57
100	75
44	140
130	88
70	175
47	59
52	135
210	130
80	180
215	70
373	80
60	140
105	140
75	122
160	28
120	35
120	65
387	48
155	
120	
57	

TOTAL	7,668
MEAN	99.58
STANDARD DEVIATION	67.48

TABLE XXII

EXPERIMENT 2

Speed of free linear arm movement in reproducing 1.0 second in the first session (N = 77). All scores are inches per second.

	Delay (in seconds)						
	0	5	10	15	20	30	60
	7.27	7.50	12.50	6.00	15.83	24.54	4.00
	5.00	3.00	10.00	8.57	4.29	12.67	5.00
	11.11	4.29	5.45	10.00	10.00	12.22	5.71
	5.00	8.75	1.67	29.00	6.25	6.00	5.08
	11.11	4.17	20.00	6.25	7.06	3.33	6.47
	8.46	5.45	7.14	14.29	6.67	6.15	5.38
	14.00	4.29	4.29	2.00	9.05	7.69	6.43
	6.67	11.43	32.50	2.50	5.38	8.57	2.86
	6.67	12.00	10.00	5.71	5.00	12.00	7.69
	6.00	5.45	8.18	5.00	4.09	5.56	7.50
	3.85	7.50	5.00	4.29	10.00	5.26	7.14
TOTAL	85.14	73.83	116.73	93.61	83.62	103.99	63.26
MEAN	7.740	6.712	10.612	8.510	7.602	9.454	5.751
STD. DEV. *	2.987	2.872	8.353	7.282	3.292	5.632	1.423

GRAND TOTAL	620.18
MEAN	8.054
STANDARD DEVIATION	5.355

* STD. DEV. = STANDARD DEVIATION

TABLE XXIII

EXPERIMENT 2

Speed of free linear arm movement in reproducing 2.0 seconds in the first session (N = 77). All scores are inches per second.

	Delay (in seconds)						
	0	5	10	15	20	30	60
	7.22	7.33	10.53	9.17	13.33	22.50	8.54
	4.44	4.12	8.12	10.71	4.38	12.37	6.80
	14.00	5.45	3.48	7.60	6.47	8.42	4.07
	6.21	8.75	2.86	28.26	5.00	11.42	6.82
	11.54	8.13	11.90	8.24	7.00	3.57	10.33
	9.37	6.15	13.00	8.57	6.82	8.67	12.27
	14.09	4.17	5.83	3.33	9.09	6.15	6.67
	9.47	8.95	39.33	2.73	6.45	6.96	2.11
	6.47	15.38	10.00	6.36	8.00	13.85	5.65
	5.38	6.67	4.55	6.00	3.67	4.69	7.33
	4.00	6.50	5.88	4.38	6.92	7.62	6.11
TOTAL	92.19	81.60	115.48	95.35	82.13	106.22	76.70
MEAN	8.381	7.418	10.498	8.688	7.466	9.656	6.973
STD. DEV.*	3.434	2.960	9.684	6.635	2.421	5.055	2.638

GRAND TOTAL	649.67
MEAN	8.437
STANDARD DEVIATION	5.433

* STD. DEV. = STANDARD DEVIATION

TABLE XXIV

EXPERIMENT 2

Speed of free linear arm movement in reproducing 4.0 seconds in the first session (N = 77). All scores are inches per second.

	Delay (in seconds)						
	0	5	10	15	20	30	60
	1.11	5.76	8.00	8.65	15.81	10.00	7.95
	4.86	4.88	5.83	8.89	8.24	7.78	10.29
	12.80	3.68	4.44	10.45	7.30	9.20	4.59
	4.59	8.39	3.14	29.07	8.38	21.67	7.43
	12.50	14.67	16.67	6.15	4.20	3.75	8.21
	8.14	4.00	10.00	6.92	5.61	10.00	9.00
	12.07	5.00	10.61	2.92	7.56	6.97	7.14
	7.18	11.38	39.20	5.00	6.41	6.05	4.67
	8.24	12.35	7.50	13.08	8.75	11.20	5.14
	8.46	7.21	6.74	8.93	4.39	3.83	6.67
	4.05	10.77	8.85	4.25	5.95	7.14	4.21
TOTAL	84.00	88.09	120.98	104.31	82.60	97.59	75.30
MEAN	7.636	8.008	10.998	9.483	7.509	8.872	6.845
STD. DEV. *	3.618	3.589	9.554	6.789	3.011	4.663	1.902

GRAND TOTAL	652.87
MEAN	8.479
STANDARD DEVIATION	5.474

* STD. DEV. = STANDARD DEVIATION

TABLE XXV

EXPERIMENT 2

Speed of free linear arm movement in reproducing 8.0 seconds in the first session (N = 77). All scores are inches per second.

	Delay (in seconds)						
	0	5	10	15	20	30	60
	4.20	9.57	8.06	9.17	16.22	10.00	8.54
	4.58	3.86	6.31	10.19	10.30	7.95	7.38
	11.67	3.52	4.56	5.39	6.35	8.14	3.80
	5.07	5.69	2.75	25.32	8.28	18.13	6.28
	8.69	16.15	12.05	8.00	2.93	3.44	10.71
	7.14	4.87	7.63	8.21	5.20	13.50	11.53
	13.21	5.71	10.83	2.77	9.43	5.33	9.79
	6.00	10.46	36.17	5.00	7.58	6.58	3.93
	6.48	13.43	8.97	11.54	6.98	14.55	3.50
	7.50	6.67	6.34	7.95	3.70	3.37	5.28
	5.14	13.04	7.56	3.07	7.78	7.12	5.93
TOTAL	79.68	92.97	111.23	96.61	84.75	98.11	76.67
MEAN	7.244	8.452	10.112	8.783	7.705	8.919	6.970
STD. DEV. *	2.778	4.122	8.608	5.873	3.436	4.498	2.716

GRAND TOTAL	640.02
MEAN	8.312
STANDARD DEVIATION	5.070

* STD. DEV. = STANDARD DEVIATION

TABLE XXVI

EXPERIMENT 2

Speed of free linear arm movement in reproducing 16.0 seconds in the first session (N = 77). All scores are inches per second.

	Delay (in seconds)						
	0	5	10	15	20	30	60
	3.60	5.34	9.29	8.89	14.45	9.90	8.97
	4.12	4.12	5.83	12.00	3.61	8.93	11.54
	11.51	4.36	4.35	7.45	6.12	7.69	4.38
	5.26	5.86	4.16	28.25	7.21	11.42	5.71
	10.27	16.28	15.22	9.51	1.63	4.75	8.70
	7.19	4.62	7.62	8.28	5.39	11.03	9.40
	13.91	5.15	12.72	7.11	10.62	7.29	9.46
	7.29	10.94	38.06	3.00	7.14	6.15	12.17
	8.07	13.66	8.11	8.64	7.16	13.46	2.63
	7.69	7.09	5.65	6.55	4.47	4.92	5.20
	4.28	11.89	10.71	2.59	6.21	7.38	6.00
TOTAL	83.19	89.31	121.72	102.27	74.01	92.92	84.16
MEAN	7.563	8.119	11.065	9.297	6.728	8.447	7.651
STD. DEV. *	3.122	4.097	9.156	6.528	3.283	2.654	2.910

GRAND TOTAL	647.58
MEAN	8.410
STANDARD DEVIATION	5.228

* STD. DEV. = STANDARD DEVIATION

T A B L E XXVII

EXPERIMENT 2

Reproduction of time signals by key-pressing in the first session (N = 43). All scores are seconds.

	1 Second	2 Seconds	4 Seconds	8 Seconds	16 Seconds
	1.3	2.7	5.7	8.8	15.6
	1.0	1.5	4.4	9.2	17.2
	1.5	2.3	5.2	8.3	15.0
	0.7	2.0	3.5	7.4	14.9
	1.4	1.5	4.0	7.3	16.3
	0.7	1.2	3.1	8.2	16.0
	1.2	2.1	3.9	8.5	16.0
	1.0	2.3	5.0	8.4	17.1
	0.5	1.1	2.3	4.9	13.4
	0.9	1.9	4.3	7.4	14.4
	0.8	2.3	4.3	8.1	14.5
	0.8	2.1	4.3	7.3	17.2
	1.1	2.1	5.0	7.0	14.2
	1.1	1.8	4.2	7.4	15.9
	1.0	1.7	3.9	6.9	16.7
	1.0	2.1	4.0	8.4	16.6
	0.9	2.2	3.5	7.2	15.5
	1.2	2.0	3.6	8.3	14.6
	1.0	2.0	3.2	7.1	16.8
	1.4	2.3	5.2	6.5	13.0
	0.7	2.0	3.9	7.8	17.8
	1.2	2.1	4.4	8.6	16.2
	1.1	2.2	3.7	7.4	16.3
	1.1	1.5	3.7	8.1	15.0
	1.8	2.5	3.7	8.0	17.9
	1.3	2.2	4.7	8.5	11.0
	1.0	2.5	5.2	6.8	15.0
	2.5	3.7	7.8	11.4	19.4
	0.7	1.9	4.6	7.6	18.2
	0.8	2.1	3.4	6.1	11.8
	1.6	3.7	3.7	8.7	15.6
	1.0	1.5	4.1	6.7	9.7
	1.2	3.4	5.2	8.0	17.7
	0.9	1.5	2.6	7.0	14.2
	1.3	3.5	4.4	8.3	13.9
	1.2	2.2	3.7	6.5	15.8
	0.9	2.7	3.8	7.5	16.3
	1.4	1.8	4.2	7.2	16.1
	1.3	2.3	4.3	8.6	14.7
	1.4	3.2	4.2	8.6	17.2
	1.0	2.4	3.7	6.3	13.6
	1.7	2.4	4.3	7.8	15.5
	1.5	2.2	8.5	11.7	21.4
TOTAL	49.1	94.7	184.4	335.8	671.4
MEAN	1.14	2.20	4.29	7.81	15.61
STD. DEV.*	0.361	.592	1.095	1.179	2.066

* STD. DEV. = STANDARD DEVIATION

TABLE XXVIII

EXPERIMENT 2

Intra-individual ratios of performance in the second session divided by performance in the first session, in judging 16 seconds. The ratios are (a) speed of free linear movement; (b) time reproduced by free linear movement; (c) distance of free linear movement; and (d) verbal estimate (N = 56).

	Speed 2 / Speed 1	Reproduction 2 / Reproduction 1	Distance 2 / Distance 1	Estimate 2 / Estimate 1
	1.95	1.03	2.00	1.18
	.75	.77	.58	1.07
	.79	.93	.73	.94
	.89	.82	.73	1.10
	.90	.73	.66	.75
	.51	.99	.51	1.00
	1.12	.94	1.05	1.00
	1.24	.84	1.05	.77
	1.54	.78	1.20	.80
	1.30	1.09	1.43	1.15
	1.32	.81	1.07	.85
	.97	1.01	.98	.78
	.72	.68	.49	.50
	.78	1.02	.80	1.00
	1.11	.94	1.05	1.02
	1.96	1.22	2.39	1.00
	.81	1.00	.81	1.00
	1.55	1.23	1.91	1.04
	1.13	1.32	1.49	1.00
	.81	1.19	.96	1.40
	.97	1.08	1.05	1.00
	1.03	.81	.84	.71
	1.03	.36	.37	.55
	1.39	.52	.72	.81
	.80	.66	.44	.65
	1.47	.73	1.07	1.00
	1.03	.79	.81	1.00
	1.47	.91	1.33	.71
	1.34	1.07	1.24	1.12
	.76	1.48	1.26	.95
	1.17	.67	.79	1.57
	1.31	.61	.81	.75
	1.14	.80	.71	.86
	4.29	.24	1.02	.89
	1.39	1.00	1.39	1.23
	.60	.76	.45	.39
	.98	.86	.84	.73
	.92	.60	.56	.76
	.76	.76	.58	.19
	1.12	1.33	1.49	.94
	1.18	.95	1.12	.95
	2.67	1.75	4.67	.86
	.98	.87	.84	.79
	3.06	1.43	4.35	3.85
	1.00	.83	.87	.50
	1.21	.69	.84	1.00
	.63	1.33	.85	.87
	1.09	.58	.63	.61
	.93	.83	.77	.73
	.76	1.17	.89	.93
	.76	.95	.72	.71
	.89	.58	.51	.50
	.83	.93	.77	1.14
	.36	1.70	.61	.91
	.76	1.13	.86	.95
	1.11	.75	.83	.53
TOTAL	65.34	51.85	59.79	51.99
MEAN	1.167	0.926	1.068	.928
STD. DEVIATION *	.6234	.2910	.7663	.4613

* STD. DEVIATION = STANDARD DEVIATION

TABLE XXIX

EXPERIMENT 2

Intra-individual ratios of performance in the second session divided by performance in the first session, in judging 8 seconds. The ratios are (a) speed of free linear movement; (b) time reproduced by free linear movement; (c) distance of free linear movement; and (d) verbal estimate (N = 56).

	Speed 2 / Speed 1	Reproduction 2 / Reproduction 1	Distance 2 / Distance 1	Estimate 2 / Estimate 1
	1.66	.75	1.24	1.00
	.58	1.15	.67	1.12
	1.30	1.02	1.32	1.00
	1.00	.74	.74	.71
	.99	.79	.79	.80
	.36	1.13	.69	.50
	1.23	1.31	1.61	1.00
	.93	.87	.81	.69
	.82	1.05	1.04	.87
	1.67	1.07	1.79	1.00
	1.40	1.15	1.62	.81
	.94	1.18	1.11	.87
	.63	.71	.45	.36
	.73	1.37	1.00	1.00
	.47	.99	.46	1.09
	1.39	.96	1.33	.86
	.86	.89	.76	.89
	1.35	1.08	1.46	.92
	1.03	1.19	1.23	.80
	1.45	1.09	1.58	1.67
	1.33	.99	1.31	1.00
	1.15	.54	.62	.67
	1.40	.45	.68	.67
	1.39	.53	.74	.83
	.89	.94	.84	.80
	1.89	.68	1.29	1.37
	.85	1.18	1.00	1.50
	2.09	.80	1.67	.80
	1.24	1.05	1.30	.78
	2.30	1.17	2.69	.89
	.63	.92	.58	.80
	1.21	.61	.74	.60
	1.13	.68	.84	.85
	1.08	.82	.88	.71
	1.35	1.03	1.38	1.14
	.49	.69	.34	.23
	.82	1.00	.82	2.00
	1.40	.64	.89	.83
	.68	.69	.47	.60
	1.40	.56	.78	.70
	.78	.91	.71	.90
	2.50	1.53	3.82	.86
	.93	1.07	1.00	.80
	.87	.87	.76	3.12
	1.20	1.11	1.33	.64
	1.04	1.35	.77	.77
	1.00	.93	.93	.88
	1.03	.86	.88	.87
	.73	.98	.57	.85
	1.36	1.06	1.44	1.04
	.85	.77	.65	.80
	.75	1.02	.76	.70
	1.16	1.38	1.61	1.33
	1.59	.57	.91	.80
	.97	.70	.68	.81
	1.04	2.11	2.19	1.20
TOTAL	63.31	53.48	60.57	52.10
MEAN	1.13	0.95	1.08	0.93
STD. DEVIATION *	0.42	0.51	0.58	0.41

* STD. DEVIATION = STANDARD DEVIATION

TABLE XXX

EXPERIMENT 3

Judgement of 8 seconds by the methods of (a) free linear arm movement; (b) controlled-distance linear arm movement; (c) stationary grip; and (d) verbal estimate (N = 40). All scores are seconds.

	Free	Controlled	Stationary	Verbal Estimate
	7.2 sec.	9.5 sec.	8.2 sec.	17 sec.
	13.8	10.1	8.5	11
	8.9	7.3	8.0	11
	7.6	14.4	8.0	12
	24.0	12.1	7.7	15
	9.7	10.1	7.1	8
	8.8	9.8	8.4	15
	9.1	11.9	8.0	13
	11.1	13.7	10.4	14
	8.1	8.0	8.5	35
	18.4	18.0	9.5	18
	11.7	8.7	9.9	7
	6.8	7.7	7.0	12
	8.5	7.5	7.9	12
	9.9	7.7	5.0	9
	11.0	9.0	11.2	12
	8.8	7.4	8.1	10
	7.4	8.7	7.0	11
	7.8	8.1	7.5	11
	13.6	11.0	8.3	11
	7.4	4.8	6.2	8
	6.1	5.1	6.9	7
	9.5	8.1	6.5	4
	10.9	12.1	7.6	11
	12.0	12.1	5.3	8
	8.8	7.1	6.7	15
	9.9	6.1	8.1	10
	10.3	14.2	10.4	21
	11.3	9.8	7.5	9
	12.6	8.0	7.4	3
	3.6	3.8	4.5	4
	8.1	11.7	10.0	15
	10.6	7.3	6.2	12
	10.6	14.2	10.7	4
	8.9	7.0	8.6	7
	17.3	12.4	6.9	5
	14.8	13.8	9.2	2
	10.6	6.8	8.8	6
	8.4	8.0	7.7	15
	9.6	9.7	9.7	3
TOTAL	413.5	382.8	319.1	431
MEAN	10.34	9.57	7.98	10.77
STANDARD DEV.*	2.713	3.018	1.509	5.85

* STANDARD DEV. = STANDARD DEVIATION

TABLE XXXI

EXPERIMENT 3

Judgement of 16 seconds by the methods of (a) free linear arm movement; (b) controlled-distance linear arm movement; (c) stationary grip, and (d) verbal estimate (N = 40). All scores are seconds.

	Free	Stationary	Controlled	Verbal Estimate
	18.6 sec.	14.1 sec.	15.8 sec.	18 sec.
	16.4	13.5	21.6	37
	17.0	14.5	18.2	19
	16.9	14.8	16.3	13
	26.2	13.6	19.3	27
	18.9	13.8	18.8	8
	16.2	17.9	13.9	16
	17.3	13.5	14.9	12
	18.3	13.1	25.6	9
	13.6	13.8	22.8	10
	25.2	15.5	27.2	34
	20.6	17.5	16.9	12
	14.4	15.5	15.8	16
	18.9	17.8	12.3	14
	14.2	6.5	15.6	21
	29.9	19.1	21.5	29
	16.3	16.1	14.0	17
	14.4	13.9	10.9	9
	15.7	16.1	16.1	10
	22.9	14.6	17.3	7
	10.4	15.8	12.0	15
	12.2	13.7	10.5	14
	19.8	12.5	13.9	18
	19.0	13.3	16.4	13
	36.7	12.6	21.9	15
	11.6	12.5	13.6	10
	19.2	15.1	15.3	10
	22.2	20.9	22.7	16
	19.8	15.0	16.5	14
	21.0	12.1	19.7	9
	8.2	11.3	9.9	5
	16.0	17.7	15.6	24
	18.6	16.1	17.9	16
	23.0	15.2	22.5	9
	14.1	16.0	16.6	9
	34.5	14.6	17.5	17
	20.6	14.0	25.6	16
	18.8	14.2	17.5	15
	16.6	17.7	15.7	20
	16.0	16.6	18.3	18
TOTAL	750.2	592.1	694.4	618
MEAN	18.75	14.80	17.36	15.45
STD. DEVIATION *	5.681	2.398	4.069	7.05

* STD. DEVIATION = STANDARD DEVIATION

TABLE XXXII

EXPERIMENT 3

(a) Average time reproduced by free linear arm movement; (b) distance moved in reproducing time; (c) speed of linear arm movement, and (d) verbal estimate in response to a signal of 8 seconds. (N = 40).

	Reproduced Time (Seconds)	Distance (inches)	Speed (ins./sec.)	Verbal Estimate (Seconds)
	7.2 sec.	30 ins.	4 ins./sec.	8 sec.
	13.8	60	4 ins./sec.	25
	8.9	50	6	11
	7.6	20	3	6
	24.0	170	7	15
	9.7	40	4	4
	8.8	60	7	10
	9.1	90	10	6
	11.1	60	5	4
	8.1	20	2	4
	18.4	230	12	22
	11.7	30	3	6
	6.8	70	10	10
	8.5	20	2	10
	9.9	110	11	12
	11.0	130	12	13
	8.8	30	3	28
	7.4	60	8	7
	7.8	40	5	7
	13.6	50	4	7
	7.4	30	4	13
	6.1	70	11	7
	9.5	60	6	10
	10.9	30	3	8
	12.0	60	5	9
	8.8	50	6	7
	9.9	70	7	6
	10.3	30	3	11
	11.3	40	4	8
	12.6	30	2	5
	3.6	50	14	3
	8.1	30	4	10
	10.6	30	3	12
	10.6	70	7	5
	8.9	10	1	4
	17.3	50	3	8
	14.8	40	3	12
	10.6	60	6	10
	8.4	50	6	10
	9.6	20	2	9
TOTAL	423.5	2,250	222	382
MEAN	10.59	56.25	5.55	9.6
STANDARD DEVIATION	2.713	41.35	3.19	5.27

TABLE XXXIII

EXPERIMENT 3

(a) Average time reproduced by free linear arm movement; (b) distance moved in reproducing time; (c) speed of linear arm movement; and (d) verbal estimate in response to a signal of 16 seconds. (N = 40).

	Reproduced Time (In Seconds)	Distance (inches)	Speed (ins./sec.)	Verbal Estimate (Seconds)
	18.6 sec.	80 ins.	4 ins./sec.	17 sec.
	16.4	70	4	30
	17.0	120	7	19
	16.9	40	2	13
	26.2	230	9	28
	18.9	40	2	7
	16.2	90	6	17
	17.3	190	11	14
	18.3	110	6	8
	13.6	30	2	10
	25.2	330	1	32
	20.6	50	2	12
	14.4	220	15	20
	18.9	70	4	21
	14.2	150	11	17
	29.9	240	8	25
	16.3	80	5	35
	14.4	80	6	13
	15.7	70	4	13
	22.9	80	3	13
	10.4	40	4	16
	12.2	140	11	11
	19.8	120	6	25
	19.0	60	3	15
	36.7	190	5	30
	11.6	70	6	10
	19.2	100	5	15
	22.2	50	2	19
	19.8	70	4	12
	21.0	50	2	8
	8.2	60	7	6
	16.0	50	3	24
	18.6	40	2	16
	23.0	130	6	12
	14.1	20	1	12
	34.5	110	3	16
	20.6	60	3	21
	18.8	100	5	17
	16.6	120	7	20
	16.0	40	2	16
TOTAL	750.5	3,990	199	685
MEAN	18.75	99.75	4.78	17.125
STD. DEV.*	5.68	66.41	3.08	6.97

* STD. DEV. = STANDARD DEVIATION

TABLE XXXIV

EXPERIMENT 3

Intra-individual ratios of performance in second session over performance in first session in judging 8 seconds : ratios of (a) time reproduced by free linear movement; (b) distance moved in reproducing time; (c) speed of free linear movement; and (d) verbal estimate (N= 40).

	Reproduction 2 / Reproduction 1	Distance 2 / Distance 1	Speed 2 / Speed 1	Estimate 2 / Estimate 1
	9	11	12	10
	10	10	10	10
	8	6	7	12
	11	10	9	10
	14	13	9	10
	9	10	11	8
	12	12	10	10
	15	28	18	14
	12	10	8	10
	13	15	11	8
	11	11	10	12
	9	11	12	10
	11	10	9	10
	14	16	11	15
	11	11	10	15
	13	9	7	9
	10	13	13	10
	9	14	16	13
	11	12	11	13
	12	14	11	13
	13	14	11	12
	13	11	8	10
	10	10	10	8
	12	14	12	10
	10	9	9	11
	14	12	9	12
	9	10	11	20
	9	8	9	14
	10	12	12	10
	19	25	13	17
	10	12	12	12
	14	10	7	5
	19	10	5	19
	11	15	14	11
	10	12	12	20
	12	13	11	26
	10	8	8	13
	8	11	14	10
	14	11	8	7
	12	11	11	12
TOTAL	463	484	421	481
MEAN	11.6	11.1	10.5	12.0
STANDARD DEVIATION	2.49	3.90	2.47	3.91

TABLE XXXV

EXPERIMENT 3

Intra-individual ratios of performance in fourth session over performance in third session in judging 16 seconds : ratios of (a) time reproduced by free linear movement; (b) distance moved in reproducing time; (c) speed of free linear movement; and (d) verbal estimate (N = 40).

	Reproduction 4 / Reproduction 3	Distance 4 / Distance 3	Speed 4 / Speed 3	Estimate 4 / Estimate 3
	10	10	9	11
	7	7	10	9
	12	10	8	10
	6	8	14	11
	10	9	9	8
	14	10	7	10
	9	8	9	8
	11	12	11	15
	10	8	8	10
	11	17	17	15
	12	12	10	12
	12	16	13	11
	10	8	8	10
	21	33	16	14
	12	15	12	13
	20	16	8	30
	12	9	7	11
	10	15	15	12
	10	11	11	11
	14	11	8	12
	11	12	11	11
	11	13	12	9
	9	8	9	8
	15	15	10	15
	10	10	10	10
	13	21	16	20
	9	7	8	10
	10	10	10	10
	10	10	10	10
	15	17	11	9
	9	8	9	7
	8	6	7	6
	10	10	10	11
	11	10	9	11
	10	10	10	10
	10	8	8	8
	11	11	10	6
	11	12	11	11
	8	8	10	9
	11	12	10	11
TOTAL	445	463	411	445
MEAN	11.1	11.6	10.3	11.1
STANDARD DEVIATION	2.85	4.73	2.43	3.97

TABLE XXXVI

EXPERIMENT 2

Judgement of 16 seconds by the methods of (a) reproduction by free linear arm movement; (b) reproduction by key-pressing, and (c) verbal estimate (N = 43). All scores are seconds.

	Verbal Estimate	Key-pressing Reproduction	Linear movement Reproduction
	14 Seconds	15.6 Seconds	11.1 Seconds
	13	17.2	11.4
	14	15.0	11.9
	24	14.9	43.3
	16	16.3	14.6
	25	16.0	15.3
	16	16.0	13.1
	21	17.1	8.5
	16	13.4	5.5
	13	14.4	11.6
	15	14.5	4.3
	17	17.2	10.4
	18	14.2	14.0
	25	15.9	12.0
	15	14.7	10.8
	20	16.6	12.5
	12	15.5	13.8
	10	14.6	10.5
	24	16.8	18.0
	25	13.0	10.0
	35	17.8	16.1
	24	16.2	13.7
	17	15.0	16.3
	17	15.2	14.5
	18	17.9	9.0
	20	15.0	16.6
	11	19.4	12.2
	14	18.2	14.7
	20	11.8	10.4
	25	11.0	19.0
	20	15.6	10.5
	10	9.7	9.6
	17	17.7	19.6
	19	14.2	9.1
	13	13.9	0.7
	30	15.8	12.0
	19	16.3	6.8
	12	16.1	14.5
	52	14.7	15.6
	9	17.2	16.0
	14	13.6	14.0
	35	15.5	16.1
	25	21.4	14.9
TOTAL	829	671.4	534.5
MEAN	19.28	15.61	12.430
STANDARD DEVIATION	7.909	2.066	3.958

TABLE XXXVII

EXPERIMENT 2

Intra-individual ratios of judgement of 16 seconds in the second session divided by judgement of 16 seconds in the first session, using the methods of (a) reproduction by free linear arm movement; (b) reproduction by key-pressing; and (c) verbal estimate (N = 31).

	Key-pressing $\frac{t2}{t1}$*	Verbal $\frac{t2}{t1}$	Linear Movement $\frac{t2}{t1}$
	.90	1.15	1.03
	.97	1.14	.77
	.72	.94	.93
	.90	.84	.82
	1.02	.75	.78
	.99	1.15	1.09
	1.10	1.13	.81
	.89	.64	1.01
	1.04	.94	1.00
	1.04	.92	1.23
	.84	1.00	1.32
	1.01	1.40	1.19
	1.03	1.00	1.08
	1.03	1.20	.81
	.95	1.46	.79
	.89	.57	.91
	.99	1.17	1.07
	.95	.89	1.48
	.91	1.00	.24
	.86	1.07	1.00
	.96	.35	.76
	1.47	1.36	.86
	.98	1.00	1.33
	1.34	1.10	1.75
	.96	.84	.87
	1.30	3.84	1.43
	.92	.47	.83
	.90	.91	.83
	1.28	1.04	1.17
	.99	.93	.95
	.88	.64	.58
TOTAL	31.01	32.84	30.72
MEAN	1.0003	1.059	0.991
STANDARD DEVIATION	.1543	.5665	.2835

* $\frac{t2}{t1} = \frac{\text{16-second judgement in second session}}{\text{16-second judgement in first session}}$

TABLE XXXIX

EXPERIMENT 2

Judgement of 8 seconds by the methods of (a) verbal estimate; (b) reproduction by key-pressing; and (c) reproduction by free linear arm movement (N = 43). All scores are seconds.

	Verbal Estimate	Key-pressing	Free Linear Movement
	7.0 seconds	9.2 seconds	8.3 seconds
	7.0	8.3	6.0
	8.0	7.3	6.1
	14.0	8.2	7.0
	8.0	8.5	5.7
	9.0	8.4	5.7
	6.0	7.4	5.8
	9.0	8.1	1.3
	8.0	7.3	3.9
	8.0	7.0	6.2
	12.0	7.4	6.5
	8.0	6.9	5.7
	12.0	8.4	6.9
	6.0	7.2	7.3
	4.0	8.3	5.9
	14.0	7.1	6.0
	15.0	7.8	8.9
	15.0	8.6	7.9
	8.0	8.0	4.7
	7.0	11.4	3.3
	7.0	7.6	7.4
	7.0	6.1	6.4
	24.0	8.5	7.5
	11.0	8.7	10.0
	7.0	6.7	5.5
	10.0	7.0	4.3
	10.0	8.3	1.6
	15.0	6.5	6.1
	6.0	7.2	8.2
	33.0	8.6	8.4
	8.0	6.3	7.8
	15.0	11.7	5.9
	7.0	8.8	6.9
	10.0	7.4	7.1
	9.0	8.4	5.7
	6.0	4.9	5.4
	11.0	6.5	5.3
	10.0	7.4	4.0
	9.0	8.1	7.8
	10.0	6.8	7.4
	6.0	8.0	8.8
	10.0	7.5	2.0
	7.0	8.6	7.1
TOTAL	433.0	336.3	265.7
MEAN	10.07	7.82	6.18
STANDARD DEVIATION	5.23	1.18	1.93

TABLE XL

EXPERIMENT 2

Intra-individual ratios of judgement of 8 seconds in the second session divided by judgement of 8 seconds in the first session, using the methods of (a) reproduction by free linear arm movement; (b) reproduction by key-pressing; and (c) verbal estimate (N = 31).

	Verbal $\frac{t2}{t1}$*	Key-pressing $\frac{t2}{t1}$	Linear Movement $\frac{t2}{t1}$
	1.00	.79	.75
	1.12	.92	1.15
	1.00	1.05	1.02
	.71	.85	.74
	.75	.86	1.05
	1.17	.95	1.07
	.89	.84	1.15
	.87	1.05	1.18
	1.00	.91	.89
	.92	1.19	1.08
	1.00	1.00	1.19
	1.25	1.01	1.09
	1.00	1.07	.99
	1.50	.81	.54
	1.21	.90	1.18
	.73	.94	.80
	.87	.86	1.05
	.87	.84	1.17
	.86	.78	.82
	1.14	.87	1.03
	.43	.74	.69
	.75	1.00	1.00
	.73	1.06	.56
	.86	1.04	1.53
	.70	.91	1.07
	2.50	1.14	.87
	.53	1.17	1.11
	1.00	.97	.78
	.82	1.00	1.06
	1.00	1.06	.77
	.90	1.01	1.00
	.80	.75	1.02
TOTAL	30.88	30.33	31.40
MEAN	.965	.948	.981
STANDARD DEVIATION	.3450	.1249	.2047

$* \frac{t2}{t1} = \frac{\text{judgement of 8 seconds in second session}}{\text{judgement of 8 seconds in first session}}$

TABLE XLI

EXPERIMENT 2

(a) Extra version; (b) Manifest Anxiety; (c) Variability* in judgement of 8 seconds; and (d) variability in speed of linear arm movement in free reproduction of time (N = 54). * Variability = $\Sigma X^2 - \frac{\Sigma(X)^2}{N}$

Subject	Extra-Version	Manifest Anxiety (N = 38)	Variability l.m. Reproduction 8.0 sec.	Variability Verbal Estimate 8.0 sec.	Variability In Speed of linear Movement
2	8	12	4.93	0.00	0.33
3	8	13	3.54	8.75	1.05
5	10	11	1.23	0.75	1.34
6	12		4.53	8.75	0.85
7	8	39	1.51	2.00	0.63
9	8		.50	1.00	0.87
10	8	12	0.96	9.00	1.20
11	8	10	3.35	12.75	0.59
12	6	25	1.45	5.00	1.50
15	12	21	0.35	0.75	1.57
16	2		3.88	2.75	4.95
17	10		3.35	10.75	0.88
18	8	12	1.31	38.75	0.71
20	8	14	3.86	1.00	0.45
21	6		0.14	26.75	0.80
22	2		17.41	9.00	2.52
23	8		0.95	0.75	1.67
24	10	28	1.71	2.75	1.62
25	10	22	1.09	8.75	0.77
26	8		6.60	22.00	0.87
27	0	23	0.29	0.00	3.07
28	0	14	4.15	2.75	2.13
29	4	14	8.02	6.75	3.16
30	10	21	6.87	2.75	2.24
33	6	14	2.69	18.00	2.12
34	4	13	0.75	18.00	1.19
36	12	8	1.69	34.25	1.31
37	6	8	1.59	80.75	1.76
40	10		6.26	9.00	1.77
41	6	31	1.73	8.00	1.09
45	4	28	6.15	0.75	8.94
47	4		7.24	14.00	2.71
48	10	16	1.15	0.75	1.48
49	12	20	32.41	100.00	1.39
50	8	36	5.01	26.75	2.20
52	12	8	8.27	38.00	1.05
53	4	15	3.85	100.00	0.82
55	10	22	27.93	10.00	0.53
56	12		1.29	2.75	1.50
57	4		4.35	2.75	0.45
59	8		2.26	2.75	1.62
60	2	22	.21	100.00	5.51
61	8	11	4.89	31.00	0.61
64	8		54.91	20.75	1.17
66	8	15	3.15	2.75	0.87
67	8	12	0.91	10.75	0.82
68	6	19	3.19	2.75	1.83
69	12		1.06	9.00	2.38
71	4	9	4.39	3.00	0.81
73	12	24	2.95	100.00	2.39
74	12	17	2.37	2.75	1.45
75	6	25	.89	1.00	3.67
76	6		8.53	4.00	1.78
77	10	15	8.52	9.00	0.80
TOTAL	408	679	292.57	947.50	91.79
MEAN	7.56	17.87	5.47	17.55	1.70
STD.DEV.*	3.19	7.60	8.99	27.06	1.43

* STD.DEV. = STANDARD DEVIATION

TABLE XLII

EXPERIMENT 2

*Variability in judgement of 16 seconds by the method of (a) free linear movement reproduction; and (b) verbal estimate (N = 54).

$$\text{*Variability} = \Sigma X^2 - \frac{\Sigma(X)^2}{N}$$

Subject	Variability l.m. Reproduction 16.0 sec.	Variability Verbal Estimate 16.0 sec.
2	3.29	11.00
3	7.98	20.75
5	24.08	2.75
6	9.45	4.75
7	4.85	21.75
9	0.27	1.00
10	17.37	4.00
11	3.07	54.00
12	12.51	9.00
15	3.51	2.75
16	.65	10.00
17	.20	14.00
18	5.31	38.75
20	2.21	1.00
21	.63	4.75
22	2.59	0.75
23	5.05	2.75
24	3.87	17.00
25	16.03	9.00
26	3.93	147.00
27	0.99	.00
28	92.01	8.00
29	69.95	59.00
30	43.54	34.75
33	4.26	14.75
34	7.79	40.75
36	5.65	169.75
37	1.89	29.00
40	23.41	9.00
41	47.88	226.75
45	18.01	5.00
47	89.58	22.00
48	0.43	8.75
49	5.57	208.75
50	97.27	118.00
52	35.85	51.00
53	7.34	250.00
55	14.54	21.00
56	5.13	6.00
57	52.69	6.75
59	1.39	17.00
60	8.93	250.00
61	8.13	140.75
64	14.29	18.75
66	8.75	20.75
67	34.83	49.00
68	5.37	10.75
69	3.41	17.00
71	2.58	22.75
73	39.81	250.00
74	1.45	2.75
75	3.51	2.00
76	45.83	5.00
77	7.61	2.00
TOTAL	936.52	2,474.25
MEAN	17.34	45.82
STANDARD DEVIATION	24.04	65.50

TABLE XLIII

EXPERIMENT 3

Individual differences in time judgement of 8 seconds in Experiment 3. (N = 40).

Variables listed :-

1. (a) Short Extraversion Scale Scores.
   (b) Long Extraversion Scale Scores. (M.P.I.)

2. Manifest Anxiety.

3. (a) Memory for correct serial position of a list of nonsense syllables.
   (b) Memory for content of a list of nonsense syllables.

4. Metaphor Preference.

5. Verbal estimate (average of first session).

6. Controlled linear movement reproduction (average of first session).

7. Free linear movement reproduction (average of first session).

8. Variability in verbal estimate.*

9. Variability in controlled linear movement reproduction.*

10. Error in verbal estimate.

11. Error in controlled linear movement reproduction.

12. Reproduction by stationary grip (average of first session).

* Variability = sum of squares of first session scores

$$\Sigma x^2 = \Sigma X^2 - \frac{\Sigma(X)^2}{N}$$

TABLE XLIII

	1 (a)	1 (b)	2	3 (a)	3 (b)	4	5 Seconds	6 Seconds
	6	23	12	2	7	16	16	7.8
	10	26	10	7	9	15	15	8.1
	10	38	29	2	5	39	15	12.8
	2	34	16	5	6	14	15	9.5
	10	38	15	4	7	20	12	15.0
	10	41	25	3	6	33	6	6.9
	8	27	13	4	9	26	15	11.7
	6	28	15	4	6	18	4	8.1
	4	24	12	2	3	24	13	12.2
	8	34	6	0	9	35	17	9.6
	6	23	15	6	7	35	5	6.4
	4	18	15	6	7	32	11	8.7
	4	34	24	3	5	8	12	7.9
	0	20	25	3	4	11	5	15.5
	4	14	12	1	7	7	14	13.5
	6	18	16	6	8	16	11	12.3
	2	24	15	2	4	30	8	11.8
	0	26	6	7	10	35	4	13.8
	8	30	19	4	7	39	10	6.3
	10	35	13	5	8	34	12	7.5
	6	21	12	2	4	36	7	13.8
	10	29	19	13	13	10	7	8.6
	12	30	19	0	6	19	11	6.7
	10	30	20	0	3	33	7	9.8
	2	14	15	0	4	22	11	10.8
	4	23	8	3	6	23	5	4.0
	8	24	17	1	4	18	2	14.0
	8	30	19	6	8	20	11	10.0
	4	23	18	4	8	26	8	9.4
	8	29	14	3	6	19	10	5.5
	6	14	24	4	9	25	18	18.3
	8	26	11	3	8	20	9	7.6
	10	33	8	3	5	0	5	12.7
	10	30	13	4	5	23	3	8.1
	6	20	6	5	9	19	8	10.2
	6	28	7	4	9	17	7	7.2
	0	6	20	2	6	27	35	8.4
	2	5	21	5	9	32	7	5.1
	10	30	16	3	8	24	4	3.9
	8	30	16	8	9	26	11	7.4
TOTAL	256	1,030	616	149	273	926	406	386.6
MEAN	6.4	25.7	15.4	3.7	6.8	23.2	10.1	9.66
STD. DEV.*	3.39	7.94	5.51	2.48	2.13	9.25	5.73	3.29

*STD.DEV. = STANDARD DEVIATION

TABLE XLIII (Contd.)

EXPERIMENT 3

	7 Seconds	8 Seconds	9 Seconds	10 Seconds	11 Seconds	12 Seconds
	7.2	8	2.09	8	0.2	8.2
	13.8	7	1.05	7	5.8	8.5
	8.9	0	17.12	7	0.9	8.0
	7.6	7	8.28	7	0.4	8.0
	24.0	6	72.84	4	16.0	7.7
	9.7	0	4.95	2	1.7	7.1
	8.8	8	34.79	7	0.8	8.4
	9.1	3	4.53	4	1.1	8.0
	11.1	2	13.74	5	3.1	10.4
	8.1	8	16.37	9	0.1	8.5
	18.4	5	3.23	3	10.4	9.5
	11.7	3	3.21	3	3.7	9.9
	6.8	7	17.10	4	1.2	7.0
	8.5	3	156.91	3	0.5	7.9
	9.9	7	10.81	6	1.9	5.0
	11.0	1	21.73	3	3.0	11.2
	8.8	3	17.89	0	0.8	8.1
	7.4	6	39.33	4	0.6	7.0
	7.8	5	16.75	2	0.2	7.5
	13.6	4	13.45	4	5.6	8.3
	7.4	3	65.89	1	0.6	6.9
	6.1	4	24.52	1	1.9	6.9
	9.5	2	9.14	3	1.5	6.5
	10.9	5	9.53	1	2.9	7.6
	12.0	5	18.65	3	4.0	5.3
	8.8	1	4.23	3	0.8	6.7
	9.9	2	36.07	6	1.9	8.1
	10.3	7	19.37	3	2.3	10.4
	11.3	3	15.83	0	3.3	7.5
	12.6	2	2.56	2	4.6	7.4
	3.6	1	34.96	10	4.4	4.5
	8.1	6	2.63	1	0.1	10.0
	10.6	5	28.70	3	2.6	6.2
	10.6	3	7.13	5	2.6	10.7
	8.9	3	21.06	0	0.9	8.6
	17.3	3	11.03	1	9.3	6.9
	14.8	6	89.41	27	6.8	9.2
	10.6	3	2.71	1	2.6	8.8
	8.4	2	12.45	4	0.4	7.7
	9.6	5	3.60	3	1.6	9.7
TOTAL	413.5	158	895.64	170	113.1	319.1
MEAN	10.34	3.9	22.4	4.2	2.82	7.98
STD.DEV.*	2.72	2.51	28.91	4.39	3.17	1.51

* STD.DEV. = STANDARD DEVIATION

TABLE XLIV

EXPERIMENT 3

Individual differences in time judgement of 16 seconds in Experiment 3. (N = 40).

Variables listed :-

1. (a) Short Extraversion Scale Scores.
   (b) Long Extraversion Scale Scores. (M.P.I.)

2. Manifest Anxiety.

3. Metaphor Preference.

4. Verbal estimate (average of third session).

5. Controlled linear movement reproduction (average of third session).

6. Free linear movement reproduction (average of third session).

7. Variability in verbal estimate.*

8. Variability in controlled linear movement reproduction.*

9. Error in verbal estimate.

10. Error in controlled linear movement reproduction.

11. Reproduction by stationary grip (average of third session).

* Variability = sum of squares of third session scores

$$\Sigma x^2 = \Sigma X^2 - \frac{\Sigma(X)^2}{N}$$

TABLE XLIV

EXPERIMENT 3

	1 (a)	1 (b)	2	3	4 Seconds	5 Seconds	6 Seconds
	8	34	6	35	18	15.8	18.6
	8	30	19	20	37	21.6	16.4
	2	25	21	39	19	18.2	17.0
	10	38	15	20	13	16.3	16.9
	10	38	29	39	27	19.3	26.2
	6	40	6	19	8	18.8	18.9
	2	34	16	14	16	13.9	16.2
	4	24	12	24	12	14.9	17.3
	4	14	12	7	9	25.6	18.3
	0	6	20	27	10	22.8	13.6
	6	14	24	25	34	27.2	25.2
	10	25	18	29	12	16.9	20.6
	10	39	86	11	16	15.8	14.4
	4	34	24	8	14	12.3	18.9
	8	26	11	20	21	15.6	14.2
	10	34	28	11	29	21.5	29.9
	10	30	12	25	17	14.0	16.3
	4	18	15	32	9	10.9	14.4
	10	44	6	30	10	16.1	15.7
	2	20	22	22	15	12.0	10.4
	2	10	21	32	14	10.5	12.2
	6	28	15	18	18	13.9	19.8
	6	18	16	16	13	16.4	19.0
	2	24	15	30	15	21.9	36.7
	6	28	10	20	10	13.6	11.6
	8	30	19	39	10	15.3	19.2
	8	31	16	17	16	22.7	22.2
	10	30	20	33	14	16.5	19.8
	10	30	13	23	9	19.7	21.0
	10	30	16	24	5	9.9	8.2
	6	27	24	25	24	15.6	16.0
	10	35	13	34	16	17.9	18.6
	0	26	6	35	9	22.5	23.0
	6	28	7	17	9	16.6	14.1
	10	33	8	0	17	17.5	34.5
	8	24	17	18	16	25.6	20.6
	10	41	25	33	15	17.5	18.8
	10	26	10	15	20	15.7	16.6
	6	25	13	14	18	18.3	16.0
TOTAL	264	1,080	631	922	618	694.4	750.2
MEAN	6.60	27.0	15.77	23.05	15.4	17.4	18.75
STD.DEV.*	3.22	8.60	6.00	9.27	7.07	4.07	5.68

* STD.DEV. = STANDARD DEVIATION

TABLE XLIV (Contd.)

EXPERIMENT 3

	7 Seconds	8 Seconds	9 Seconds	10 Seconds	11 Seconds
	3	1.68	2	0.2	14.1
	75	44.15	21	5.6	12.5
	0	62.75	3	2.2	14.5
	3	7.05	3	0.3	14.8
	47	19.89	11	3.3	13.6
	1	22.91	8	2.8	13.8
	21	7.82	0	2.1	17.9
	5	10.65	4	1.1	13.5
	4	20.17	7	9.6	13.1
	8	68.86	6	6.8	13.8
	69	139.82	18	11.2	15.5
	1	5.66	4	0.9	17.5
	7	6.11	0	0.2	15.5
	9	7.20	2	3.7	17.8
	19	39.99	5	0.4	6.5
	119	15.55	13	5.5	19.1
	6	12.19	1	2.0	16.1
	4	2.86	7	5.1	13.9
	9	11.41	6	0.1	16.1
	7	30.10	9	1.3	14.6
	5	11.73	1	4.0	15.8
	2	2.07	2	5.5	13.7
	13	11.99	2	2.1	12.5
	5	4.63	3	0.4	13.3
	135	25.35	1	5.9	12.6
	0	12.00	6	2.4	12.5
	9	6.86	6	0.7	15.1
	19	35.35	0	6.7	20.9
	0	11.58	2	0.5	15.0
	7	24.97	7	3.7	12.1
	1	58.29	11	6.1	11.3
	3	8.29	8	0.4	17.7
	0	13.05	0	1.9	16.1
	19	37.04	7	6.5	15.2
	19	35.45	7	0.6	16.0
	0	47.03	1	1.5	14.6
	27	27.56	0	9.6	14.0
	6	20.00	1	1.5	14.2
	1	7.88	4	0.3	17.7
	5	0.55	2	2.3	16.6
TOTAL	693	938.49	201	127.0	592.1
MEAN	17.3	23.46	5.0	3.2	14.80
STD.DEV.*	30.00	25.36	4.72	2.85	2.40

* STD.DEV. = STANDARD DEVIATION

TABLE XLV

EXPERIMENT 2

Intra-individual ratios of delayed linear arm movement reproduction of 1 second divided by immediate linear arm movement reproduction of 1 second. (N = 77). Delay in seconds.

	Delay (in seconds)						
	0	5	10	15	20	30	60
	1.22	1.00	1.20	1.54	1.50	1.10	1.00
	0.67	2.50	1.60	0.87	0.47	1.50	0.91
	1.00	0.64	1.83	0.78	0.83	0.82	1.55
	0.50	0.89	0.55	0.91	0.89	0.42	0.92
	1.33	2.40	1.00	1.00	1.42	1.33	2.83
	1.44	1.10	1.40	1.08	1.33	1.00	1.44
	1.15	1.40	0.87	0.77	0.91	1.30	1.75
	1.50	0.87	1.78	2.00	2.60	1.50	1.17
	1.09	1.25	0.67	0.50	1.20	0.50	1.18
	1.00	0.79	0.79	0.62	1.16	1.80	0.92
	1.00	0.89	0.92	0.70	1.14	1.90	1.56
TOTAL	11.90	13.73	12.61	10.77	13.45	13.17	15.23
MEAN	1.082	1.248	1.146	0.979	1.223	1.197	1.385
STD.DEV.*	.2879	.6019	.4274	.4163	.5186	.4629	.5363

GRAND TOTAL	90.86
MEAN	1.180
STANDARD DEVIATION	0.49

* STD.DEV. = STANDARD DEVIATION

TABLE XLVI

EXPERIMENT 2

Intra-individual ratios of delayed linear arm movement reproduction of 2 seconds divided by immediate linear arm movement reproduction of 2 seconds (N = 77). Delay in seconds.

	Delay (in seconds)						
	0	5	10	15	20	30	60
	1.12	1.13	1.06	1.20	1.36	0.65	1.95
	0.90	0.61	2.29	1.08	0.67	1.36	1.14
	0.87	0.89	1.05	1.00	0.77	0.79	0.75
	0.97	0.84	0.50	1.15	0.61	0.44	0.85
	0.52	0.68	0.81	0.94	1.15	0.50	3.00
	0.94	0.57	0.80	2.33	0.92	1.00	1.22
	0.85	1.06	0.92	0.48	1.14	1.13	1.23
	1.19	0.68	0.88	0.73	2.00	0.66	2.37
	1.00	1.05	0.76	0.46	0.94	0.68	1.00
	0.87	1.20	0.95	0.71	0.83	2.13	0.75
	1.00	0.79	0.81	0.80	1.37	1.05	1.12
TOTAL	10.23	9.50	10.84	10.88	11.76	10.39	15.38
MEAN	0.930	0.864	0.985	0.989	1.069	0.945	1.398
STD.DEV.*	0.1646	0.2078	0.4390	0.4863	0.3826	0.4603	0.6957

GRAND TOTAL	78.98
MEAN	1.026
STANDARD DEVIATION	0.47

* STD. DEV. = STANDARD DEVIATION

T A B L E XLVII

EXPERIMENT 2

Intra-individual ratios of delayed linear arm movement reproduction of 4 seconds divided by immediate linear arm movement reproduction of 4 seconds (N = 77). Delay in seconds.

	Delay (in seconds)						
	0	5	10	15	20	30	60
	0.80	0.89	0.88	0.91	1.34	1.31	1.33
	1.06	1.34	1.33	1.59	0.94	1.07	0.71
	0.78	0.83	1.03	0.92	1.09	0.74	2.10
	0.70	1.11	0.95	0.96	0.77	0.86	0.80
	1.04	1.00	0.94	1.22	0.83	0.86	0.80
	1.34	1.30	0.81	1.15	1.17	0.90	1.36
	0.78	0.73	1.14	0.89	0.63	0.85	1.12
	0.76	0.78	0.81	0.71	1.03	0.83	0.94
	0.94	0.40	0.80	0.46	1.00	0.61	0.62
	0.87	0.91	1.13	0.65	0.80	1.21	0.41
	1.06	1.00	1.08	1.00	0.91	1.04	1.12
TOTAL	10.13	10.29	10.90	10.46	10.51	10.28	11.31
MEAN	0.921	0.935	0.991	0.951	0.955	0.935	1.028
STD.DEV.*	.1806	.2544	.1603	.2838	.1934	.1931	.4403

GRAND TOTAL	73.88
MEAN	0.959
STANDARD DEVIATION	0.26

* STD. DEV. = STANDARD DEVIATION

TABLE XLVIII

EXPERIMENT 2

Intra-individual ratios of delayed linear arm movement reproduction of 8 seconds divided by immediate linear arm movement reproduction of 8 seconds (N = 77). Delay in seconds.

	Delay (in seconds)						
	0	5	10	15	20	30	60
	1.13	0.79	0.91	0.91	0.99	0.76	1.34
	1.48	1.27	1.00	1.51	0.54	1.26	1.01
	1.18	0.89	0.80	1.11	0.90	0.80	1.11
	0.66	0.97	0.85	1.13	0.54	1.45	1.59
	0.81	0.35	1.11	0.53	0.79	0.69	2.00
	0.91	0.62	1.16	1.22	1.18	0.49	1.18
	0.93	1.06	1.00	0.60	1.06	1.36	0.84
	0.96	0.89	0.78	0.79	0.89	0.51	1.33
	1.04	0.56	0.63	0.35	0.78	0.89	0.90
	1.04	1.03	0.87	0.56	0.97	1.22	0.93
	0.94	0.31	0.87	1.25	1.08	0.97	0.43
TOTAL	11.08	8.74	9.98	9.96	9.72	10.40	12.66
MEAN	1.007	0.795	0.907	0.905	0.884	0.945	1.151
STD.DEV.*	.2042	.2877	.1473	.3517	.1965	.3208	.3966

GRAND TOTAL	72.54
MEAN	0.942
STANDARD DEVIATION	.30

* STD.DEV. = STANDARD DEVIATION

T A B L E   XLIX

EXPERIMENT 2

Intra-individual ratios of delayed linear arm movement reproduction of 16 seconds divided by immediate linear arm movement reproduction of 16 seconds (N = 77). Delay in seconds.

	Delay (in seconds)						
	0	5	10	15	20	30	60
	0.86	1.54	1.24	1.11	1.11	1.14	1.17
	0.84	0.89	0.85	1.25	0.91	1.30	0.91
	1.49	0.60	0.77	0.95	0.98	1.18	1.23
	0.87	1.14	0.93	0.96	1.16	0.33	1.19
	1.70	0.93	1.01	1.16	1.00	0.89	2.18
	1.33	0.99	0.50	1.01	0.82	1.84	2.19
	1.14	1.00	1.50	0.58	1.06	0.90	1.00
	1.07	0.82	0.72	0.61	1.01	0.96	0.49
	1.04	0.80	0.60	0.73	0.94	1.00	1.13
	1.37	0.99	1.41	0.67	0.83	0.86	1.19
	1.05	0.67	0.92	1.21	1.13	1.45	1.00
TOTAL	12.76	10.37	10.45	10.24	10.95	11.85	13.68
MEAN	1.160	0.943	0.950	0.931	0.995	1.077	1.244
STD.DEV.*	.2670	.2390	.3050	.2343	.1136	.3673	.4848

GRAND TOTAL	80.30
MEAN	1.043
STANDARD DEVIATION	0.33

Totals for ratios at all five signal lengths

TOTAL	56.10	52.63	54.78	52.31	56.39	55.01	68.26
MEAN	1.020	0.957	0.996	0.951	1.025	1.000	1.241
STD.DEV.*	.2437	.3822	.3307	.3678	.3385	.4368	.5401

* STD.DEV. = STANDARD DEVIATION

TABLE L

EXPERIMENT 2

Proportion of error $\frac{(\text{error})}{(\text{signal})}$ in reproducing 1 second by free linear movement. (N = 77).

	Delay (in seconds)						
	0	5	10	15	20	30	60
	.1	.2	.2	1.0	.7	.1	.0
	.4	.0	.2	.3	.2	.5	.0
	.1	.3	.1	.3	.3	.1	.4
	.0	.2	.4	.0	.5	.5	.2
	.1	.2	.0	.2	.2	.2	.7
	.3	.1	.4	.4	.2	.3	.3
	.5	.3	.3	.0	1.1	.3	.4
	.4	.3	.4	.2	.3	1.1	.7
	.2	.0	.2	.3	.4	.5	.3
	.5	.1	.1	.2	1.2	.1	.2
	.3	.8	.2	.3	.2	.9	.4
TOTAL	2.9	2.5	2.5	3.2	5.3	4.6	3.6
MEAN	0.3	0.2	0.2	0.3	0.5	0.4	0.3
STANDARD DEVIATION	0.17	0.21	0.12	0.25	0.35	0.31	0.22

GRAND TOTAL	24.6
MEAN	0.32
STANDARD DEVIATION	0.26

T A B L E LI

EXPERIMENT 2

Proportion of error $\frac{(\text{error})}{(\text{signal})}$ in reproducing 2 seconds by free linear movement. (N = 77).

	Delay (in seconds)						
	0	5	10	15	20	30	60
	0.10	.25	.05	.20	.50	.90	1.05
	.10	.05	.20	.30	.50	.05	.25
	.00	.45	.15	.25	.20	.65	.25
	.45	.20	.30	.15	.15	.30	.10
	.35	.20	.05	.15	.00	.25	.50
	.20	.35	.00	.40	.10	.30	.10
	.10	.40	.40	.40	.65	.15	.05
	.05	.05	.25	.45	.40	.35	.05
	.15	.35	.20	.45	.25	.60	.15
	.35	.05	.10	.25	.50	.05	.25
	.00	.40	.15	.20	.30	.15	.10
TOTAL	1.85	2.75	1.85	3.20	3.55	3.75	2.85
MEAN	0.17	0.25	0.17	0.29	0.32	0.34	0.26
STANDARD DEVIATION	0.14	0.14	0.11	0.11	0.19	0.26	0.28

GRAND TOTAL	19.80
MEAN	0.26
STANDARD DEVIATION	0.20

TABLE LII

EXPERIMENT 2

Proportion of error $\left(\frac{\text{error}}{\text{signal}}\right)$ in reproducing 4 seconds by linear movement. (N = 77).

	Delay (in seconds)						
	0	5	10	15	20	30	60
	.10	.18	.25	.08	.25	.15	.10
	.12	.08	.10	.32	.25	.12	.15
	.38	.28	.10	.10	.58	.52	.52
	.08	.22	.12	.08	.08	.70	.12
	.40	.62	.18	.02	.08	.20	.30
	.08	.25	.38	.02	.02	.55	.25
	.28	.60	.18	.40	.12	.18	.30
	.03	.28	.38	.45	.02	.05	.62
	.15	.58	.50	.68	.40	.38	.08
	.35	.08	.08	.30	.02	.18	.62
	.08	.68	.36	.00	.50	.22	.05
TOTAL	2.02	3.60	2.60	2.45	1.88	3.25	3.125
MEAN	0.18	0.33	0.24	0.22	0.17	0.30	0.28
STANDARD DEVIATION	0.13	0.25	0.14	0.21	0.17	0.20	0.21

GRAND TOTAL	18.92
MEAN	0.25
STANDARD DEVIATION	0.20

TABLE LIII

EXPERIMENT 2

Proportion of error $\frac{(\text{error})}{(\text{signal})}$ in reproducing 8 seconds by linear movement. (N = 77).

	Delay (in seconds)						
	0	5	10	15	20	30	60
	.14	.29	.22	.25	.06	.31	.02
	.04	.29	.19	.34	.08	.10	.05
	.25	.32	.29	.11	.59	.46	.11
	.11	.28	.14	.01	.08	.80	.02
	.24	.84	.09	.50	.20	.24	.05
	.12	.51	.26	.02	.04	.75	.26
	.34	.56	.25	.41	.10	.06	.41
	.12	.19	.41	.52	.22	.09	.65
	.32	.56	.64	.68	.46	.31	.00
	.40	.02	.11	.45	.25	.11	.34
	.20	.71	.49	.06	.12	.09	.66
TOTAL	2.29	4.58	3.09	3.36	2.20	3.32	2.59
MEAN	0.21	0.42	0.28	0.30	0.20	0.30	0.24
STANDARD DEVIATION	0.11	0.23	0.16	0.22	0.17	0.25	0.24

GRAND TOTAL	21.425
MEAN	0.28
STANDARD DEVIATION	0.17

TABLE LIV

EXPERIMENT 2

Proportion of error $\left(\frac{\text{error}}{\text{signal}}\right)$ in reproducing 16 seconds by linear movement. (N = 77).

	Delay (in seconds)						
	0	5	10	15	20	30	60
	.31	.18	.12	.12	.19	.40	.09
	.29	.47	.25	.37	.04	.22	.02
	.26	.66	.32	.01	.24	.43	.00
	.17	.27	.22	.14	.08	.96	.12
	.09	.73	.14	.02	.35	.25	.01
	.04	.35	.34	.09	.28	.58	.07
	.28	.58	.06	.44	.11	.20	.19
	.10	.27	.39	.50	.26	.11	.86
	.26	.49	.54	.59	.45	.19	.17
	.19	.12	.16	.47	.34	.25	.22
	.05	.77	.56	.13	.06	.14	.50
TOTAL	2.02	4.88	3.11	2.89	2.39	3.72	2.26
MEAN	0.18	0.44	0.28	0.26	0.22	0.34	0.21
STANDARD DEVIATION	0.09	0.21	0.16	0.20	0.13	0.24	0.25

GRAND TOTAL	21.28
MEAN	0.28
STANDARD DEVIATION	0.21

TABLE LV

EXPERIMENT 2

Intra-individual ratios of speed of linear movement in delayed reproduction of 1 second divided by speed of linear movement in immediate reproduction of 1 second. (N = 77).

	Delay (in seconds)						
	0	5	10	15	20	30	60
	0.93	1.00	1.25	.58	1.27	.61	.50
	0.75	0.60	1.25	.98	.80	1.15	.92
	0.91	0.59	1.09	.82	1.20	.90	.86
	0.77	1.31	.92	1.52	.70	.26	.55
	1.11	.52	1.43	1.00	.85	.75	.18
	1.09	1.06	.45	1.55	2.00	1.14	.61
	0.91	.72	.86	.52	1.39	.43	.73
	0.89	1.31	.91	.50	.67	1.00	.43
	0.73	1.07	1.33	1.00	2.50	1.09	1.41
	1.00	0.85	.95	.50	.43	.56	.89
	0.96	0.75	.50	.86	.87	.58	.71
TOTAL	10.05	9.78	10.94	9.83	12.68	8.47	7.79
MEAN	0.914	0.889	0.995	0.894	1.153	0.770	0.708
STANDARD DEVIATION	.1183	.2644	.3025	.3570	.5919	.2915	.3061

GRAND TOTAL	69.54
MEAN	0.90
STANDARD DEVIATION	0.3701

TABLE LVI

EXPERIMENT 2

Intra-individual ratios of speed of linear movement in delayed reproduction of 2 seconds divided by speed of linear movement in immediate reproduction of 2 seconds. (N = 77).

	Delay (in seconds)						
	0	5	10	15	20	30	60
	.77	1.07	1.00	.92	1.13	1.15	1.12
	.89	.88	.52	1.16	.94	1.12	.88
	2.68	.89	.76	.73	.79	1.26	.90
	1.17	1.43	.73	3.14	.50	1.14	.89
	.99	.77	1.93	.99	1.40	1.25	.30
	1.22	1.67	2.03	.49	1.49	1.08	.92
	1.11	.35	1.08	.76	1.26	.54	.76
	1.26	.77	1.22	.82	.82	1.16	.28
	.79	1.27	1.05	1.02	1.28	.94	1.08
	.81	1.11	.65	.60	.44	.78	.98
	.89	.50	.59	.97	1.09	.63	.70
TOTAL	12.58	10.71	11.56	11.60	11.14	11.05	8.81
MEAN	1.144	.974	1.051	1.055	1.013	1.005	0.801
STD.DEV.*	.5135	.3708	.4865	.6845	.3313	.2354	.2666

GRAND TOTAL	77.45
MEAN	1.006
STANDARD DEVIATION	0.4494

* STD.DEV. = STANDARD DEVIATION

T A B L E LVII

EXPERIMENT 2

Intra-individual ratios of speed of linear movement in delayed reproduction of 4 seconds divided by speed of linear movement in immediate reproduction of 4 seconds. (N = 77).

	Delay (in seconds)						
	0	5	10	15	20	30	60
	.26	1.07	1.01	.58	1.37	.84	.73
	.80	1.42	.93	.43	.40	.48	1.70
	1.17	.77	.97	1.02	1.13	1.20	1.11
	.87	2.13	1.06	1.54	1.21	1.12	.93
	1.20	.96	1.82	.73	1.20	.82	.72
	.93	.66	1.15	.76	1.96	.80	.55
	.99	.61	1.40	.99	.91	.78	.62
	1.18	1.24	.96	1.41	1.06	.96	1.07
	1.97	1.26	.89	1.31	1.24	1.64	1.34
	2.11	1.69	.91	.67	.51	.99	1.54
	.64	.93	.82	.94	.86	1.16	.57
TOTAL	12.12	12.74	11.92	10.38	11.85	10.79	10.88
MEAN	1.102	1.158	1.084	.944	1.077	.98	.981
STD.DEV.*	.5130	.4391	.2751	.3582	.4034	.2898	.4017

GRAND TOTAL	80.68
MEAN	1.048
STANDARD DEVIATION	.3912

* STD.DEV. = STANDARD DEVIATION

TABLE LVIII

EXPERIMENT 2

Intra-individual ratios of speed of linear movement in delayed reproduction of 8 seconds divided by speed of linear movement in immediate reproduction of 8 seconds. (N = 77).

	Delay (in seconds)						
	0	5	10	15	20	30	60
	.92	1.43	.94	.86	1.52	1.03	.74
	.83	.87	1.08	.52	1.40	.79	1.20
	.98	.61	.92	.62	1.04	1.52	.84
	.72	1.90	.86	2.16	1.40	.57	.88
	.96	1.71	1.45	1.00	1.21	.92	.32
	1.10	1.06	1.11	1.05	1.78	1.32	.67
	.98	.72	1.16	.62	1.33	.72	.83
	.66	1.09	.94	1.71	1.06	1.09	.63
	1.02	.97	.75	1.74	1.28	1.58	1.07
	1.19	1.13	1.48	.91	.45	.77	.89
	1.20	.95	.85	1.02	1.11	.89	.98
TOTAL	10.56	12.44	11.54	12.21	13.58	11.20	9.05
MEAN	.960	1.131	1.049	1.11	1.235	1.018	.823
STD.DEV.*	.1652	.3799	.2278	.5058	.3209	.3159	.2241

GRAND TOTAL	80.58
MEAN	1.046
STANDARD DEVIATION	0.3464

* STD. DEV. = STANDARD DEVIATION

TABLE LIX

EXPERIMENT 2

Intra-individual ratios of speed of linear movement in delayed reproduction of 16 seconds divided by speed of linear movement in immediate reproduction of 16 seconds. (N = 77).

	Delay (in seconds)						
	0	5	10	15	20	30	60
	.82	1.08	.84	.65	4.34	.88	.77
	.53	1.12	1.18	.69	.97	.67	1.41
	1.08	1.02	.87	1.21	.92	.91	1.00
	1.01	1.49	1.48	1.12	.93	.40	.89
	1.01	1.07	1.25	.96	1.29	.99	.26
	1.59	1.31	1.15	.92	1.37	1.17	.46
	1.34	.58	1.03	1.32	1.23	1.00	.87
	1.28	1.12	1.06	1.59	.99	1.05	1.84
	1.24	.99	.79	1.21	1.22	1.27	.89
	.99	1.01	.93	.63	.58	1.00	.78
	.91	.78	1.13	1.19	.96	.89	.87
TOTAL	11.80	11.57	11.71	11.49	14.80	10.23	10.04
MEAN	1.073	1.052	1.065	1.045	1.345	.930	.913
STD.DEV.*	.2702	.2272	.1354	.2893	.9710	.2245	.4026

GRAND TOTAL	81.64
MEAN	1.060
STANDARD DEVIATION	.4669

Total scores for all 5 signal lengths

TOTAL	57.11	57.24	57.67	55.51	64.05	51.74	46.57
MEAN	1.038	1.041	1.049	1.009	1.165	.941	.847
STD.DEV.*	.3702	.3586	.3146	.4661	.5885	.2869	.3369

*STD.DEV. = STANDARD DEVIATION

T A B L E LX

EXPERIMENT 2

Individual differences in the judgement of 8 seconds by the methods of (a) free linear movement and (b) verbal estimate. (N = 54).

Variables listed :-

1. Extraversion (short scale).

2. Manifest Anxiety.

3. Free linear movement reproduction of 8 seconds (total of 4 trials over two sessions).

4. Verbal estimate of 8 seconds (total of 4 trials over two sessions).

5. Error in free linear movement reproduction of 8 seconds (total error in 4 trials over two sessions).

6. Error in verbal estimate of 8 seconds (total error in 4 trials over two sessions).

T A B L E LX

EXPERIMENT 2

Subject	1	2	3 sec.	4 sec.	5 sec.	6 sec.
2	8	12	25.7	28	- 6.3	- 4
3	8	13	25.6	37	- 6.4	+ 5
5	10	11	26.3	31	- 5.7	- 1
6	12		27.8	49	- 4.2	+ 17
7	8	39	20.9	36	- 11.1	+ 4
9	8		22.0	38	- 10.0	+ 6
10	8	12	21.0	38	- 11.0	+ 6
11	8	10	26.5	45	- 5.5	+ 13
12	6	25	24.7	30	- 7.3	- 2
15	12	21	24.6	27	- 7.4	- 5
16	2		8.0	39	- 24.0	+ 44
17	10		19.1	33	- 12.9	+ 1
18	8	12	11.4	25	- 20.6	- 7
20	8	14	18.8	26	- 13.2	- 6
21	6		31.2	116	- 0.8	+ 84
22	2		15.0	30	- 17.0	- 2
23	8		24.3	35	- 7.7	+ 3
24	10	28	28.1	49	- 3.9	+ 17
25	10	22	26.2	39	- 5.8	+ 7
26	8		27.2	44	- 4.8	+ 12
27	0	23	28.2	24	- 3.8	- 8
28	0	14	18.3	19	- 13.7	- 13
29	4	14	18.4	31	- 13.6	- 1
30	10	21	16.7	23	- 15.3	- 9
33	6	14	16.5	40	- 15.5	+ 8
34	4	13	26.7	52	- 5.3	+ 20
36	12	8	32.3	61	+ 0.3	+ 29
37	6	8	31.9	74	- 0.1	+ 42
40	10		22.8	38	- 9.2	+ 6
41	6	31	15.1	40	- 16.9	+ 8
45	4	28	22.1	27	- 9.9	- 5
47	4		15.2	28	- 16.8	- 4
48	10	16	29.9	31	- 2.1	- 1
49	12	20	28.1	52	- 3.9	+ 20
50	8	36	31.9	43	- 0.1	+ 11
52	12	8	33.0	48	- 9.0	+ 16
53	4	15	33.3	120	- 8.7	+ 88
55	10	22	30.2	36	- 1.8	+ 4
56	12		32.9	37	+ 0.9	+ 5
57	4		28.5	31	- 3.5	- 1
59	8		17.6	37	- 14.4	+ 5
60	2	22	5.8	46	- 26.2	+ 41
61	8	11	27.8	45	- 4.2	+ 13
64	8		32.5	37	+ 0.5	+ 5
66	8	15	31.1	31	- 0.9	- 1
67	8	12	27.8	33	- 4.2	+ 1
68	6	19	26.7	27	- 5.3	- 5
69	12		35.2	105	+ 3.2	+ 73
71	4	9	25.3	34	- 6.7	+ 2
73	12	24	24.3	79	- 7.7	+ 47
74	12	17	23.4	29	- 8.6	- 3
75	6	25	8.2	18	- 23.8	- 14
76	6		28.1	50	- 3.9	+ 18
77	10	15	20.8	26	- 11.2	- 6
TOTAL	408	679	1,301.0	2,247	456.8	783.0
MEAN	7.6	17.87	24.1	41.6	8.5	14.5
STD.DEV.*	3.19	7.60	6.85	21.07	6.38	19.70

* STD.DEV. = STANDARD DEVIATION

TABLE LXI

EXPERIMENT 2

Individual differences in the judgement of 16 seconds by the methods of (a) free linear movement and (b) verbal estimate. (N = 54).

Variables listed :-

1. Free linear movement reproduction of 16 seconds (total of 4 trials over two sessions).

2. Verbal estimate of 16 seconds (total of 4 trials over two sessions).

3. Speed of free linear movement in reproducing time signals (average of first session speed).

4. Error in free linear movement reproduction of 16 seconds (total error in 4 trials over two sessions).

5. Error in verbal estimate of 16 seconds (total error in 4 trials over two sessions).

TABLE LXI

EXPERIMENT 2

Subject	1	2	3	4	5
2	49.7 sec.	54 sec.	4.60 ins/sec.	- 14.3 sec	- 10 sec
3	38.3	65	12.20	- 25.2	+ 1
5	51.2	65	10.82	- 12.8	+ 1
6	53.9	87	8.06	- 10.1	+ 23
7	39.8	71	13.46	- 24.2	+ 7
9	46.6	74	7.19	- 17.4	+ 10
10	42.5	64	7.01	- 21.5	0
11	56.5	80	4.26	- 7.5	+ 16
12	39.9	54	7.10	- 20.1	- 10
15	46.7	55	7.49	- 17.3	- 9
16	16.5	76	11.88	- 47.5	+ 12
17	40.7	60	5.02	- 23.4	- 4
18	22.6	45	4.86	- 41.4	- 19
20	34.8	44	13.36	- 29.2	- 20
21	55.9	175	6.62	- 8.1	+ 111
22	19.4	55	9.94	- 44.6	- 9
23	52.9	75	9.68	- 11.1	+ 11
24	53.4	98	7.22	- 10.6	+ 34
25	55.5	70	4.46	- 8.5	+ 6
26	55.7	93	2.92	- 8.3	+ 29
27	56.9	48	15.17	- 7.1	- 16
28	54.1	48	9.08	- 9.9	- 16
29	41.8	70	8.86	- 22.2	+ 6
30	35.2	49	37.05	- 28.8	- 15
33	25.2	85	7.60	- 38.8	+ 21
34	65.4	107	8.38	+ 1.4	+ 43
36	61.7	125	8.18	- 2.3	+ 61
37	55.4	106	27.98	- 8.6	+ 42
40	49.4	73	3.63	- 14.6	+ 9
41	30.8	93	3.65	- 33.2	+ 29
45	39.9	55	11.28	- 20.1	- 9
47	32.4	40	7.16	- 31.6	- 24
48	59.9	61	7.25	- 4.1	- 3
49	34.6	59	7.02	- 29.4	- 5
50	61.3	92	4.56	- 2.7	+ 28
52	57.5	86	9.15	- 6.5	+ 22
53	42.0	173	6.59	- 22.0	+129
55	52.8	62	4.06	- 11.2	- 2
56	66.1	76	7.37	+ 2.1	+ 12
57	50.3	53	9.92	- 13.7	- 11
59	33.0	70	9.13	- 31.0	+ 6
60	8.3	146	13.73	- 55.7	+ 82
61	50.2	87	3.77	- 13.8	+ 23
64	52.3	65	6.86	- 11.7	+ 1
66	55.0	61	4.47	- 9.0	- 3
67	57.3	70	6.90	- 6.7	+ 6
68	53.4	55	7.60	- 10.6	- 9
69	67.9	206	8.20	+ 3.9	+142
71	52.4	61	6.26	- 11.6	- 3
73	42.6	130	9.52	- 21.4	+ 66
74	49.3	61	7.90	- 14.7	- 3
75	13.7	40	5.13	- 50.3	- 24
76	46.1	78	4.92	- 17.9	+ 14
77	31.9	49	5.88	- 32.1	- 15
TOTAL	2,458.6 sec.	4,200 sec.	462.36 ins/sec.	1,003.8 sec.	1,242 sec.
MEAN	45.5	77.8	8.56	18.6	23.0
STD.DEV.*	13.48	34.15	5.53	13.05	30.25

*STD.DEV. = STANDARD DEVIATION

TABLE LXII

EXPERIMENT 2

Measures of unstructured motor speed and primary functioning (N = 54).

Subject	1. Tapping (preferred speed)	2. Tapping (maximum speed)	3. Crosses (maximum speed)	4. Handwriting (personal speed)
2	105/min.	187/min.	52/min.	139 sec.
3	58	170	52	135
5	67	155	59	152
6	44	120	66	133
7	112	175	60	101
9	26	202	59	135
10	46	201	59	111
11	80	119	56	149
12	44	165	47	130
15	53	219	61	94
16	57	163	62	117
17	48	191	62	102
18	115	160	59	128
20	52	116	58	108
21	33	162	68	98
22	76	182	58	132
23	25	136	56	118
24	33	195	65	110
25	50	162	64	122
26	89	138	55	145
27	89	206	59	107
28	22	162	54	131
29	43	99	56	114
30	55	182	54	138
33	71	171	56	140
34	56	165	63	117
36	46	177	58	105
37	73	182	62	103
40	39	128	57	101
41	50	173	61	118
45	50	194	57	152
47	153	191	59	112
48	30	168	48	172
49	65	170	57	96
50	69	120	60	105
52	68	170	53	146
53	23	100	50	132
55	30	188	57	119
56	122	195	65	87
57	45	110	62	104
59	137	183	59	102
60	105	184	55	129
61	67	192	59	134
64	90	156	49	153
66	50	210	59	111
67	72	158	50	153
68	21	233	65	104
69	57	118	56	90
71	40	185	66	130
73	22	122	52	96
74	44	188	62	144
75	32	169	50	125
76	190	192	71	127
77	43	133	47	135
TOTAL	3,382	8,992	3,126	6,591
MEAN	62.6	166.5	57.9	122.1
STD.DEVIATION*	34.53	30.93	5.34	22.8

* STD.DEVIATION = STANDARD DEVIATION

TABLE LXIII

EXPERIMENT 2

Metaphor Preference scores and time judgement variables. (N = 40).

Variables listed are :-

1. Metaphor Preference score (high score denotes preference for swift metaphors of time).
2. Linear movement reproduction of 8 seconds (first session).
3. Linear movement reproduction of 16 seconds (first session).
4. Verbal estimate of 8 seconds (first session).
5. Verbal estimate of 16 seconds (first session).
6. Error in linear movement reproduction of 8 seconds (first session).
7. Error in linear movement reproduction of 16 seconds (first session).
8. Error in verbal estimate of 8 seconds (first session).
9. Error in verbal estimate of 16 seconds (first session).
10. Reproduction of 16 seconds by key-pressing (first session).
11. Average individual speed of linear movement reproduction of time in the first session.
12. Intra-subject variability of speed of linear movement reproduction of time in the first session.

TABLE LXIII

EXPERIMENT 2

1	2 Seconds	3 Seconds	4 Seconds	5 Seconds	6 Seconds
26	6.9	11.1	7	16	1.1
11	6.0	11.9	7	15	2.0
28	6.1	14.6	8	17	1.9
2	5.7	8.5	10	22	2.3
13	1.3	4.3	11	20	6.7
15	3.5	6.8	11	16	4.5
34	6.5	11.7	7	15	1.5
22	3.5	8.2	6	11	4.5
25	5.7	10.8	10	17	2.3
1	6.0	16.9	9	22	2.0
40	2.9	7.4	12	20	5.1
34	8.9	16.1	15	35	0.9
34	7.9	13.7	18	25	0.1
13	4.0	16.3	5	18	4.0
18	3.8	8.0	10	14	4.2
28	7.5	13.9	10	16	0.5
21	7.4	16.6	10	20	0.6
5	8.8	17.8	12	25	0.8
33	6.2	11.9	30	80	1.8
19	4.3	8.8	14	24	3.7
15	6.1	12.0	14	28	1.9
13	2.8	2.3	5	11	3.2
22	5.7	13.1	8	15	2.3
18	4.8	13.0	8	15	3.2
17	4.3	9.1	10	19	3.7
14	7.2	15.2	13	22	0.8
16	7.1	18.6	10	23	0.9
23	5.9	14.9	20	40	2.1
20	7.8	14.1	21	44	0.2
21	8.4	15.6	27	55	0.4
18	6.4	10.4	13	18	1.6
28	2.7	8.0	5	17	5.3
0	3.9	10.4	8	18	4.1
26	8.3	11.4	7	11	0.3
2	8.5	19.0	24	30	0.5
33	4.1	7.0	8	22	3.9
29	4.7	12.9	6	14	3.3
36	6.5	12.5	7	14	1.5
7	2.0	6.8	8	20	6.0
17	7.8	14.0	10	17	0.2
TOTAL 797	227.9	475.6	454	901	97.9
MEAN 19.9	5.7	11.9	11.3	22.5	2.4
STD. DEV.* 10.17	1.975	3.873	5.831	12.81	1.789

* STD. DEV. = STANDARD DEVIATION

TABLE LXIII (contd.)

	7 Seconds	8 Seconds	9 Seconds	10 (N = 21) Seconds	11 Inches/Sec.	12 Inches/Sec.
	4.9	1	0	15.6	4.7	2.34
	4.1	1	1	15.0	12.2	1.05
	1.4	0	2	16.3	10.8	1.34
	7.5	2	6	17.1	4.0	0.57
	11.7	3	4	14.5	11.9	4.95
	9.2	3	0		4.9	0.71
	4.3	1	1		10.6	0.77
	7.8	2	5		13.4	0.45
	5.2	2	1	14.7	4.5	0.77
	0.9	1	6		8.9	3.16
	8.6	4	4		8.9	1.00
	0.1	7	19	17.8	8.2	1:31
	2.3	10	9	16.2	28.0	1.76
	0.3	3	2	15.0	7.6	1.30
	8.0	2	2		3.6	1.09
	2.1	2	0		3.7	0.84
	0.6	2	4	15.0	15.1	0.95
	1.8	4	9		9.1	1.05
	4.1	22	64		6.6	0.82
	7.2	6	8		7.2	1.38
	4.0	6	12	15.8	3.8	0.61
	13.7	3	5		5.1	3.67
	2.9	0	1	16.0	7.1	1.50
	3.0	0	1		7.0	1.20
	6.9	2	3	14.2	9.1	1.62
	0.8	5	6		4.3	0.59
	2.6	2	7		6.3	1.59
	1.1	12	24	21.4	9.5	2.39
	1.9	13	28		6.6	0.80
	0.4	19	39	14.7	8.2	2.38
	5.6	5	2	11.8	7.0	1.39
	8.0	3	1		5.9	0.80
	5.6	0	2	17.2	5.0	0.88
	4.6	1	5	17.2	4.6	0.33
	3.0	16	14	11.0	4.6	2.20
	9.0	0	6		7.6	2.12
	3.1	2	2		7.9	1.45
	3.5	1	2		11.3	8.94
	9.0	0	4	16.3	9.9	2.46
	2.0	2	1	13.6	6.3	0.81
TOTAL	182.8	167	312	326.4	321.0	65.34
MEAN	4.6	4.2	7.8	15.5	8.0	1.63
STD. DEV.*	3.317	5.292	11.70	2.102	4.254	1.490

* STD. DEV. = STANDARD DEVIATION

T A B L E LXIV

EXPERIMENT 2

n Achievement scores and time judgement variables. (N = 40).

Variables listed are :-

1. n Achievement score.
2. Reproduction of 8 seconds by linear movement (first session).
3. Reproduction of 16 seconds by linear movement (first session).
4. Verbal estimate of 8 seconds (first session).
5. Verbal estimate of 16 seconds (first session).
6. Error in reproduction of 8 seconds by linear movement (first session).
7. Error in reproduction of 16 seconds by linear movement (first session.)
8. Error in verbal estimate of 8 seconds (first session).
9. Error in verbal estimate of 16 seconds (first session).
10. Reproduction of 16 seconds by key-pressing (first session).
11. Average individual speed of linear movement reproduction of time in the first session.
12. Intra-individual variability in speed of linear movement reproduction of time in the first session.

TABLE LXIV

EXPERIMENT 2

1	2 Seconds	3 Seconds	4 Seconds	5 Seconds	6 Seconds
0.3	8.9	13.3	10.0	24.0	0.9
1.7	5.5	11.5	9.5	20.0	2.5
3.3	5.5	11.9	7.5	18.0	2.5
2.3	5.9	11.6	6.5	13.0	2.1
0.3	2.5	6.8	10.5	16.0	5.5
2.3	4.8	3.7	8.5	14.0	3.2
3.7	6.5	12.0	12.0	23.0	1.5
4.3	7.0	13.8	6.0	12.0	1.0
4.0	5.3	9.8	6.5	11.0	2.7
2.0	3.7	7.4	12.0	20.0	4.3
4.7	6.3	18.0	11.0	27.0	1.7
3.7	7.1	14.5	11.0	18.0	0.9
1.3	4.7	12.2	8.5	9.0	3.3
1.7	7.8	14.7	7.5	13.0	0.2
1.0	8.5	17.8	14.5	25.0	0.5
3.0	10.1	10.5	10.5	18.0	2.1
3.7	3.0	6.8	10.5	20.0	5.0
1.3	10.8	14.3	11.0	15.0	2.8
0.7	7.1	14.5	7.5	15.0	0.9
5.3	5.2	12.9	6.5	14.0	2.8
3.0	8.4	13.3	11.0	20.0	0.4
2.0	6.5	11.1	8.0	16.0	1.5
3.3	5.3	11.9	9.5	15.0	2.7
2.0	5.5	15.2	5.0	22.0	2.5
0.0	6.9	11.7	8.5	15.0	1.1
1.0	6.5	14.0	9.0	18.0	1.5
0.3	3.4	10.5	9.0	14.0	4.6
3.7	7.5	16.9	13.0	22.0	0.5
3.7	4.4	10.0	11.0	20.0	3.6
3.3	8.4	16.1	17.5	35.0	0.4
0.3	7.4	16.3	21.5	18.0	0.6
2.0	4.3	8.0	10.0	14.0	3.7
1.7	6.2	13.9	10.5	16.0	1.8
1.3	8.5	19.0	9.5	30.0	0.5
2.0	7.7	11.9	19.0	20.0	0.3
2.7	4.5	8.8	7.0	24.0	3.5
1.3	4.8	9.1	10.0	19.0	3.2
1.0	6.2	12.0	10.5	28.0	1.8
0.7	7.4	18.3	9.5	23.0	0.6
1.3	5.1	16.0	9.5	12.0	2.9

	1	2	3	4	5	6
TOTAL	87.2	251.1	502.0	406.0	746.0	84.1
MEAN	2.18	6.3	12.5	10.1	18.6	2.1
STD. DEV.*	1.349	1.844	3.406	3.286	5.450	1.389

* STD. DEV. = STANDARD DEVIATION

TABLE LXIV (contd.)

EXPERIMENT 2

	7 Seconds	8 Seconds	9 Seconds	10 (N = 21) Seconds	11 Inches/Sec.	12 Inches/Sec.
	2.7	4.0	8	14.9	5.2	0.62
	4.5	1.5	4		13.5	0.63
	4.1	0.5	2		7.2	0.87
	4.4	1.5	3	14.4	7.5	1.57
	9.2	2.5	0		4.9	0.71
	12.3	0.5	2		9.9	2.52
	4.0	4.0	7	15.9	7.2	1.62
	2.2	3.0	4	15.5	15.2	3.07
	6.2	1.5	5		37.0	2.24
	8.6	4.0	4		8.9	1.00
	2.0	3.0	11	16.8	8.4	1.19
	1.5	3.0	2	15.2	9.2	2.62
	3.8	0.5	7	19.4	7.2	2.71
	1.3	0.5	3	18.2	7.2	1.48
	1.8	6.5	9		9.1	1.05
	5.5	2.5	2	15.6	4.1	0.53
	9.2	2.5	4	16.3	9.9	2.46
	1.7	2.0	1		6.9	1.17
	1.5	0.5	1	16.1	7.6	1.83
	3.1	1.5	2		7.9	1.45
	2.7	3.0	4		4.9	1.78
	4.9	0.0	0	15.6	4.7	2.34
	4.1	1.5	1	15.0	12.2	1.05
	0.8	3.0	6		4.3	0.59
	4.3	0.5	1		10.6	0.77
	2.0	1.0	2	14.2	9.7	1.67
	5.5	1.0	2	14.6	9.1	2.13
	0.9	5.0	6		8.9	3.16
	6.0	3.0	4		10.1	1.27
	0.1	9.5	19	17.8	8.2	1.31
	0.3	13.5	2	15.0	7.6	1.30
	8.0	2.0	2		3.6	1.09
	2.1	2.5	0		3.7	0.84
	3.0	1.5	14	11.0	4.6	2.20
	4.1	11.0	4		6.6	0.82
	7.2	1.0	8		7.2	1.38
	8.9	2.0	3	14.2	9.1	1.62
	4.0	2.5	12	15.8	3.8	0.61
	2.3	1.5	7		6.9	0.82
	0.0	1.5	4	17.2	4.5	0.71
TOTAL	160.8	111.0	182.0	328.7	334.3	58.80
MEAN	4.04	2.8	4.5	15.6	8.4	1.5
STD. DEV.*	2.858	2.322	4.000	7.912	5.292	0.728

* STD. DEV. = STANDARD DEVIATION