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by

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ABSTRACT:

A series of experiments was carried out to investigate: (1) the effect of a background sound applied at either the input and/or the output stages on judgements of visual intervals made using the methods of verbal estimation, operative estimation, and reproduction; (2) the effect of lack of knowledge of the method of response during the input stage of temporal information on the judgement made; (3) the effect of auditory visual cross-modal stimuli on reproductions of intervals; (4) the effect of lack of knowledge of the mode of response during the input of cross-modal temporal stimuli.

Analysis of the data revealed: (1) the background sound, when applied in the standard stage of the method of verbal estimation, increased the estimate of the interval; when applied to the judgement stage of the method of operative estimation decreased the production of the interval; when applied to the standard stage of the method of reproduction increased the judgement of the interval; and when applied to the judgement stage of the method of reproduction decreased the reproduction of the interval; (2) that lack of knowledge of the method of response during the standard presentation may decrease the accuracy of the judgement; (3) that the auditory visual cross-modal difference in time estimation was consistent in both the input and output stages of the method of reproduction; (4) that lack of knowledge of the mode of response during the standard stage of cross-modal temporal processing had no effect on the resulting judgements.

The results were discussed in terms of further defining the concept of an 'internal clock' hypothesized by Cohen (1965).

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INTRODUCTION

Research concerning time estimation, that is, the study of the ability to judge intervals in terms of duration, has been centered around contextual factors involving the judgement process and the relationships between these factors. It is noted that although many studies concerned with the estimation of time provide information concerning relationships among and between methodological and modal factors, there have been few attempting to relate these variables to a mechanism of man's time sense. The present research is concerned with the relationship of these factors to a hypothesized 'internal clock' postulated by Cohen (1965). It attempts to illustrate that the effects of methodological and modal factors in time estimation can be explained in terms of an 'internal clock' model.

HISTORICAL REVIEW

The study of man's ability to estimate intervals has had a confused and varied history. As long ago as 1891, Nichols, in a review of time and its study in psychology, stated:

> "Casting an eye backward we can but be struck by the wide variety of explanation offered for the time mystery. Time has been called an act of mind, of reason, of perception, of intuition, of sense, of memory, of will, of all possible compounds and compositions to be made up of them. It has been deemed a general sense accompanying all mental content in a manner similar to that conceived of pain and pleasure. It has been assigned a separate special, disparate sense, to nigh a dozen kinds of feeling, some familiar, some strangely invented for the difficulty. It has been explained by 'relations', by 'earmarks', by 'signs', by 'remnants', by 'struggles' by 'strifes', by 'luminous trains', by 'shocks of spurious present', by 'apperception'. It has been declared 'apriori', 'innate', 'intuitive', 'empirical', 'mechanical'. It has been deducted from within and without, from heaven and earth, and several things difficult to imagine as either (cited by Ornstein, 1969, p. 16)."

If perhaps Nichols could have cast an eye into the future his statement would have been further appreciated.

Many early philosophers were concerned with the nature of time. They theorized on whether time was eternal, and whether time existed independent of the mind. The Platonic philosophers felt that time was the mobile image of eternity revealing itself in a world governed by cycles of recurring change (Fraisse, 1963). From this rather vague reference of times relation to changing

events, and the statement that time does not exist without change (Aristotle; in Fraisse, 1963), the theorizing about the nature of time turned inward to the self. Descartes (Fraisse, 1963), in reflecting on the basis of the notion of time, suggested that it was related to our immediate experience. He considered that time had its origin in inner experience and that the ideas of time and duration were the same.

The concept of time slowly changed from an external phenomenon to a mixture of external events and their effects on the internal perceptions of these events. Hume (Fraisse, 1963) stated that whenever we have no successive perceptions, we have no notion of time. He argued that time was discovered by some perceivable succession of changeable events or objects. Following Hume's linking of external events and perceptions, Kant further emphasized the role of the mind in time perception. He stated: "The unity of time cannot arise from a diversity of sensations, but only from the way in which the diversity is linked together by the mind [P.5]." (Fraisse, 1963). He considered that the need for a common time at the root of the laws of science resulted from the pure form of the intuition of the senses. The commonality comes not from external events but from operations of the mind in accordance with the constant law governing the substance of the mind. Time therefore becomes apparent through the activity of the individual.

James (White, 1963), in extending Kant's theorizing, suggested that time consisted of natural units of duration which were a function of the organism itself. James referred to these

units as 'the law of time's discrete flow'. He felt that the natural units of duration were the result of the waxing and waning of the brain processes, and that without these processes there would be no conception of time. James then attributed the perception of time to the neurophysiological functioning of the organism.

Discrete Units Of Time

The concept of time had now evolved from a vague reference to experience to a rather sophisticated reference to units of duration and brain processes. Bergson (White, 1963) further added to its evolution by theorizing that perceived time was a series of natural units of duration which he called 'moments'. He argued that we perceive the world at durations equal to these moments, and then we join these perceptions together in order to give us a continuous picture of reality. He judged that it was on the basis of these moments that we perceived psychological time. Bergson's concept of time, besides again stressing discrete units of duration, suggested a definite cognitive process in man's time sense.

The basis of these units or moments, however, needed further clarification in terms of source and manner of functioning. Pieron (White, 1963) stated:

> "Units of time exist.....The time units we use in our actions are functions of the speed of deep seated organic processes, conditioning metabolism and various vital activities, such as the propogation of the nervous discharge. There is a time appropriate to the organism, of which the units are a function of the speed of the biological processes." (P.577).

He suggested that individual time is correlated to these phenomena in a manner that cannot be observed directly. Thus each individual has a way of measuring time against a common base.

These units of duration were later considered as periods of a hypothetical scanning process which was coordinated from a clocking center. Wiener (1948) argued that in the operation of the brain some sort of scanning mechanism would be necessary. He stated:

> "The scanning apparatus should have an intrinsic period of operation which should be identifiable in the performance of the brain.....While this cyclical process might be a locally determined one, there is evidence that there is a wide spread synchronization in different parts of the cortex, suggesting that it is driven by some clocking center [P. 165] ".

However Wiener was more concerned with information intake than temporal perception.

Stroud (1955), in a similar approach to Wiener's, called each period of scanning a 'moment' and suggested that during these discrete moments the individual incorporates the information contained in each. These moments are then strung together to give an organized picture of reality. Each moment is a unit of psychological time on which is based the individual's ability to perceive time. Although Stroud did not relate these 'moments' to physiological processes, he saw them as a perceptual model by which man's time estimation ability could be explained.

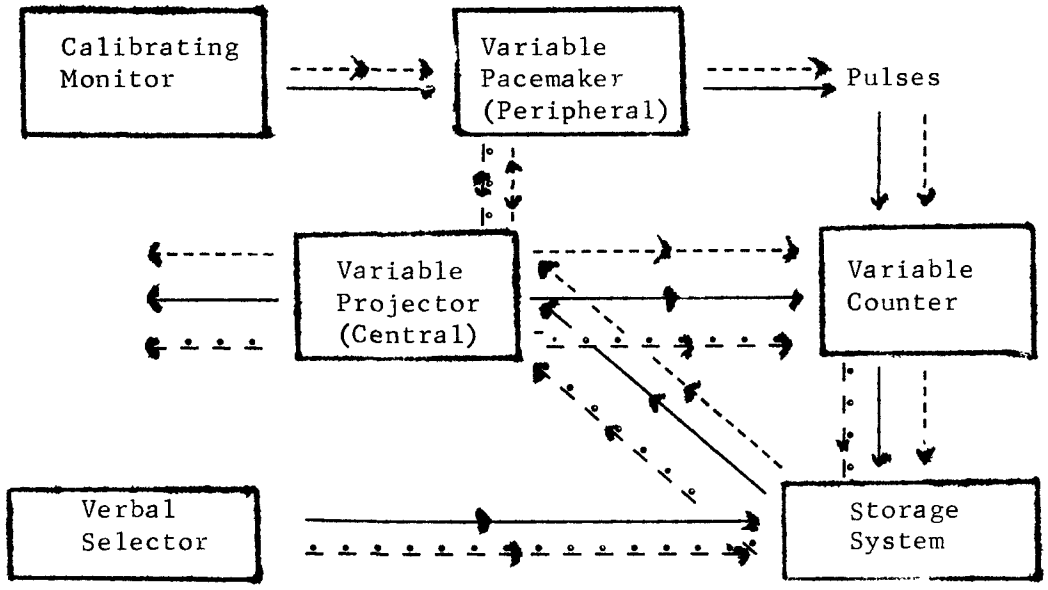
Internal Clock Models

The theorizing about moments and units of duration became an integral part of theories attempting to define the controlling basis

of these units. This controlling basis became known as an 'internal clock', which was envisaged as the coordinator and the producer of these units, and thus as the basis of man's time sense.

An approach to the study of man's time sense has been to propose hypothetical models of the 'internal clock' in attempts to understand and relate contextual factors in time estimation. Treisman (1963) has postulated a mechanistic model based on the idea of a pacemaker producing pulsations which are counted and then compared with the interval to be judged. He felt that this model would account for the fluctuations in time estimation data, and would also provide a feasible means of relating contextual variables to man's psychochronometric ability.

Cohen (1965) added sophistication to Treisman's original idea, while proposing his model of the 'internal clock' as "a simple scheme which seems to integrate the essential features of subjective time (p.83)." Cohen suggested that the 'clock' consists of a variable pacemaker, a variable counter, a storage system, a verbal selector, a variable projector, and calibrating monitors (see Figure 1). The variable pacemaker emits a continuous and regular stream of pulses with the frequency of these pulses being determined by the sensory input at that time. These inputs are called calibrating monitors. The number of pulses is recorded by the variable counter and from there the input passes on to the storage system which files the temporal information in a way consistent with the manner of input. For example: (a) When the temporal information is given in the form of a verbal label during



Method of verbal estimation ——→
Method of operative estimation - - - →
Method of reproduction ------→

FIGURE 1 Cohen's model of the 'internal clock' mechanism with illustrations of the temporal processing under the methods of verbal estimation, operative estimation and reproduction.

the input stage, it is coded as part of the verbal selector system. In this case the temporal information is not processed as pulsations during input, so there is no calibrating monitor influence on the verbal label. (b) When the temporal information is presented in operative terms, it is coded into the storage system as the number of pulses that are produced by the variable pacemaker during the input of the information. In this case the calibrating monitors have a direct effect on the information input, as they determine the number of pulsations that are produced by the variable pacemaker. The recording of the temporal information in the storage system concludes the input stage.

During the output stage of temporal processing, the information is taken from the storage system in a manner consistent with the response and is projected by the variable projector. Thus: (a) If during output a verbal response is required, a label is taken from the verbal selector and is projected. In this case there is no calibrating monitor influence as the information is not in pulsation form. (b) If an operative production of the interval is required, the temporal information is transmitted in the form of pulses from the storage system to the variable projector. So the manner of projection is determined by the calibrating monitors, as they control the rate of pulsation by the variable pacemaker, which in turn calibrates the rate of projection. The projection of the temporal information completes the processing by the 'internal clock'.

Cohen's model presents a variable system which would be affected differently by each calibrating monitor. However, the value of hypothetical models lies in their ability to relate contextual factors in the area the model represents. Cohen's model, besides integrating the essential features of subjective time, must also be able to relate contextual factors in the field of time estimation.

Methodological Variables

An important contextual factor in the study of psychochronometric ability is the methodology used. Three methods are commonly used in time estimation research: verbal estimation; operative estimation; and reproduction.

These three methods examine all the meaningful combinations of the standard (stimulus) and judgement (response) in terms of subjective and objective time (Bindra and Waksberg, 1956). The remaining method is for both the standard and judgement stages to be in terms of subjective time. Although this would illustrate individual differences it would be meaningless since the data could not be converted to measurable entities to allow comparison, and will therefore not be used in this study.

Table 1 defines the terms 'standard' and 'judgement' and also illustrates their classification as subjective and objective for the three methods. These differ in the manner in which the temporal stimuli are presented. When verbal estimation is required the experimenter delimits the interval operatively (demonstrates

TABLE 1

Significance Of The Terms Standard, Judgement, And Elapsed Time In The Verbal Estimation, Operative Estimation, And Reproduction Methods Of Time Estimation.

Terms	Methods		
	Verbal Estimation	Operative Estimation	Reproduction
Standard	Interval delimited operatively by E; refers to clock (objective) time.	Interval stated verbally by E; refers to subjective time.	Interval delimited operatively by E; refers to objective time.
Judgement	Verbal estimate made by S; refers to subjective time	Operative estimate made by S; refers to objective time.	Operative estimate made by S; refers to objective time.
Elapsed time	Refers to the objective duration of the standard (operatively defined)	Refers to the objective duration of S's judgement (operatively defined)	Refers to the objective duration of the Standard as well as S's judgement (operatively defined)

the duration of the standard) and asks the subject to verbally estimate its duration in terms of clock time. With this method the response is an identification of the appropriate objective category. With the method of operative estimation, the subject is required to delimit operatively (judgement) the duration of an interval which is stated verbally by the experimenter (standard). In this method the subjective category is the verbal naming of the interval by the experimenter, and the corresponding magnitude is the measured response of the subject. In the method of reproduction, the subject is required to operatively reproduce a standard that the experimenter has operatively delimited. Here the subject does not make an overt identification of the subjective scale in either the standard or the judgement as both stages are in operative terms.

A number of studies have shown that time estimations made under the three methods differ. Ochberg, Pollack, and Meyer (1965) illustrated significant differences in the time estimations made using verbal estimation and reproduction. They had three groups of subjects: women blindfolded after ocular surgery, women not blindfolded after ocular surgery, and visually normal women not blindfolded. Their task was to attempt to judge a 16 second interval using the two methods. In comparing the results they found that the judgements made using verbal estimation were not related to those made using the method of reporduction for any group. They also reported that the judgements made under the method of verbal estimation differentiated among the three groups while those made

under the method of reproduction did not. They concluded that the verbal estimation and reproduction methods were completely different tasks, and that the method of reproduction "says nothing about 'time sense' (p. 655)." They felt that the method of reproduction involved the ability to concentrate and reproduce the stimulus with no reference to a subjective impression of the duration of the stimulus. On the other hand, the use of verbal estimation made the subject reveal her subjective impression (internal norms) of the interval to be judged, thus making this measure a more valid indicator of the subject's time sense.

Clausen (1950) also illustrated differences in judgements made under the three methods. He had his subjects judge intervals of 5, 10, and 15 seconds. The results indicated that the subjects overestimated the intervals when using the method of verbal estimation, and underestimated the intervals when using the methods of operative estimation, and reproduction. In addition he found that time estimations made under the methods of verbal and operative estimation were negatively correlated. He also reported that time estimations made using the method of reproduction were not significantly correlated to those made under the methods of verbal and operative estimation. He concluded that the temporal process using the method of reproduction involved a different underlying function than the temporal process using verbal and operative estimation.

In an explanation similar to that of Ochberg, Pollack, and Meyer (1965), Clausen claimed that the method of reproduction does not require the subject to refer to objective time, as both the

standard and judgement are in terms of the subject's internal time. In other words, the subject provides his own temporal reference as the basis for his judgement. With the methods of verbal and operative estimation, the subject has to relate his subjective time to clock time, thus making the comparison between subjective time and clock time possible. He did not feel however, that the method of reproduction was separate from the individual's time sense as did Ochberg et. al. Other studies have supported Clausen's findings that the temporal estimations made under the three methods differ (Seigman 1962; du Preez 1963).

It should be noted that Seigman's conclusion concerning the difference of temporal processing under the three methods was not the same as Clausen's. In a study comparing the judgements of 5 and 20 second durations for the three methods, he found that judgements made under the method of verbal estimation were negatively correlated with those made under the method of operative estimation, and were not correlated to judgements made under the method of reproduction. Whereas Clausen stated that the method of reproduction involved a different underlying function from the one responsible for the methods of verbal and operative estimation, Seigman stated that the temporal processing for the three methods involved the same underlying temporal process. He explained the lack of correlation of the verbal and operative estimation judgements with the reproduction method judgements as a result of factors which affected only the former two judgement methods. He felt that these factors were not concerned with the temporal information process but

he did not suggest what these might be.

The above studies have illustrated that time estimations made using the methods of verbal estimation, operative estimation, and reproduction differ, but none has attempted to explain the relationships found. Bindra and Waksberg (1956), in an article on the methods and terminology used in time estimation, discussed the processing of temporal information under each of the three methods in terms of an 'internal clock' analogy. This analogy suggests that the individual has an internal pacemaker that produces subjective temporal units.

The units:

> "refer to subjective temporal norms of the magnitude of the duration of seconds and minutes, and these are presumably acquired through learning. These subjective units, like the internal clock, may be presumed to vary from individual to individual and from the same individual from occasion to occasion depending on the internal and external conditions (p.158)."

These units are counted by the individual and are used as measures of intervals. That is, if 10 of these are produced during an interval the subject would perceive the interval as being 10 seconds in duration.

In their explanation of time estimations made under the three methods a regular relationship among the methods was noted. For example, if the pacemaker is pulsating twice per second during a standard interval of 8 seconds the number of pulsations would be 16. Using the method of verbal estimation, this would give rise to a response of 16 seconds in the judgement stage. With the method of operative estimation, a verbal standard of 8 seconds is

produced in 4 seconds as the pacemaker produces the number of pulses required to fulfill the 8 second criterion in half the time, i.e. 8 pulses in 4 seconds. Finally, with the method of reproduction, the pacemaker pulsates 16 times in the standard stage. In the judgement stage the pacemaker must again pulsate 16 times in order to meet the criterion set in the standard stage. If the pacemaker pulsates at the same rate in both the standard and judgement stages of this method, the result is an accurate reproduction of the standard. Their explanation suggests a negative relationship between judgements made under the methods of verbal and operative estimation, and a lack of correlation between these judgements and those made under the method of reproduction.

The analysis of time estimation concepts by Bindra and Waksberg, in terms of a common underlying process, an 'internal clock', and the effect of the pacemaker and the number of pulses for each method on the individual's perception of the pulses, would seem to logically account for the negative correlation found by Clausen (1950) and Seigman (1962) between the judgements made under the methods of verbal and operative estimation and the lack of correlation between reproduction judgements and those made under the methods of verbal and operative estimation. Thus the explanation of the differences in the estimations made under the three methods in terms of temporal information processing by an 'internal clock' seems quite feasible.

Methodologies And The Internal Clock

The processing of the temporal information under the three methods of psychochronometry can also be illustrated using Cohen's (1965) model of the 'internal clock'. Table 2 provides a summary of the 'mechanisms' involved in this model. From this table it can be seen that the methods of verbal and operative estimation are subject to variables which do not affect estimations made using the method of reproduction. For example, the methods of verbal and operative estimation involve classification as verbal labels in one stage of temporal processing, while the method of reproduction judgements are processed through the 'internal clock system' in terms of pulsations without any reference to a verbal label.

It is also important to note the relationship of the effect of the calibrating monitors in terms of the standard and judgement stages of temporal processing for the three methods. Examination of Table 2 illustrates that verbal and operative estimation judgements are inversely related in the location of the effect of the calibrating monitor, with the method of verbal estimation judgements being affected in the standard stage, and the method of operative estimation judgements being affected in the judgement stage. This may mean that similar variables would have an inverse effect on the temporal processing under these two methodologies. The method of reproduction, when compared in terms of the location of the effect of the calibrating monitors is not related to those of verbal and operative estimation.

The inverse relationship of the effect of the calibrating

TABLE 2

The Internal Clock Stages Involved With The Processing Of Temporal Information Under The Methods Of Verbal Estimation, Operative Estimation, And Reproduction For The Standard And Judgement.

Stimulus And Response Stages	Methods		
	Verbal Estimation	Operative Estimation	Reproduction
Standard	Calibrating Monitor Variable Pacemaker Variable Counter Storage System	Verbal Selector	Calibrating Monitor Variable Pacemaker Variable Counter Storage System
Judgement	Verbal Selector	Storage System Variable Projector Calibrating Monitor Variable Counter	Storage System Variable Projector Calibrating Monitor Variable Counter

monitors for the methods of verbal and operative estimation, and the lack of relationship between these methods and the method of reproduction is similar to the results of studies comparing time estimations made using the three methods (Clausen 1950; Seigman 1962). This adds support for the concept of a common underlying function being responsible for temporal processing (Seigman 1962). That is, an internal clock', within which the temporal processing under each method is affected differently by the calibrating monitors.

Du Preez (1963) provided further support for Seigman's suggestion. He had subjects estimate a 16 second interval using the methods of verbal estimation and reproduction. He found no correlation between the judgements made under the two methods. On a retest in a months time, he found that ther was still no correlation between the judgements made under the two methods. It was noted however, that even though the estimations in the retest differed from the initial test, the change in the estimations under the methods was significantly correlated. On this basis he rejected the hypothesis that the temporal processing under the methods of verbal estimation and reproduction involved different underlying functions and suggested that the same underlying function was responsible for all temporal processing.

A further possibility is that the temporal processing for each of the three methods is a distinct process within an 'internal clock', which is affected in a consistent way by the surrounding conditions (calibrating monitors). This would mean that in

du Preez's (1963) first session, the temporal judgements made under the methods of verbal estimation and reproduction, although not correlated, would be affected by the same calibrating monitors. In his second session these same methods were used, but it is quite probable that the background conditions changed. This would result in different calibrating monitors, which in turn would cause the judgements in the two sessions to differ. The change in the calibrating monitor influence would be proportional in terms of its effects on the responses made using the two methods. This would mean that if a calibrating monitor affected the temporal processing under the methods in a specific manner, and on retesting the calibrating monitor changed, then the change in judgements would be related in a proportionate way, even though the judgements themselves were not related.

The aforementioned studies were concerned with methodological variables and underlying processes, but made no attempt to relate their results directly to a model of the 'internal clock'. They point out that time estimations under the three methods differ, but there is no attempted explanation of the difference that goes beyond a vague mention of temporal processing. Although Cohen's model of the 'internal clock' suggests that the temporal processing under the three methods differs, it remains to confirm this difference in terms of his model. If the effects of a constant external condition (calibrating monitor) could be illustrated as having specific effects on the temporal processing under each

method at specific stages (standard and judgement), then there would be further evidence that Cohen's model of the 'internal clock' might be justified.

Modal Variables In Time Estimation

A further variable which plays an important part in time estimation is the mode of presentation of the stimulus interval and response. Studies have shown an auditory-visual difference in time judgement which is independent of stimulus properties, method, and the number of response categories (Goldstone and Goldfarb 1964).

Goldstone, Boardman, and Lhamon (1959) investigated auditory-visual differences in absolute judgements of the subject's concept of one clock second. In the first of a series of three experiments, the effect of prior experience with one sense mode upon temporal judgements made with another sense mode was studied. Subjects were required to judge an auditory interval and then a visual interval using the modified method of limits. The authors found that the subjects' absolute judgement of a one second interval for the visual mode was longer than their estimation of a one second interval for the auditory mode, or in other words, the amount of objective time taken to fill a one second interval would be greater for the visual mode than the auditory. In the second study, the effect of recent and remote anchor stimuli upon auditory and visual judgements of a duration of one second was examined.

Once again it was noted that a one second estimation in the auditory mode was shorter in duration than a one second estimation in the visual mode. Having observed the auditory-visual difference, the sensory dominance of auditory and visual temporal stimuli was studied by presenting both modal temporal stimuli at the same time. This was done to determine which mode was dominant when the two modes were compared in temporal terms. Using auditory and visual stimuli, the intensities of which were based on their previous research of modal intensity discrimination, it was found that the judgements made corresponded to the mode that had the higher intensity. They attributed this effect to the subject attending to the more intense mode. They concluded that there was a fundamental difference between auditory and visual time perception such that "more visual clock time is judge necessary to fulfill a basic temporal concept. Visual durations that were the same as auditory durations were judged shorter (p. 246)." They suggested further study of the auditory-visual difference but made no attempt to explain the difference that they found.

In a later study on intersensory difference in temporal judgement, Goldstone, Jernigan, Boardman, and Lhamon (1959) compared auditory and visual concepts of one clock second while attempting to equalize the area of stimulation. They felt that the difference found in their earlier study (Goldstone, Boardman, and Lhamon 1959) might have been caused by the fact that the subject's attention was totally on the auditory stimulus (due to the use of

the earphones which excluded other auditory stimulation), and only partially on the visual stimulus (due to the use of a small bulb in the presentation of the visual stimulus). This meant that the subjects might have been distracted by other visual stimuli while they were judging the visual intervals. Using the same auditory stimulus and a visual stimulus that took up the total field of vision, they found the same difference as in their former study. That is, that the amount of objective time taken for a one second interval in the visual mode was longer than that time taken for a one second interval in the auditory mode. However, the authors still made no attempt to account for the difference.

Behar and Bevan (1961) also illustrated an auditory-visual difference in time estimation. In one of a series of experiments, using the method of single stimuli, and durations of 1, 2, 3, 4, and 5 seconds, they compared auditory and visual time judgements, and found that for the 1 - 5 second range auditory durations were judged twenty per cent longer than visual durations of the same length. They concluded that auditory intervals were consistently judged longer than visual intervals of the same length.

Goldstone and Goldfarb (1963) carried out further studies to explore the differential effects of auditory and visual inputs upon the absolute judgement of filled and unfilled durations. Previous studies concerning the modal differences had used stimulus intervals involving a constant presentation of the stimulus mode, i.e., continuous sound or light. If the modal difference could be obtained by using empty stimulus intervals bounded by short discrete

sounds or lights, then the auditory-visual difference could not be a function of the action of perceiving the stimulus. Using the method of single stimuli, and a series of seven durations from .15 to 1.95 seconds, the authors had subjects judge the standard intervals with a nine point scale. Their results demonstrated that the auditory-visual difference, previously shown with absolute judgement of continuous sounds and lights, was also obtained when subjects judged an empty interval. They concluded that the auditory-visual difference in the estimations of short durations remained a basic fact of human time judgement. This suggests that the modal difference in temporal perception may be a function of modal classification of the temporal information by a processing system or 'internal clock'.

In another study Goldstone and Goldfarb (1964) stated that, "no experiment has investigated whether auditory durations are judged longer than visual durations, and visual duration are judged shorter than auditory durations upon direct comparison (p. 483)." Using the method of comparison and a stimulus interval of one second, they had subjects compare the duration of auditory and visual stimuli. They found a significant difference between the two modes, with the auditory durations being judged longer than the visual durations. Other studies have supported this intersensory difference (Goldstone and Goldfarb 1964; Goldfarb and Goldstone 1964). Goldstone and Goldfarb (1964) concluded:

> "Mode is indeed a relevant variable in determining the psychological referent point, at least when magnitude judgements of time are involved. The persistence of

> this intermodal phenomenon.....lends credence to the assumption that it is a basic difference between the senses in judging time. (p. 383)."

Since research has reliably illustrated this difference in time perception, the focus should now turn to an attempt to arrive at a causal basis of this difference. A possible means of doing this would be to understand the modal difference in terms of Cohen's model of the 'internal clock'.

Internal Clock And Modal Temporal Perception

In terms of Cohen's model of the 'internal clock' it would be reasonable to expect that the difference in the perception of duration with the auditory and visual modes would be due to a different number of pulses produced by the variable pacemaker for each mode. In view of the findings reported, this difference would be such that more pulses would be produced during an auditory interval than during a visual interval of the same objective length. This, in turn, would result in the auditory interval being judged longer than the visual interval. The quantitative difference in pulse production by the variable pacemaker would be due to the effect of the different modes acting as calibrating monitors, suggesting that the modal difference would not be a function of two different systems of processing of temporal information by the 'internal clock' proper, but rather, a function of external factors that calibrate the 'internal clock' system (calibrating monitors). It remains, however, for research to delineate the causal basis of this modal difference in temporal perception.

DEVELOPMENT OF HYPOTHESIS

The studies described in the following four chapters of this thesis examine several features of psychochronometry in terms of a hypothesized model of the 'internal clock'. They are concerned with (i) the effect of a background sound on visual temporal judgements made using the methods of verbal estimation, operative estimation, and reproduction; (ii) the effect of knowledge or lack of knowledge of the method of response during stimulus presentation on time estimation ability; (iii) the cross-modal difference in time perception between the auditory and the visual modes; and (iv) the effect of knowledge or lack of knowledge concerning the mode of response during stimulus presentation on time estimation ability.

Study 1

Study 1 investigated the influence of a background sound calibrating monitor, presented at certain stages (input or output) of temporal processing, on judgements made under the methods of verbal estimation, operative estimation, and reproduction.

In previous research relative to this investigation Hirsch, Bilger, and Deatherage (1965) compared the effects of background conditions (those not directly relevant to the stimulus) of quiet and noise on judgements of auditory and visual intervals. Using the method of reproduction, they found that in the noise condition

both the auditory and visual intervals were reproduced as shorter when compared to the same intervals reproduced in the quiet condition (without the background noise). An example of this would be a ten second interval produced as eight seconds in the noise condition and eleven seconds in the quiet condition. That is, in the noise condition the individual's subjective second was smaller than his subjective second in the quiet condition. An explanation of this phenomenon in terms of the 'internal clock' pacemaker concept means that the pulsator produces the same number of pulses at a faster rate in the noise condition than in the quiet condition, thus making the reproduction in the noise condition objectively shorter.

Hirsch et. al. (1965) illustrated the effect of a background sound only on judgements made using the method of reproduction, but it is possible that judgements made under the methods of verbal and operative estimation may also be affected in a specific manner. It is suggested, in terms of Cohen's model of the 'internal clock', that a background sound might affect the temporal processing under the three methods at the points in the 'clock' model where the temporal information is in pulsation terms. The temporal processing under the method of verbal estimation should be subject to the background sound conditions during the stimulus stage, such that the number of pulses from the pacemaker would increase. This in turn would result in an increase of the countable events which would cause the verbal estimate of the interval to be greater than a verbal estimate of the same interval without the background sound present.

The temporal processing under the method of operative estimation should be subject to the background sound condition only during the judgement stage, and the effect would be such that during the output stage (judgement) the variable projector would project the temporal information required to meet the criterion set in the standard stage at a faster rate. This in turn would make the objective measure of the interval shorter than an interval operatively produced at a slower rate without the background sound present.

Finally the temporal processing under the method of reproduction should be affected by the background sound conditions at both the input and output stages such that, if a background sound was present in the input stage and absent in the output stage, the number of pulses produced by the pacemaker would be maximized in the input and produced at a slower rate in the output. This would result in the reproduction being longer than one with no background sound in the standard stage. Further, where no background sound occurred in the standard stage but a background sound was present in the judgement stage, the smaller number of pulses from the standard stage would be reproduced at a faster rate in the judgement stage. This would decrease the objective length of the reproduction.

Thus a means of determining whether the temporal processing under the three methods is differentially affected by a constant background sound condition would be to apply the sound condition to the standard and judgement stages of visual temporal processing for the three methods. Table 3 illustrates these applications and suggestions. The location and manner of the effects of the

TABLE 3

Applications Of The Background Sound And No Background Sound Conditions To The Standard And Judgement Stages Of The Methods Of Verbal Estimation, Operative Estimation, And Reproduction.

Methods	Processing Stages	
	Standard	Judgement
Verbal Estimation	Background Sound	Background Sound
	Background Sound	No Background Sound
	No Background Sound	Background Sound
	No Background Sound	No Background Sound
Operative Estimation	Background Sound	Background Sound
	Background Sound	No Background Sound
	No Background Sound	Background Sound
	No Background Sound	No Background Sound
Reproduction	Background Sound	Background Sound
	Background Sound	No Background Sound
	No Background Sound	Background Sound
	No Background Sound	No Background Sound

background sound on estimations of visual intervals, using the three methods, may result in a clarification of the differences (Clausen 1950; Seigman 1962) found among the estimations made with the methods. It may also demonstrate that the explanation of the differences in the estimations made using the three methods in terms of the effects of calibrating monitors at different stages of temporal processing within an 'internal clock' model is a useful way of relating time estimation results. Study 1 attempts to illustrate the value of Cohen's model of the 'internal clock' under these conditions.

From these assumptions the following hypotheses have been developed:

1 Using the method of verbal estimation, a background sound introduced at the standard stage of temporal processing will significantly increase the estimations of the duration of a visual stimulus over that of the no background sound condition.

2 Using the method of operative estimation, a background sound introduced at the judgement stage of temporal processing will significantly decrease the estimations of the duration of a visual stimulus over that of the no background sound condition.

3 Using the method of reproduction, a background sound introduced at the standard stage of temporal processing will significantly increase the estimations of the duration of a visual stimulus over that of the no background sound condition.

4 Using the method of reproduction, a background sound introduced at the judgement stage of temporal processing will significantly decrease the estimations of a visual stimulus over that of the no background condition.

Study 2

Clausen (1950) and Seigman (1962) reported that time estimations

made using the methods of verbal estimation and reproduction were not correlated. In discussing Cohen's model of the 'internal clock', it was suggested that the processing of the temporal information for these two methods is similar until it reaches the storage system. At this point the information must be channelled in a manner consistent with the method of response. For example, if the method of verbal estimation is to be used in the response, the information is channelled into the storage system where a verbal label is applied and projected. However, with the method of reproduction, the temporal information is channelled into the storage system and is projected in terms of pulses. This raises the question of whether the 'internal clock' plays a directive role in the decision concerning the manner of processing that corresponds with each method. That is, if the method of verbal estimation is used in the judgement, how is the 'internal clock system' directed to process the temporal information, and at what point during the temporal process does this channelling occur?

Study 2, by delaying the knowledge of the method of response until after the temporal information has been incorporated (after the standard) investigates the role the 'internal clock' has in the channelling of the temporal information. If the accuracy of time estimation is impaired in the condition where the knowledge of the method of response is withheld until after the presentation of the standard, then it is suggested that the decision concerning the method of response and the temporal information processing that corresponds with that method, is not a function of the clock system proper. However, if the accuracy of time estimation is not impaired

in this condition, then it may be that the 'internal clock' plays a major role in channelling the temporal information in a specified manner.

The hypothesis extended here is:

> The accuracy of time estimation will be significantly greater when the method of response is known before the presentation of the standard than if the method of response is not known until after the standard presentation.

Study 3

Several studies have illustrated differences between auditory and visual temporal perception (Goldstone 1964; Behar and Bevan 1961; Goldfarb 1964) such that auditory durations were verbally estimated as longer than visual durations of the same length, and reproduced as shorter, regardless of the contextual alteration. Cohen's (1965) model of the 'internal clock' may provide an explanation of the difference between the estimations made under the two modes, i.e., the difference may be a function of the effects of each mode acting as different calibrating monitors. This would mean that the auditory-visual modal difference is consistent throughout the processing of the temporal information by the 'internal clock'. Study 3 attempts to illustrate this by comparing the cross-modal differences during the input (standard) and output (judgement) processing stages of temporal information under the method of reproduction. This results in a logical sequence of comparisons which are listed in Table 4. In one comparison, the input conditions of the two compared judgements are in cross-modal terms while the output modal conditions are constant, allowing a study

TABLE 4

Comparisons Of Cross-Modal Estimations Using The Method Of Reproduction

Stimulus And Response Modal Conditions			Comparison Meanings
Standard		Judgement	
Visual		Auditory	The judgements compared in these cases study the cross-modal difference at the input stage of temporal processing.
	with		
Auditory		Auditory	
Auditory		Visual	
	with		
Visual		Visual	
Visual		Auditory	The judgements compared in this case study the cross-modal difference at both the input and output stages of temporal processing.
	with		
Auditory		Visual	
Visual		Visual	The judgements compared in these two cases study the cross-modal difference at the output stage of temporal processing
	with		
Visual		Auditory	
Auditory		Auditory	
	with		
Auditory		Visual	
Visual		Visual	In this case there is no cross-modal interaction at either the input or output stages of temporal processing.
	with		
Auditory		Auditory	

of the modal difference during the input stage of temporal processing. In the second comparison the input and output stages of the comparison pair are in cross-modal terms. This investigates the cross-modal difference at both these stages of temporal processing. The third comparison condition has the judgement stage varied in cross-modal terms while the standard stage is held constant, thus examining the modal difference during the output stage of temporal processing. In the final comparison the input and output conditions for one of the comparison pair is visual, while the input and output conditions for the other of the comparison pair are auditory. This comparison studies the modal difference when no cross-modal interaction occurs at any stage.

If the modal difference is consistent throughout the processing of the cross-modal information by the 'internal clock', then the modal difference can be said to be a function of the modes acting as calibrating monitors and not of 'internal clock' processing factors. If however, the modal difference occurs at only one stage (input or output) of temporal processing within the 'clock', then above comparisons will indicate its location.

The hypothesis states:

> The modal difference between auditory and visual temporal perception is consistent at all stages of temporal processing under the method of reproduction.

Study 4

Studies have illustrated that perceptions of auditory and visual temporal intervals differ (Goldstone 1964; Goldfarb 1964) such that auditory durations are judged longer than visual durations.

These studies raise the question of the extent the 'clock' proper is involved with the decision concerning the manner of processing of temporal information that corresponds with each mode. That is, if temporal information in the visual mode is processed through the 'internal clock' during the standard stage of processing, and the mode of the temporal information is changed in the judgement stage to auditory, how does the clock system coordinate the temporal processing that corresponds with each mode?

There are two possibilities. The first is that the rate of temporal information processing is controlled by the calibrating monitor of each mode, i.e., the 'internal clock' processing of the modal temporal information involves no decision process, but rather follows the lead of stimulus conditions. On the other hand, if the modal difference between the auditory and visual modes is due to factors within the 'clock system' then there must be a point within the 'clock' that directs the processing of the temporal information in a manner consistent with the mode being used.

If the processing corresponding to each mode is a function of central factors within the 'internal clock', then knowledge of the switch in the mode of response before the standard presentation of the temporal information should make the judgement more accurate than if this information is not given until after the standard has been presented. This is expected, as in the condition where the individual has been given knowledge of the change in the mode of response there would be a lessening of confusion in terms of

classifying the mode of temporal processing and thus a greater accuracy. If, however, the processing of modal temporal information is a function of factors outside the 'internal clock' proper (calibrating monitors), then there would be no difference between the condition where the knowledge of the mode change is known before the standard presentation, and the condition where it is not known. This research attempts to delineate the involvement of the 'clock' with the coordination of the processing of the modal temporal information.

The hypothesis states:

> The accuracy of time estimation ability will be significantly greater when the mode of response is known before the onset of the standard, than if the mode of response is not known until after the standard has been presented.

METHOD

Subjects

The subjects were six male students enrolled in an experimental Psychology Course at Waterloo Lutheran University. All subjects were volunteers and were paid $30.00 each to participate in the research. Each student had a basic knowledge of experimental psychology and the relevant factors in psychological research. This sophistication led to a greater degree of reliability in his performance since he was more aware of the ethics involved in being a subject.

Procedure

Every subject attended two sessions daily, each session scheduled for the same time every day for 38 days (Appendix A, Table A 1). The two sessions for each subject were separated by at least three hours, so that the effect of one session upon the other was minimal.

The order of presentation of the four studies was counter-balanced (Appendix A, Table A 2) in such a way that one half of the subjects began with Study 1 in the first session while the other half began with Study 2. On completion of their respective studies the subjects who had completed Study 1 began Study 2, and those subjects who completed Study 2 began Study 1. The same procedure was followed for the second session; that is, one half of the subjects started with Study 3, and one half started with Study 4.

On completion of their initial studies each subject then started the remaining study.

Apparatus

The apparatus consisted of a timer, a clock, a display board, earphones, and a response keyboard. A Hunter 111 B Timer (the standard timer) operated by the experimenter (E), activated the auditory and visual stimuli for the desired durations. A Venner TSA 3314 Millisecond Stopclock (the judgement clock), which recorded the duration of the subject's (S) response, was controlled by S through the response keys. The timer, clock, and recording materials were situated behind a plywood screen which separated the E from the subject.

The S was seated in front of the plywood screen on a comfortable chair. Immediately in front of him was a control panel with a 40 watt bulb, the visual stimulus. This bulb was shielded by a white frosted jewel covering to minimize the effect of the initial glare of the bulb. The auditory stimulus was generated from a tone generator (1,000 Hz) positioned on E's side of the plywood screen. This stimulus was delivered through earphones connected to the control panel. Mounted on a response keyboard immediately to the right of the control panel were two telegraph keys, one normally open and one normally closed. To initiate the response, S pressed and released the normally open telegraph key, and to terminate his response he pressed and released the normally closed response key. Both keys were mounted on a single board to facilitate the initiation and termination of the judgement with a

minimum of physical movement by S.

The temporal stimuli were presented by E through a push on switch. The modes of the stimulus and response, auditory or visual were controlled by a toggle switch on E's side of the plywood panel.

On the stimulus panel in front of S were two small pilot lights, a green one and a red one, which were controlled by E. In Study 2 the green light indicated to the S that the method of reproduction was to be used, while the red light signified that the method of verbal estimation was to be used. Appendix B, Figure 1 illustrates a schematic diagram of the apparatus, and Figure II in the same Appendix is a photograph of the S's side of the plywood screen.

Training Sessions

Three training sessions were given to each S using the methods of verbal estimation, operative estimation, and reproduction, with intervals chosen randomly from 1 to 60 seconds, using both auditory and visual stimuli.

When the subject had entered the testing room he was seated in front of the stimulus panel and the apparatus was explained to him

> "In front of you there is a stimulus board on which you see a light in the center. The light is both a stimulus light and a response light. This will be used to present the visual temporal stimulus and also to present your response. This is what it will look like. (demonstration) Also there is a set of earphones which will be used to convey to you both the stimulus and response sounds. You may put on the earphones and I will demonstrate the stimulus sound. If you find the sound the least bit uncomfortable please inform me. (demonstration) You will be informed of the mode of the stimulus and the method of response that corresponds with

> the study in question. To the right of the stimulus board you will notice two telegraph keys mounted on a single board. These keys will be used to initiate and terminate your response to the temporal stimulus. The telegraph key on the left, when pressed, will initiate the response. When this is done either the light or the sound, depending on the situation, will come on. When you feel that the light or sound has been on long enough to be equal to the stimulus duration you will press and release the key on the right of the keyboard. This will terminate the response and will provide a measure of the duration of your response. After pressing and releasing each key you should remove your finger from the key completely and let your hand rest comfortably on the table beside the keyboard. Are there any questions concerning the apparatus? You may try the keys."

At this point any questions regarding the apparatus were answered.

Instructions were then given concerning the methods used in the studies:

> "In the following studies you will be estimating intervals using three methods. These are the methods of verbal estimation, operative estimation, and reproduction. With the method of verbal estimation you will receive a temporal stimulus that will be either visual or auditory. While this interval is being presented you will attend to the light or sound. When the stimulus duration terminates you will attempt to estimate its duration verbally, i.e. 24 seconds. While you attend to the temporal stimulus you should not attempt to count in a manner that aids your estimation. Rather, you should base your estimation on the experience of the interval elapsed. If you find that you have counted in any way please inform me so that the data can be dealt with accordingly."

Then the method of verbal estimation was demonstrated and any questions concerning it were answered. Instructions were then given for the method of operative estimation.

> "With the method of operative estimation, an interval will be named verbally by me and you should attempt to operatively produce your estimate of the interval. You will do so by the use of the response keys. For example, if I ask you to produce an interval of ten seconds, you will press and release the key on the left of the keyboard. This will initiate either the light or the sound. When you feel that the light or the sound has been on for the length of time that the verbal label necessitates you should press and release the key on the right of the keyboard. This will terminate the light or the sound and will provide a measure of the duration of your response. As with the method of verbal estimation you should not attempt to count or use any means of measuring your response other than your own feelings of the duration as a whole."

The method of operative estimation was then demonstrated and any queries concerning it were dealt with. Instructions concerning the method of reproduction were then read to the S.

> "With the method of reproduction a stimulus light or sound will be presented to you for a certain duration. On completion of this stimulus interval you will attempt to reproduce it. To initiate your response you press and release the response key on the left of the keyboard. This will turn on the light or the sound. When you feel that the response interval has been on as long as the stimulus interval, you should press and release the response key on the right of the keyboard. This will terminate the light or the sound and will serve as a measure of the duration of your response. Once again you should not attempt to use any counting means of measuring either the stimulus or response interval. Rather you should experience the interval and base your response on this experience. If you find that you have counted in any way please inform me so that the data can be dealt with accordingly."

The method was demonstrated and questions concerning it were answered.

The training sessions were then initiated.

STUDY 1

Study 1 was designed to determine the effects of a background sound, delivered at the input and/or output stages of visual intervals, on time estimations using the methods of verbal estimation, operative estimation, and reproduction. The hypotheses are:

1 Using the method of verbal estimation, a background sound introduced at the standard stage of temporal processing will significantly increase the estimations of the duration of a visual stimulus over that of the no background sound condition.

2 Using the method of operative estimation, a background sound introduced at the judgement stage of temporal processing will significantly decrease the estimations of the duration of a visual stimulus over that of the no background sound condition.

3 Using the method of reproduction, a background sound introduced at the standard stage of temporal processing will significantly increase the estimations of the duration of a visual stimulus over that of the no background sound condition.

4 Using the method of reproduction, a background sound introduced at the judgement stage of temporal processing will significantly decrease the estimations of a visual stimulus over that of the no background condition.

Method

Each subject was presented with the light stimulus in four different durations, under four background sound conditions using the three methods of time estimation. The duration of the light stimuli were 3, 14, 38, and 47 seconds. The background conditions were: the visual standard with a background sound and the visual judgement with a background sound (BB); the visual standard with a background

sound and the visual judgement with no background sound (BN); the visual standard with no background sound and the visual judgement with a background sound (NB); and the visual standard with no background sound and the visual judgement with no background sound (NN).

Design

Each subject completed all four background conditions using one of the estimation methods before beginning the second. The order of presentation of the methods was counterbalanced over subjects. The counterbalanced order is listed in Appendix C, Table C1. The testing for each method was divided into thirty minute sessions.

Within every method, each of the four intervals was judged ten times under each experimental condition, resulting in a total of 160 trials for each method. Thirty second pauses were allowed between each trial to give the subject a chance to return to a baseline in functioning so that the ongoing response would not be affected by the previous response. The conditions were presented randomly across trials within each method.

Procedure

On entering the testing room the subject was seated in front of the control panel. The following instructions were read:

> "This study is concerned with the estimation of visual intervals in the presence of a background sound. You will be presented with visual intervals which you should attempt to estimate. In some cases there will be a background sound present either when the stimulus is presented or when you make your response. In other cases there will be no background sound present. You are to direct your concentration mainly on the visual stimulus. The stimuli used are the same as those used in the training sessions. In this study you will use the method indicated to you. Estimate the intervals as closely as you are able. Base your estimate on the time elapsed. Do not attempt to guess

> the interval or count in any way that aids your estimation. If you do happen to count in any observable way, please inform me so that the data can be dealt with accordingly. You will be given a rest period whenever you feel that your concentration is slipping. The first method used is the method of ' '. Are there any questions? We will have a five minute practice session and a short rest before beginning the actual study."

At this point practice trials were started. These consisted of visual temporal stimuli, having intervals chosen randomly from 1 to 60 seconds, presented under the method and background sound conditions to be used in the following session. After five minutes of practice, a five minute rest was given, following which the thirty minute experimental session was started.

The visual standards were presented and the subject's judgements were recorded on a score sheet.

Results

The judgements were averaged across all subjects for each background sound condition, method, and interval. Table 5 lists and Figure 2 illustrates these means. Examination of Figure 2 indicates that for the 14, 38, and 47 second intervals, verbal estimation judgements had the shortest duration, followed by reproduction judgements, with operative estimation judgements having the longest duration. For the 3 second interval the order was reversed with verbal estimation judgements the longest, followed by reproduction judgements, with operative estimation judgements having the shortest duration.

An analysis of variance (summarized on Table 6), based on the average judgement for each subject in every background sound

TABLE 5

The Mean Judgement In Each Interval For The Methods Of Verbal Estimation, Operative Estimation, And Reproduction, In The Four Conditions Of Background Sound

Methods	Intervals	Background Sound Conditions*			
		BB	BN	NB	NN
Verbal Estimation	3	3.76	3.57	3.02	3.27
	14	13.68	13.79	11.81	12.07
	38	32.90	34.13	29.01	28.76
	47	39.89	39.31	35.07	34.96
Operative Estimation	3	2.48	2.77	2.53	2.76
	14	17.70	19.43	17.41	20.48
	38	46.42	49.11	45.47	49.83
	47	57.63	61.81	56.17	63.29
Reproduction	3	2.70	3.20	2.91	3.05
	14	15.41	17.12	15.35	15.39
	38	36.92	42.46	37.03	38.01
	47	45.88	49.20	44.25	46.76

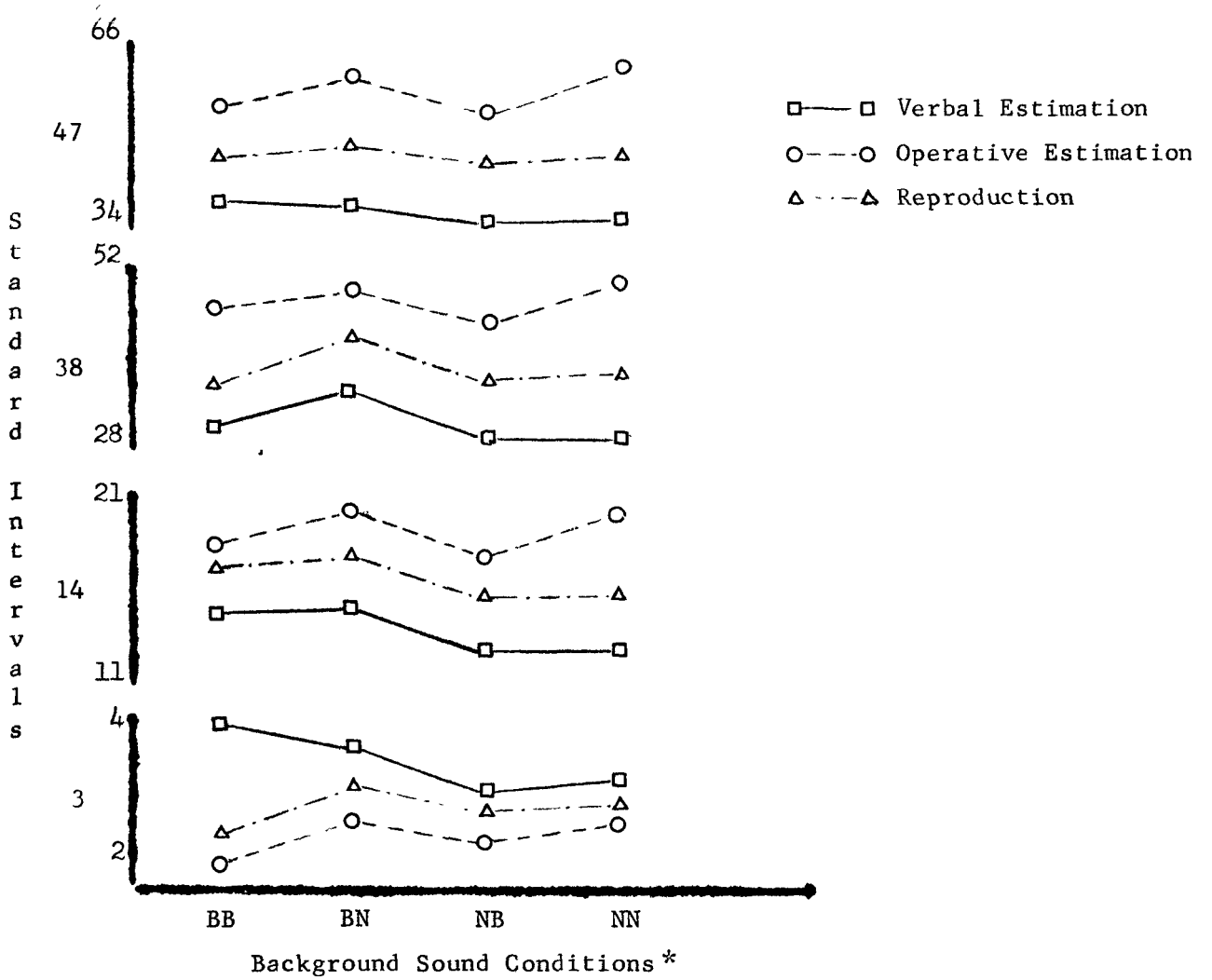


FIGURE 2 The Mean Judgement For Each Method, Interval, And Background Sound Condition.

* BB - Background Sound Standard-Background Sound Judgement
BN - Background Sound Standard-No Background Sound Judgement
NB - No Background Sound Standard-Background Sound Judgement
NN - No Background Sound Standard-No Background Sound Judgement

TABLE 6

The Summary Of The Analysis Of Variance For The Methods, Background Sound Conditions, And Intervals Data.

Verbal Estimation, Operative Estimation, Reproduction Methods; BB, BN, NB, And NN Background Sound Conditions*; 3, 14, 38, And 47 Second Intervals.

Source	d.f.	M.S.	F	P
Methods (M)	2	2929.97	10.78	$<.05$
Error	10	271.84		
Background Sound Conditions (B)	3	108.25	19.72	$<.05$
Error	15	5.49		
Intervals (I)	3	30794.04	1129.61	$<.05$
Error	15	27.61		
M x B	6	39.75	7.64	$<.05$
Error	30	5.20		
M x I	6	656.96	13.49	$<.05$
Error	30	48.67		
B x I	9	16.42	6.90	$<.05$
Error	45	2.38		
M x B x I	18	5.93	2.19	$<.05$
Error	90	2.71		

*BB - Background Sound Standard-Background Sound Judgement
BN - Background Sound Standard-No Background Sound Judgement
NB - No Background Sound Standard-Background Sound Judgement
NN - No Background Sound Standard-No Background Sound Judgement

condition, method, and interval (these means are illustrated in Appendix C. Tables C2, C3, C4) indicates that the judgements made using the three methods differ significantly. A Neuman-Keuls Test for means (Winer 1962) revealed that the above mentioned differences were significant at the 14, 38, and 47 second intervals, but not at the 3 second interval (see Table 7).

The summary of the analysis of variance also shows that the background sound conditions significantly affected the judgements of the standard intervals across both method and interval. These differences will be discussed under sections dealing with the three methods.

Verbal Estimation

Table 5 provides the means for each of the four background sound conditions and intervals across subjects using the method of verbal estimation. It can be seen that judgements with the background sound in the standard stage (BB and BN conditions) were estimated as longer than those made under conditions of no background sound in this stage (NB and NN conditions). When the background sound was held constant in the standard stage, and varied in the judgement stage (BB-BN and NB-NN comparisons) there was little difference between the judgements for all four intervals.

A Neuman-Keuls Test for means (Winer 1962), summarized on Table 8, revealed significant differences between the conditions with the background sound and those with no background sound in the standard stage for the 14, 38, and 47 second intervals. However for the 3 second interval no significant differences were obtained.

TABLE 7

Neuman-Keuls Test Of Means For The Methods Of Verbal Estimation, Operative Estimation, And Reproduction In The 3, 14, 38, And 47 Second Intervals.

3 Second Interval

	Operative Estimation	Reproduction	Verbal Estimation
	2.63	2.96	3.40
2.63		0.33	0.77
2.96			0.44

14 Second Interval

	Verbal Estimation	Reproduction	Operative Estimation
	12.84	15.82	18.76
12.84		2.98*	5.92*
15.82			2.94*

38 Second Interval

	Verbal Estimation	Reproduction	Operative Estimation
	31.20	38.61	47.71
31.20		7.41*	16.51*
38.61			9.10*

47 Second Interval

	Verbal Estimation	Reproduction	Operative Estimation
	37.31	46.52	59.72
37.31		9.21*	22.41*
46.52			13.20*

* $p < .05$

TABLE 8

Neuman-Keuls Test Of Means For The Method Of Verbal Estimation Judgements In The 3, 14, 38, And 47 Second Intervals For The BB, BN, NB, And NN Background Sound Conditions.*

3 Second Interval

	NB	NN	BN	BB
	3.02	3.27	3.57	3.76
3.02		0.25	0.55	0.74
3.27			0.30	0.49
3.57				0.19

14 Second Interval

	NB	NN	BB	BN
	11.81	12.07	13.68	13.79
11.81		0.26	1.87**	1.98**
12.07			1.61**	1.72**
13.68				0.11

38 Second Interval

	NN	NB	BB	BN
	28.75	29.00	32.90	34.13
28.75		0.25	4.15**	5.38**
29.00			3.90**	5.13**
32.90				1.23**

47 Second Interval

	NN	NB	BN	BB
	34.97	35.07	39.31	39.89
34.97		0.10	4.34**	4.92**
35.07			4.24**	4.82**
39.31				.0.58

* BB - Background Sound Standard-Background Sound Judgement
BN - Background Sound Standard-No Background Sound Judgement
NB - No Background Sound Standard-Background Sound Judgement
NN - No Background Sound Standard-No Background Sound Judgement

** $p < .05$

The test also revealed that there were no significant differences between judgements that had the background sound held constant in the standard stage of the comparisons and varied in the judgement stage. The one exception to this was the BB-BN comparison in the 38 second interval, with the BN condition judgements found to be significantly longer than the BB condition judgements.

The above results suggest that a background sound affects the verbal estimation of a visual interval by increasing the estimate. This effect is relevant only if the background sound is applied during the standard stage of temporal processing.

Operative Estimation

Table 5 lists the mean estimates for the four background sound conditions in each interval across all subjects for the method of operative estimation. This table reveals that judgements made when the background sound was present in the judgement stage (BB and NB) were shorter in duration than those made under conditions of no background sound in this stage (BN and NN). Also, when the background sound was held constant in the judgement stage and varied in the standard stages (BB-NB and BN-NN comparisons) there was very little difference between the mean judgements.

A Neuman-Keuls Test for means (Winer 1962) summarized in Table 9 indicated significant differences between comparisons that had the background sound and those with no background sound in the judgement stage for the 14, 38, and 47 second intervals in the above mentioned manner. For the 3 second interval there was no significant difference between the means of the background sound conditions

TABLE 9

Neuman-Keuls Test Of Means For The Method Of Operative Estimation Judgements In The 3, 14, 38, And 47 Second Intervals, And The BB, BN, NB, And NN Background Sound Conditions*.

3 Second Interval

	BB	NB	NN	BN
	2.48	2.53	2.76	2.77
2.48		0.05	0.28	0.29
2.53			0.23	0.24
2.76				0.01

14 Second Interval

	NB	BB	BN	NN
	17.41	17.70	19.43	20.48
17.41		0.29	2.02**	3.09**
17.70			1.73**	2.78**
19.43				1.05**

38 Second Interval

	NB	BB	BN	NN
	45.47	46.43	49.11	49.83
45.47		0.96**	3.64**	4.36**
46.43			2.68**	3.40**
49.11				0.72

47 Second Interval

	NB	BB	BN	NN
	56.17	57.63	61.81	63.29
56.17		1.46**	5.64**	7.12**
57.63			4.18**	5.66**
61.81				1.48**

* BB - Background Sound Standard-Background Sound Judgement
BN - Background Sound Standard-No Background Sound Judgement
NB - No Background Sound Standard-Background Sound Judgement
NN - No Background Sound Standard-No Background Sound Judgement

** $p < .05$

although, the direction of the differences was similar to that in the three longer intervals.

In the majority of the comparisons where the background sound was held constant in the judgement stage and varied in the standard stage there were no consistent significant differences in the mean judgements. Although in three cases there were significant differences (NN>BN comparison, 14 second interval; NB<BB and NN>BN comparisons, 47 second interval; BB>NB comparison, 38 second interval) there was no consistent direction in terms of effect.

The above results suggest that a background sound affects the operative estimation of a visual stimulus in a manner that decreases the duration. This effect is relevant only during the judgement stage of temporal processing for the 14, 38, and 47 second intervals.

Reproduction

For the method of reproduction, reference to Table 5 (means for the four background sound conditions in each interval across all subjects) indicates that judgements made under the BN condition were longer in duration than those under the BB, NN, and NB conditions. Also judgements made under the NB condition were reproduced as shorter than the NN condition judgements.

A Neuman-Keuls Test for means (Winer 1962) shown on Table 10 indicates no consistency in the comparisons. Two of the comparison pairs studied the effect of the background sound in the judgement stage (BB-BN; NB-NN). In the BB-BN comparison, the BB condition judgements

TABLE 10

Neuman-Keuls Test Of Means For The Method Of Reproduction Judgements In The 3, 14, 38, And 47 Second Intervals, And The BB, BN, NB, And NN Background Sound Conditions*.

3 Second Interval

	BB	NB	NN	BN
	2.70	2.91	3.05	3.20
2.70		0.21	0.35	0.50
2.91			0.14	0.29
3.05				0.15

14 Second Interval

	BB	NN	NB	BN
	15.35	15.39	15.41	17.12
15.35		0.04	0.06	1.77**
15.39			0.02	1.73**
15.41				1.71**

38 Second Interval

	BB	NB	NN	BN
	36.92	37.03	38.01	42.46
36.92		0.11	1.09**	5.54**
37.03			0.98**	5.43**
38.01				4.45**

47 Second Interval

	NB	BB	NN	BN
	44.25	45.88	46.76	49.20
44.25		1.63**	2.51**	4.95**
45.88			0.88**	3.32**
46.76				2.44**

* BB- Background Sound Standard-Background Sound Judgement
BN- Background Sound Standard-No Background Sound Judgement
NB- No Background Sound Standard-Background Sound Judgement
NN- No Background Sound Standard-No Background Sound Judgement

** $p < .05$

were significantly shorter than the BN judgements for the 14, 38, and 47 second intervals. There was no significant difference between judgements under these two conditions for the 3 second interval. In the NB-NN comparison, the NB condition judgements were significantly shorter than those in the NN condition for the 38 and 47 second intervals, while no significant difference was found between judgements made under these conditions for the 3 and 14 second intervals.

Two more comparisons studied the effect of the background sound on judgements of visual intervals during the standard stage of temporal processing (BB-NB; BN-NN). In the BB-NB comparison, judgements were significantly shorter for the NB condition than those under the BB condition for the 47 second interval only. Although not significant for the 3, 14, and 38 second intervals, the direction of the difference between the judgement conditions was similar to that of the 47 second interval. In the BN-NN comparison, the NN condition judgements were significantly shorter than those under the BN condition for the 14, 38, and 47 second intervals, while for the 3 second interval there were no significant differences.

Further comparisons investigated the effect of changing the background sound in both the standard and judgement stages (BN-NB). Table 10 indicates that judgements made under the BN condition were significantly longer than those under the NB condition for the 14, 38, and 47 second intervals, while for the 3 second interval there were once again no differences.

In the final comparison condition, BB-NN, there was no interaction of the background sound in either the standard or judgement stages. In this case there was no significant difference between the judgements made under these conditions for the 3 and 14 second intervals, however, for the 38 and 47 second intervals the NN condition judgements were significantly longer than the BB condition judgements.

Summary

Judgements of a visual interval made using the method of verbal estimation were significantly shorter with a background sound at the standard stage for the 14, 38, and 47 second intervals than with no background sound.

With the method of operative estimation judgements of visual intervals were significantly shorter with a background sound in the judgement stage than those made without the background sound present. This occurred in the 14, 38, and 47 second intervals.

Visual temporal judgements made using the method of reproduction were significantly affected by a background sound in both the standard and judgement stages for the 14, 38, and 47 second intervals, such that reproductions made in the presence of a background sound in the judgement stage were shorter than those made with the background sound absent in that stage, and reproductions made with the background sound present in the standard stage were longer than those without the background sound at that point. The significance of the differences however, were not as consistent as expected and are considered further in the Discussion.

Discussion

The results of Study 1 will be discussed in separate sections corresponding to the effect of the background sound on judgements made under the three methods. However, attention will first be given to the overall differences found in the judgements. Studies concerned with time estimations made under the three methods found that operative estimation judgements were shorter than verbal estimation judgements, and those made under the method of reproduction fell in between (Clausen 1950; Seigman 1962). However, the judgements resulting from this study were opposite in direction for the 14, 38, and 47 second intervals; with the mean judgements being longer under the method of operative estimation, with the method of reproduction being next longest, followed by the method of verbal estimation judgements which were the shortest in duration. But the mean judgements were in the opposite direction for the 3 second interval with the method of operative estimation judgements being the shortest, followed by reproduction judgements, and then verbal estimation judgements which were the longest. However, for this interval the differences were not significant.

Although illustrating differences between overall judgements made under the three methods was not the purpose of this study, the reversal found in the order of the magnitude of the judgements, and its opposition to previously reported results merits further research.

Verbal Estimation

The explanation of temporal processing in terms of Cohen's

model of the 'internal clock' for the method of verbal estimation suggests that the effect of background sound, used as a calibrating monitor, is significant only in the standard stage (input) of the temporal process. The results of this study consistently pointed this out for the 14, 38 and 47 second intervals.

In terms of the 'clock' concept, this would mean that when a background sound is presented with a visual temporal stimulus in the standard stage, the pacemaker pulsates at a faster rate, thus increasing the number of countable events that serve as the basis of the verbal response. This in turn makes the verbal estimates in this condition larger than estimates of intervals presented visually without the background sound. In this latter case, the pacemaker would pulsate at a slower rate, thus producing fewer countable events on which the verbal estimate would be based.

A further factor pointed out by the results is that the presence or absence of background sound in the judgement stage of temporal processing has no effect on the judgement made, in this case a verbal estimation. This would suggest that temporal processing by the model of the 'internal clock' is a viable way of accounting for man's time estimation ability, as the model explanation of temporal processing suggests that once the temporal information is in verbal form the calibrating monitors have no effect. In the one case where there was a significant effect of the background sound in the judgement stage, the difference between the comparison conditions although significant, was much smaller than the other significant comparisons differences.

Operative Estimation

The explanation of temporal processing for the method of operative estimation provided by Cohen's model of the 'internal clock' suggests that the effect of the background sound on the estimations made using this method is significant only in the judgement stage. The results of this study consistently point out that the effect of the background sound calibrating monitor on operative estimations of a visual interval is significant in the judgement stage of temporal processing in a manner that causes the judgement to be shorter than one without the background sound present in this stage for the 14, 38 and 47 second intervals. In terms of the 'internal clock' this would mean that the pacemaker would pulsate faster when the background sound was present, thus causing the number of required events that demark the interval to be produced faster. This results in a shortening of the production of the interval.

If the background sound is absent in the judgement stage and the subject has to operatively estimate the verbal standard visually, the pacemaker pulsates at a slower rate. Since the number of countable events that make up the verbal information is constant, then the production of these would take longer, thus increasing the length of the judgement when compared to one made with the background sound present.

Further indication that the 'clock' may provide an explanation of the effects of a background sound on operative estimations is

indicated in the lack of consistent effect of this calibrating monitor in the standard stage of temporal processing. The 'internal clock' explanation of temporal processing suggests that a calibrating monitor would have no effect when the temporal information is in verbal form, in this case, the standard stage. Of the four cases where the judgements were affected significantly in the standard stage, there was no consistent direction in terms of the effect of the background sound. The lack of consistent direction in these four cases and the lack of significance in the other comparison conditions that studied the effect of the background sound in the standard stage suggests that the differences found were a result of random fluctuations caused by factors other than the background sound calibrating monitor.

The explanation of the effect of a background sound on the operative estimation of visual intervals illustrates that the 'internal clock' hypothesis provides a reasonable manner of relating the effects of a background sound on the operative estimation of visual intervals. The lack of significance of the sound conditions on the judgements in the three second interval could possibly be a result of the short length of this standard. The subject's perception of this short standard could approximate the accurate length without regard to the background conditions.

Reproduction

For the method of reproduction, Cohen's model of the 'internal clock' suggests that the effect of a background sound is significant in both the standard and judgement stages of the temporal process.

The results in fact indicate this but the lack of consistent significance necessitates an explanation of each comparison in terms of the 'internal clock'.

With the background sound held constant in the standard stage of temporal processing, and varied in the judgement stage, the 'clock' explanation would suggest that the condition with the background sound in the judgement stage would be reproduced as *shorter than the condition without the background sound in this* stage. In one of the comparisons the direction of the differences (BB<BN) was significant and followed the 'clock' explanation for the 14, 38 and 47 second intervals. However, in the other comparison condition the differences were significant in the expected direction (NN>NB) for the 38 and 47 and not for the 3 and 14 second intervals. The lack of significance of the 3 second intervals in both comparison conditions could perhaps suggest that this interval was of short enough duration that the subjects could reproduce it accurately regardless of the background conditions.

In the condition where the background sound was held constant in the judgement stage and varied in the standard stage of temporal processing, the 'internal clock' explanation of the effect suggests that the condition with the background sound in the standard stage would be reproduced as longer than the condition without the background sound in this stage. This would be so as the number of pulses produced by the pacemaker in the standard stage would be maximized in the first condition and minimized in the second. In

both comparisons that fell under this condition, (NB-BB; BN-NN), the results were not consistent. In the NB-BB comparison, the difference (NB<BB) between these conditions was significant only in the 47 second interval. In the other comparison condition BN-NN the judgements made under these conditions were in the expected direction (BN>NN) and significant for the 14, 38, and 47 second intervals. Although the results suggest that the background sound is a significant factor in the standard stage of the method of reproduction, the lack of consistency must be examined further.

When the background sound varies in both the standard and the judgement stages (BN-NB) the 'internal clock' explanation of the effect would suggest that the condition that has the number of pulses produced in the standard stage maximized and reproduced in the judgement stage at the slowest rate (BN) would have a longer duration than the condition that has the number of pulses in the standard stage minimized and produced at a faster rate in the judgement stage (NB). The results in fact were consistent with this reasoning as the BN condition judgements were reproduced as significantly longer than the NB condition judgements for the 14, 38, and 47 second intervals. For the 3 second interval the difference between the two judgement conditions was in the expected direction, but fell short of significance.

In the final condition there was no interaction of background sound in either the standard or judgement stages (BB-NN). Here the 'internal clock' explanation suggests that there would be no difference in the judgements made under these two conditions. This is

in fact what the results indicated for the 3 and 14 second intervals; however, for the 38 and 47 second intervals there were significant differences with the NN condition being judged longer than the BB condition.

The lack of consistency for the reproduction comparison conditions could be explained through the fact that judgements made under this method allowed the subjects more variability in their responses as both the standard and judgement stages were in operative terms. In discussing the tasks on completion of the research, the subjects mentioned that the method of reproduction was the most difficult to use. Also the lack of significance of the comparisons in the 3 second interval could be explained through the fact that the interval was too short to illustrate the effects of the background conditions as the subjects could approximate the standard without regard to these conditions. However, the results strongly suggest that the 'internal clock' hypothesis is able to explain the effect of a background sound condition in standard and judgement stages of a visual interval under the method of reproduction.

In summary. The 'internal clock' explanation of temporal processing may provide a plausible explanation of the different effects of a background sound on visual judgements made under the methods of verbal estimation, operative estimation, and reproduction.

STUDY 2

Study 2 investigated the effect of knowledge as opposed to lack of knowledge of the method of response during the input stage of temporal information on the accuracy of time estimation ability. An attempt is made to delineate the role of the 'internal clock' in the channelling of the temporal information in a manner that corresponds with temporal judgements made under the methods of verbal estimation and reproduction. The hypothesis is:

> The accuracy of time estimation will be significantly greater when the method of response is known before the presentation of the standard than if the method of response is not known until after the standard presentation.

Method

The stimulus material consisted of auditory and visual temporal stimuli, with durations of 7, 19, 28, and 42 seconds.

A small green light mounted on the stimulus control panel indicated that the method of response was to be that of reproduction, and a red pilot light mounted on the control panel indicated that the method of response was verbal estimation.

The stimulus material was presented in two conditions. In one condition (KS) the subject was informed before the presentation of the standard, through the illumination of one of the pilot lights, which method of response was to be used. In the other condition (NKS) the standard was presented to the subject and immediately on

completion of the standard interval, one of the pilot lights was lit in order to give the subject knowledge of the method of response.

Design

The study was divided into blocks in terms of the mode used, i.e., auditory and visual. Each subject completed one modal block before he continued on to the next. The order of presentation was counterbalanced. Table 11 illustrates the four experimental conditions within each block.

Within the blocks each of the four intervals was judged in the four conditions, with 16 combinations in each block. Each condition was presented for ten trials, resulting in 160 trials for each block. Within each block the conditions were presented randomly across trials. Between each trial there was a 30 second pause to allow the subject to return to baseline functioning so that the ongoing response would not be influenced by the previous one.

Procedure

The subject entered the testing room and was seated on a chair in front of the control panel. Instructions were given:

> "In this study you will be presented with temporal stimuli. In some cases you will not know the method of response until after the standard has been presented. In front of you on the control panel there are two small lights, one green and one red. When the greenlight is on the method of response will be reproduction, and when the red light is on the method of response will be verbal estimation. In one condition these lights will come on after the presentation of the standard, while in the other condition the lights will come on before the standard is presented. This study will consist of two blocks. Auditory temporal stimuli will make up one block and visual temporal stimuli will make up the other block. You will be given one complete block before continuing onto the next block. In this study you are reminded to base your estimation on the time elapsed.

TABLE 11

Experimental Conditions Within The Visual And Auditory Blocks For Study 2.

Mode	Standard		Judgement
Visual	(Response Method Given Here)	Visual	Reproduction
		Visual	Verbal Estimation
		Visual (Response	Reproduction
		Visual Method Given Here)	Verbal Estimation
Auditory	(Response Method Given Here)	Auditory	Reproduction
		Auditory	Verbal Estimation
		Auditory (Response	Reproduction
		Auditory Method Given Here)	Verbal Estimation

> You should not attempt to guess the interval or the method concerned with the judgement. Are there any questions? Practice trials will begin now after which there will be a short rest. I will notify you when the study is to begin."

Five minute practice trials were started, which consisted of intervals chosen randomly from 1 to 60 seconds presented in the mode and conditions to be used in the following session. A five minute rest was given, and the thirty minute experimental session was begun. The standard intervals were presented and the subject's judgements recorded on a prepared score sheet. The number of sessions for each subject totalled 14.

Results

Table 12 shows the mean judgements made under each method for the two modalities in each interval and instruction condition. It is interesting to note that the difference between the judgements made using the two methods was in the same direction as that found in Study 1, that is, verbal estimation judgements were shorter than those under the reproduction method. Further it can be seen that judgements made under the auditory mode differ little from those under the visual mode. An analysis of variance was performed on the average of each subject's judgements of the standard durations for both modes and methods in each instruction condition. These means are listed on Tables D1 and D2 of Appendix D. A summary of the analysis of variance, presented in Table 13, indicates that the above difference between verbal estimation and reproduction judgements was significant, and that the small difference between the auditory and visual judgements was not.

TABLE 12

The Mean Judgement For Each Interval, Method, Mode, In The Knowledge (KS) And The Lack Of Knowledge (NKS) Of The Method Of Response Instruction Conditions.

Mode	Method	Instruction Conditions	Intervals			
			7	19	28	42
Auditory	Verbal Estimation	KS	5.98	16.98	24.18	36.85
		NKS	5.32	16.06	20.63	32.61
	Reproduction	KS	6.79	19.27	28.77	43.44
		NKS	6.11	18.30	27.13	39.76
Visual	Verbal Estimation	KS	6.10	17.35	25.38	37.94
		NKS	6.09	15.66	22.20	33.67
	Reproduction	KS	7.40	19.40	28.65	42.05
		NKS	6.78	18.88	27.56	42.29

TABLE 13

Summary Of The Analysis Of Variance Of Modal, Methods, Instructions, And Intervals Data For Study 2.

Auditory And Visual Modes; Verbal Estimation And Reproduction Methods; Knowledge And Lack Of Knowledge Of The Method Of Response Instruction Conditions; 7, 19, 28, And 42 Second Intervals.

Source	d.f.	M.S.	F	P
Mode (M)	1	16.02	1.02	NS
Error	5	15.69		
Method (Me)	1	665.10	9.36	$<.05$
Error	5	71.03		
Instructions (I)	1	139.45	53.70	$<.05$
Error	5	2.60		
Intervals (In)	3	8821.39	956.66	$<.05$
Error	15	9.22		
M x Me	1	1.01	0.06	NS
Error	5	17.48		
M x I	1	5.44	12.68	$<.05$
Error	5	0.43		
M x In	3	1.07	0.25	NS
Error	15	4.25		
Me x I	1	16.40	6.38	$<.05$
Error	5	2.57		
Me x In	3	77.90	8.00	$<.05$
Error	15	9.73		
I x In	3	16.54	5.78	$<.05$
Error	15	2.86		
M x Me x I	1	3.87	2.57	NS
Error	5	1.51		
M x Me x In	3	1.60	0.31	NS
Error	15	5.10		
M x I x In	3	2.40	2.53	NS
Error	15	0.95		
Me x I x In	3	5.48	1.69	NS
Error	15	3.23		
M x Me x I x In	3	3.14	1.83	NS
Error	15	1.71		

Table 13 further indicates that judgements made under the instruction conditions, KS and NKS, differed significantly, such that means of judgements under the KS condition were shorter than those of the NKS condition (Table 12). This difference is broken down across method, mode, and interval in the following sections and warrants further study.

Table 14, which shows the means for the verbal estimation judgements in the auditory mode for the two instruction conditions and four intervals, indicates that the mean judgements under the NKS condition were shorter than those made under the KS condition. A t Test (Winer 1962), illustrated on the same table, indicated that these differences were not significant for any interval.

The accuracy, that is, the difference between the standard and the judgement, of the estimations made under the two instruction conditions was also evaluated. Table 15 shows the mean accuracy scores for the judgements made under the verbal estimation method in the auditory mode for each instruction condition and interval. This table indicates that NKS condition judgements were less accurate than KS condition judgements. A t Test, reported on the same table, points out that these differences were not significant.

Reference to Table 16, which lists the mean verbal estimation judgements in the visual mode for the two instruction conditions and four intervals indicates that estimations made under the NKS instruction condition were shorter than those under the KS condition. A t Test (Winer 1962) shows that these differences were significant only in the 42 second interval.

TABLE 14

The Mean Verbal Estimation Judgements In The Auditory Mode For The Knowledge (KS) And Lack Of Knowledge (NKS) Of The Method Of Response Instruction Conditions In Each Interval; And The t Values Testing The Difference Between The Means.

Intervals	Instruction Conditions		t Values	P
	KS	NKS		
7	5.98	5.31	1.31	NS
19	16.98	16.06	0.44	NS
28	24.18	20.63	1.78	NS
42	36.85	32.61	1.77	NS

TABLE 15

The Mean Accuracy Scores For The Verbal Estimation Judgements In The Auditory Mode For The Knowledge (KS) And Lack Of Knowledge (NKS) Instruction Conditions In Each Interval; And The t Values Testing The Difference Between The Means.

Intervals	Instruction Conditions		t Values	P
	KS	NKS		
7	1.02	1.68	1.33	NS
19	2.02	2.94	1.64	NS
28	3.82	7.37	1.78	NS
42	5.15	9.39	1.61	NS

TABLE 16

The Mean Verbal Estimation Judgements In The Visual Mode For The Knowledge (KS) And Lack Of Knowledge (NKS) Of The Method Of Response Instruction Conditions In Each Interval; And The t Values Testing The Difference Between The Means.

Intervals	Instruction Conditions		t Values	P
	KS	NKS		
7	6.10	6.09	0.01	NS
19	17.35	15.66	0.96	NS
28	25.38	22.20	1.77	NS
42	37.94	33.67	2.19	$<.05$

The analysis of the accuracy of the judgements in each instruction condition and interval for the method of verbal estimation in the visual mode, as recorded in Table 17, indicates that the accuracy of judgements in the NKS condition was less than that of the KS condition judgements for all four intervals. The t values however indicated that these differences were not significant for any interval.

Table 18, which illustrates the means of the reproduction method judgements in the auditory mode for each interval suggests that the mean judgements under the NKS instruction condition were shorter than those under the KS condition. A t Test however indicated that this difference was significant only in the 42 second interval.

The evaluation of the accuracy of the judgements in each instruction condition for the method of reproduction in the auditory mode, as reported in Table 19, shows that the accuracy of the NKS condition judgements was less than those under the KS instruction condition. A t Test however indicated that these differences in accuracy were not significant for any interval.

Finally, reference to Table 20, which illustrates the means of the reproduction method judgements in the visual mode for the four intervals indicates that the NKS condition judgements were shorter in duration than those under the KS condition. These differences were not significant for any interval.

The evaluation of the accuracy of the judgements in each instruction condition for the reproduction method in the visual

TABLE 17

The Mean Accuracy Scores For The Verbal Estimation Judgements In The Visual Mode For The Knowledge (KS) And Lack Of Knowledge (NKS) Of The Method Of Response Instruction Conditions In Each Interval; And The t Values Testing The Difference Between The Means.

Intervals	Instruction Conditions		t Values	P
	KS	NKS		
7	0.90	0.91	0.16	NS
19	1.65	3.34	1.51	NS
28	2.62	5.80	1.59	NS
42	4.06	8.33	1.67	NS

TABLE 18

The Mean Reproduction Method Judgements In The Auditory Mode For The Knowledge (KS) And Lack Of Knowledge (NKS) Of The Method Of Response Instruction Conditions In Each Interval; And The t Values Testing The Difference Between The Means.

Intervals	Instruction Conditions		t Values	P
	KS	NKS		
7	6.79	6.11	1.65	NS
19	19.27	18.30	1.16	NS
28	28.77	27.13	1.05	NS
42	43.44	39.76	2.99	$<.05$

TABLE 19

The Mean Accuracy Scores For The Reproduction Judgements In The Auditory Mode For The Knowledge (KS) And Lack Of Knowledge (NKS) Of The Method Of Response Instruction Conditions In Each Interval; And The t Values Testing The Difference Between The Means.

Intervals	Instruction Conditions		t Values	P
	KS	NKS		
7	0.54	0.88	0.99	NS
19	1.09	1.44	0.59	NS
28	1.10	2.43	1.64	NS
42	1.94	2.94	1.38	NS

Table 20

The Mean Reproduction Method Judgements In The Visual Mode For The Knowledge (KS) And Lack Of Knowledge (NKS) Of The Method Of Response Instruction Conditions In Each Interval; And The t Values Testing The Difference Between The Means.

Intervals	Instruction Conditions		t Values	P
	KS	NKS		
7	7.40	6.78	1.28	NS
19	19.40	18.88	0.26	NS
28	28.65	27.56	0.24	NS
42	42.05	42.29	0.05	NS

mode (Table 21) illustrates that the accuracy of the NKS condition judgements was less than that of the KS condition judgements. The t values concerning these differences indicated that they were significant for only the 19 and 42 second intervals.

Although judgements of intervals made using the method of verbal estimation and reproduction were consistently shorter and less accurate under the NKS condition than in the KS instruction condition the majority of the differences were not significant. However due to the consistent directional difference a Sign Test (Siegal 1956) was carried out to further evaluate the judgement and accuracy differences between the two instruction conditions in each method.

A comparison of the judgements made under the method of verbal estimation in each instruction condition, based on the average of each subject's estimations in each instruction condition and interval (listed in Appendix D, Tables D1 and D2), indicated that judgements made in the NKS instruction condition were shorter in duration than those of the KS condition in 42 out of 48 comparisons. Also the comparison of the corresponding method of reproduction judgement means (also listed in Appendix D, Tables D1 and D2) pointed out that reproductions made in the NKS instruction condition were shorter than those in the KS condition in 35 out of 48 cases. The sign tests (listed in Appendix D, Table D5) based on the direction of the difference were significant for both methods at the .05 level of confidence, or in other words, judgements made under the NKS instruction condition were shorter than those in the KS condition

TABLE 21

The Mean Accuracy Scores For The reproduction Method Judgements In The Visual Mode For The Knowledge (KS) And Lack Of Knowledge (NKS) Of The Method Of Response Instruction Conditions In Each Interval; And The t Values Testing The Difference Between The Means.

Intervals	Instruction Conditions		t Values	P
	KS	NKS		
7	0.65	0.76	0.34	NS
19	1.48	3.76	2.32	.05
28	1.88	2.64	0.76	NS
42	1.72	4.83	2.76	.05

significantly frequently.

The comparison of the accuracy scores (Appendix D, Tables D3 and D4) indicated that those scores under the method of verbal estimation in the NKS instruction condition were larger than those of the KS condition in 45 out of 47 comparisons, with one case being tied. Under the method of reproduction the accuracy scores in the NKS condition were larger than those in the KS condition in 37 out of 48 comparisons. In both the above comparisons the sign test illustrated in Appendix D, Table D6, based on the direction of the differences was significant, with judgements made under the NKS instruction condition being less accurate than under the KS condition of the .05 level of confidence.

Discussion

The results have suggested that lack of knowledge of the method of response during the standard stage for both the methods of verbal estimation and reproduction results in a decline in the accuracy of the judgements such that estimations made under this condition were shorter than those made under the knowledge of the method of response condition. Although the differences in the judgements made under the two conditions were not at the level required for significance, the consistent direction of the difference and its significance based on the aposterior analysis would lend credence to the validity of the above differences. A possible reason for the lack of consistent significant difference could be the small number of subjects used in this study, which would inflate the degree of difference necessary for significance.

In terms of the 'internal clock' the results would suggest that the channelling process that concerns the processing of temporal information in a manner that corresponds with each method may not be under the control of the 'clock'. If it was a function of the clock, then the decision would take place at the point within the clock system where the difference occurs, that is, at the storage system. This suggests that if the direction was given at this point, after the standard had been presented, there would be no undue effect on the judgements made. Since there seemed to be an interuption in the temporal information processing when the instructions were given at this point, the suggestion would be that the channelling process is a function of factors outside of the clock.

It may be that this decision process takes place before the intake of temporal information. That is, if the 'clock system' is directed to process the information in a manner consistent with either the methods of verbal estimation or reproduction, it would process the information for both methods in the same way during the standard stage, and would, without hesitation store and direct the information in a manner consistent with the method of response. However, if knowledge concerning the method of response was not given until after the standard had been presented, the information would be processed in the same way for both methods in the standard, but in the judgement stage there would be a short period of confusion as the 'system' would concentrate on the method to use and not on the processing. The result of the confusion

would be a loss of some of the temporal information while the 'internal clock' was receiving direction from an outside source. This may explain the consistent judgements of shorter duration and greater inaccuracy in the condition where the method of response was not known until after the standard had been presented. This would also suggest that the 'internal clock' is rather mechanical in function and processes temporal information as it is directed by cognitive factors outside of the 'clock's' jurisdiction.

In summary, however, the failure to obtain consistent significance in the initial analysis and the significance of the aposteriori sign test would suggest that further research be carried out to examine the effect of instructions concerning the method of response on estimations of intervals.

STUDY 3

Study 3 was concerned with an investigation of whether the auditory-visual difference in time estimation ability is consistent throughout the input and output processing stages of temporal information by the 'internal clock'. The hypothesis is:

> The modal difference between auditory and visual temporal perception is consistent at all stages of temporal processing under the method of reproduction.

Method

The stimuli consisted of auditorially and visually presented intervals of 9, 17, 35, and 44 seconds. These were presented in four experimental conditions under the method of reproduction. The four conditions were: visual standard with visual reproduction (VSVR), visual standard with auditory reproduction (VSAR), auditory standard with visual reproduction (ASVR), and auditory standard with auditory reproduction (ASAR). Table 22 lists the four conditions.

Design

Subjects were required to reproduce the four intervals in the four experimental conditions. The four intervals were presented ten times in every condition, thus making a total of 160 trials for each subject. The order of these conditions was random over trials. The randomization was done before the sessions in order to insure a consistent presentation of the stimuli. Between each trial there was a 30 second pause. This allowed the subject to return to a baseline in functioning so that the ongoing response

TABLE 22

Experimental Conditions For The Standard And Judgement Stages Of The Method Of Reproduction In Study 3.

	Standard	Judgement
Experimental Conditions	Visual	Visual
	Visual	Auditory
	Auditory	Visual
	Auditory	Auditory

would not be influenced by the former one. There were eight sessions in this study.

Procedure

The subject entered the testing room and was seated in front of the control panel. Instructions were given:

> "This study is concerned with cross-modal estimation of time intervals. You will be presented with temporal intervals in one mode, which will be either auditory or visual, and will have to respond in either the auditory or visual modes. There will be trials in which the response is in the same mode as the standard and there will be trials in which the response will be in a different mode. The mode of the standard and the judgement will be controlled by myself and will be determined from the control side of the apparatus. Your reproduction of the intervals is controlled by the response keys with which you are already acquainted. Do not in any way attempt to anticipate the mode of response but rather experience the stimulus interval and reproduce it as accurately as possible. If you feel that your concentration is slipping or that you are getting tired, notify me and we will take a short break. Are there any questions? You will receive a five minute practice session in order to familiarize you with the procedure. I will notify you when the experimental trials are to begin."

After the five minute practice session the subject was given a five minute break and the thirty minute session then began. The standard intervals were presented and the subjects' judgements were recorded.

Results

The means of the subjects' reproductions for each modal condition and interval (Table 23) indicate that the auditory standard-visual response (ASVR) condition judgements were the longest in duration, the visual standard-auditory response (VSAR) judgements the shortest, and the visual standard-visual response (VSVR) and auditory standard-auditory (ASAR) response condition judgements

TABLE 23

The Mean Judgement For Each Modal Condition And Interval In Study 3.

Modal Conditions		Intervals			
Standard	Judgement	9	17	35	44
Visual	Visual	9.54	17.72	34.87	44.17
Visual	Auditory	8.63	16.72	34.84	42.42
Auditory	Visual	10.48	18.47	38.88	46.08
Auditory	Auditory	9.09	16.93	35.26	43.18

were estimated as in between the longest and shortest mean judgements with little difference between them.

An analysis of variance was performed on the average of each subject's judgements in every interval and modal condition. These averages are listed in Appendix E, Table E1. A summary of the analysis of variance, presented in Table 24, indicates that judgements made under the above modal conditions differed significantly.

A Neuman-Keuls test (Winer 1962) applied to evaluate the differences between the mean judgements in each modal condition and interval, summarized in Table 25, pointed out that judgements made under the ASVR condition were significantly longer than those judgements made under the other three modal conditions for the 35 and 44 second intervals. All the other differences were not significant.

This analysis also provides the basis of the comparisons listed on Table 4 (page 32). The first comparison studied the cross-modal difference during the input stage of temporal processing. In this case the standard stage conditions were cross-modal while the judgement stage conditions were modally constant. Two comparisons were involved. In one, the VSAR condition judgements were compared with the ASAR condition judgements. In this case the VSAR condition judgements were shorter than those made under the ASAR condition for each interval. These differences however were not significant. In the other, the ASVR condition judgements were compared with the VSVR condition judgements. Here the ASVR condition judgements were

TABLE 24

Summary Of The Analysis Of Variance Of The Modal Condition And Interval Data For Study 3.

Visual Standard-Visual Response, Visual Standard-Auditory Response, Auditory Standard-Visual Response, Auditory Standard-Auditory Response Modal Conditions; 9, 17, 35, and 44 Second Intervals.

Source	d.f	M.S.	F	P
Modal Conditions (C)	3	36.90	3.95	$<.05$
Error	15	9.33		
Intervals	3	6138.66	1037.44	$<.05$
Error	15	5.92		
C x I	9	2.87	1.08	NS
Error	45	2.64		

TABLE 25

Neuman-Keuls Test Of Mean Differences For The Visual Standard-Visual Response, (VSVR), Visual Standard-Auditory Response (VSAR), Auditory Standard-Visual Response (ASVR), Auditory Standard-Auditory Response (ASAR) Modal Conditions In Each Interval For Study 3.

		9 Second Interval		
	VSAR	ASAR	VSVR	ASVR
	8.63	9.09	9.54	10.48
8.63		0.46	0.91	1.85
9.09			0.45	1.39
10.48				0.94
		17 Second Interval		
	VSAR	ASAR	VSVR	ASVR
	16.72	16.93	17.72	18.47
16.72		0.21	1.00	1.75
16.93			0.79	1.54
17.72				0.75
18.47				
		35 Second Interval		
	VSAR	VSVR	ASAR	ASVR
	34.84	34.87	35.26	38.88
34.84		0.03	0.42	4.04*
34.87			0.39	4.01*
35.26				3.62*
38.88				
		44 Second Interval		
	VSAR	ASAR	VSVR	ASVR
	42.42	43.18	44.17	46.08
42.42		0.76	1.75	3.66*
43.18			0.99	2.90*
44.17				1.91*
46.08				

*p < .05

longer than those of the VSVR condition, but the difference was significant in only the 35 and 44 second intervals.

The second comparison was concerned with the cross-modal difference at both the input and output stages of temporal processing by the 'internal clock'. In this instance, both the standard and judgement stages of the comparison pair were in cross-modal terms, that is, the VSAR condition judgements were compared with those under the ASVR condition. Here the ASVR condition judgements were longer than the VSAR condition judgements for all intervals, but the difference was significant in only the 35 and 44 second intervals.

The third comparison examined the cross-modal difference during the output stage of modal temporal processing. In this case the standard stages of the comparison pair were constant in modal terms, while the judgement stages were cross-modal. There were two comparisons involved. In one, the VSVR condition judgements were compared with the VSAR condition judgements. In this instance the VSVR condition judgements were longer than those made under the VSAR condition for all four intervals, although the differences were not significant. In the other, the ASAR condition judgements were compared with those under the ASVR condition. Here the ASVR condition judgements were reproduced as longer than those under the ASAR condition, however, the differences were significant for only the 35 and 44 second intervals.

In the final comparison, there was no cross-modal interaction at either the input or output stages of temporal processing. Here the ASAR condition judgements were compared with the VSVR judgements.

There was no significant difference between these for any interval.

Because of the consistent directional difference of the mean judgements in every interval and modal condition, a Sign Test (Siegal 1956) based on the subjects' mean judgements, and illustrated in Appendix E, Table E2, was carried out to evaluate the directional differences. This pointed out that when mode was varied in the standard stage of the temporal process, the conditions with the auditory standard were judged longer significantly more often than those with the visual standard. Also, when mode was varied in both the standard and judgement stages, the modal condition with the auditory standard and visual judgement was judged longer significantly more often than the condition with the visual standard and the auditory judgement. Furthermore, when the mode was varied in the judgement stage and held constant in the standard stage, the conditions with the auditory judgement were reproduced shorter significantly more frequently than those with the visual judgement. Finally, in the modal condition comparison where there was no interaction of modes, VSVR with ASAR, there was no significant directional difference.

Summary

Reproductions of durations using cross-modal auditory and visual stimuli have illustrated directional consistencies, with judgements made under the ASVR condition being most frequently the longest in duration, those made under the VSAR condition being most frequently the shortest, and those made under the ASAR and VSVR conditions falling in between.

Although an analysis of these differences by the Neuman Keuls test found that the only significant differences were between the ASVR judgements and those of the other three modal conditions in the 35 and 44 second intervals, an a posteriori Sign Test pointed out that the above directional differences in the modal conditions were significant.

Discussion

The 'internal clock' explanation of the difference in the ability to judge intervals between the auditory and visual modes suggests that the variable pacemaker pulsates at a faster rate during an auditory mode than it does during a visual mode. Thus reproductions of a constant interval made under the auditory mode would not take as long as those made under the visual mode, as the criterion set forth by the standard interval would be met at a faster rate during the auditory mode. Conversely, if the judgement stage is held constant in terms of mode and the standard stage is in cross-modal terms, the reproduction of an auditory standard would take longer than one of a visual standard. This would be expected as the pacemaker would pulsate at a faster rate during an auditory standard, which in turn would result in more pulsations being produced than if the standard was visual. Since the judgement stage is constant in terms of mode, it would take the pacemaker longer to meet the criterion of the auditory standard in terms of pulses than it would the criterion established during a visual standard.

Reference to the means for each interval and modal condition indicates that the above explanation of the auditory-visual difference in temporal information processing may provide a way of accounting for the difference in the perception of the cross-modal stimuli. The 'internal clock' explanation suggests that the ASVR condition judgements would be the longest in duration, the VSAR condition judgements would be the shortest in duration, and the ASAR and VSVR condition judgements would fall in between the other two judgement conditions. This is in fact the order of the magnitude of the judgements obtained in the four modal conditions and intervals. Although the mean differences between the modal conditions were not significant in a majority of comparisons, the consistant direction of the difference of the comparisons led to a closer study of the data.

Reference to the means of each subject's judgements in each condition and interval (Appendix E) indicates that there was one subject (Number 1 in the Appendix) whose performance was exactly opposite that of the other subjects. That is, this subject reproduced auditory inputs shorter as visual outputs and visual inputs longer as auditory outputs. The degree of difference between his reproductions and those of the other subjects was quite marked, and as such could have contributed greatly to the non-significance of many of the comparisons. This would suggest that the 'internal clock' explanation may explain the modal difference in temporal perception, however, further research is necessary with perhaps a more careful selection of the type of subject involved.

Although the 'internal clock' model provides a plausible explanation of the modal difference, it remains to point out the location of this difference within the 'clock' processing. This requires a logical sequence of comparisons. The first comparison studied the cross-modal difference during the input stage of temporal information processing. In this case the input conditions were in cross-modal terms and the output conditions were modally constant. The 'clock' explanation of the modal difference would suggest that the conditions that had the auditory standard would be reproduced as longer than those that had the visual standard. In all cases for the four intervals the direction of the mean judgement differences was in the expected direction but was significant in only two of the eight comparisons. The consistent directional difference led to further testing which in turn found the direction of the difference significant. This would suggest that the cross-modal difference may in fact occur during the input stage of temporal processing. The lack of significance of the initial analysis is discussed in a later section of this discussion.

The second comparison studied the effect of the cross-modal difference at both the input and output stages of temporal processing. The 'clock' explanation of the modal difference would suggest that the auditory standard-visual response judgements would be longer than those made under the visual standard-auditory response conditions. This would be so as in the standard stage of the ASVR condition the pacemaker would produce a greater number of pulses than in the standard stage of the VSAR condition. In the judgement stage the

larger number of pulses produced in the standard stage of the ASVR condition would be reproduced at a slower rate than the fewer number of pulses produced in the standard stage of the VSAR condition. This would result in the longer ASVR condition judgements. In all comparisons of judgements made under these two conditions, the reproductions of the ASVR condition standards were longer than those of the VSAR condition, but the mean differences were significant in only the 35 and 44 second intervals. In general however, the results would suggest that the 'internal clock' may explain the modal difference in both the input and output stages of temporal information processing.

The third comparison studied the cross-modal difference during the output stage of temporal processing. In this case the input conditions were held constant and the output conditions were in cross-modal terms. The 'clock' explanation would suggest that the response conditions that had the auditory mode would have shorter reproductions than those with a visual judgement. This would be expected as the pacemaker would pulsate at a faster rate during an auditory reproduction than a visual reproduction. This in turn would mean that the number of pulses required to meet the criterion set forth in the standard stage would be reproduced at a faster rate in an auditory reproduction, thus shortening the reproduction. In all cases for the four intervals the direction of the mean differences was such that reproductions with auditory judgements were shorter than those with visual judgements. These differences though, were significant in only two comparisons.

In general however, the consistent directional difference, which was found significant in aposteriori analysis, suggests that the auditory-visual difference in time estimations occurs at the judgement stage of temporal processing.

In the final comparison, there was no cross-modal interaction in any stage of temporal processing (VSVR with ASAR condition judgements). In this case the 'internal clock' explanation would suggest no difference in the reproductions made under these two conditions as the criterion set up for each condition between the standard and judgement stages in terms of pulses produced by the pacemaker is independent of the other. This in turn would mean that no matter how many pulses were produced in the standard stage, the reproduction would be fairly accurate as the same criterion would be used in terms of pacemaker rate. The results indicated that this was so as there was no significant difference in judgements made under these conditions as well as no consistent direction to the differences.

The illustration of directional differences in cross-modal temporal judgements at both the input, and output stages of temporal processing by the 'internal clock' would suggest that the auditory-visual modal differences in time estimations may be a function of external modal rather than internal factors. The 'internal clock' however, provides a possible explanation of the modal difference as being due to the effect of each mode acting as a calibrating monitor in a manner such that an auditory temporal stimulus will cause the variable pacemaker to pulsate at a faster rate than a

visual temporal stimulus. The difference in the number of pulsations produced would result in the auditory-visual difference in temporal perception.

A point of interest in the results was the consistent performance of one subject in a manner opposite to that of the other five subjects. In terms of the 'internal clock' explanation of modal temporal processing, this subject's reproductions consistently indicated that the variable pacemaker pulsated at a faster rate during a visual stimulus input than it did during an auditory input. Personality variables may enter into this, but it is also suggested that as there are individuals who are left handed, there may be those whose 'internal clock' processes temporal information in a manner opposite to that of the majority of people.

As a result of this subject's performance, the mean differences of the judgements under the different modal conditions were smaller, which in turn contributed to the lack of significance for many of the mean differences. It had this effect because of the small number of subjects used, which would mean that one subject's performance would have an undue effect on the analysis of the data. However, the directional consistency of the other five subjects and its significance in secondary analysis suggests that the perception of auditory and visual inputs differs such that auditory durations are perceived as being longer than visual durations of the same length. This difference is consistent throughout the processing of the temporal information by the hypothetical 'internal clock'. It is important however, that further research be carried out to

delineate the nature of processing of modal temporal information for different individuals.

STUDY 4

Study 4 was concerned with the extent the 'internal clock' is involved with the decision concerning the manner of temporal information processing that corresponds with each mode. The hypothesis is:

> The accuracy of time estimation ability will be significantly greater when the mode of response is known before the onset of the standard, than if the mode of response is not known until after the standard has been presented.

Method

The stimuli consisted of auditory and visual durations of 9, 17, 35, and 44 seconds, presented under the method of reproduction. They were presented in eight conditions, which could be divided into two sections. In one section, auditory and visual standards were presented for which the subjects did not have knowledge of the mode of response (either visual or auditory), until after the standard had been presented. In the other section the subject was given knowledge of the mode of response before the presentation of the auditory or visual standard. The four conditions in each section resulted in a total of eight conditions as shown in Table 26.

In all eight conditions the knowledge of the mode of response was given by a verbal cue from E, either immediately before the standard or immediately after. The cue was a single word spoken clearly and concisely. If the auditory mode was to be used, the cue was the word "Auditory", and if the visual mode was to be used the verbal cue was the word "Visual".

TABLE 26

Experimental Conditions For The Standard And Judgement Stages Of Study 4.

	Standard		Judgement
(Response Mode Is Given Here)	Visual	(Response Mode Is Given Here)	Visual
	Visual		Auditory
	Auditory		Visual
	Auditory		Auditory
(Response Mode Is Given Here)	Visual		Visual
	Visual		Auditory
	Auditory		Visual
	Auditory		Auditory

Design

Each subject was required to reproduce the four intervals using the above mentioned conditions. Each interval was judged ten times in every condition, thus making a total of 320 trials per subject. The conditions were presented random across trial. Between each trial there was a 30 second pause. This allowed the subject to return to a baseline in functioning so that the effect of one response on another would be minimized. There were 16 sessions in this study.

Procedure

The subject entered the testing room and was seated in front of the control panel. Instructions were given:

> "In this study you will be presented with temporal stimuli in both the auditory and visual modes. In some cases you will know the mode of response before the presentation of the standard, while in other cases you will not know the mode of response until after the standard has been presented. The mode that is to be used will be indicated to you verbally. That is, if the mode to be used is visual, I will state clearly and concisely the word 'Visual', and if the mode to be used is auditory, I will state the word 'Auditory'. In some cases I will make this statement before the presentation of the standard, in other cases I will make this statement immediately after the standard has been presented. If there is any question in your mind as to what the statement was, let me know and the trial will be given again. In this study you are reminded to base your estimate on the time elapsed. You should not attempt to guess the interval or the mode with which you will reproduce the interval. Rather, you should base your estimate on your experience of the standard presented. Are there any questions? Practice trials will begin now. After these there will be a short break, then the experimental trials will being."

After the five minute practice session, the subject was given a five minute break. The 30 minute experimental sessions then began. The

standard intervals were presented and the subjects' judgements were recorded. This procedure was followed in every session.

Results

The means of the subjects' judgements for each modal condition and interval (Table 27) illustrates that the visual standard-auditory response (VSAR) condition judgements were the shortest in duration, followed by the auditory standard-auditory response (ASAR) judgements, which in turn differed little from the visual standard-visual response (VSVR) judgements. The auditory standard-visual response (ASVR) judgements were the longest in duration.

An analysis of variance, based on the average of each subject's judgements in every interval and modal condition, and instruction condition, was calculated. These averages are listed in Appendix F. Reference to the summary of this analysis, as recorded in Table 28, indicates that the judgements under the modal conditions differed significantly from one another.

A Neuman-Keuls test for means (Winer 1962) shown on Table 29 found significant differences between the mean judgements of the ASVR condition and the other three modal conditions in the 17, 35, and 44 second intervals, with the ASVR condition judgements being longer. The other significant difference was between the VSAR and ASAR conditions in the 44 second interval, with the VSAR condition judgements being shorter. Although the analysis of the judgements under the modal conditions was not the purpose of this study, it is noted that they differ from one another in a manner similar to that in Study 3.

TABLE 27

The Mean Judgement Of Each Modal Comparison Condition In Each Interval

Modal Conditions		Intervals			
Standard	Judgement	9	17	35	44
Visual	Visual	9.56	17.65	35.31	43.55
Visual	Auditory	9.14	17.94	34.93	41.05
Auditory	Visual	11.05	20.07	39.89	49.27
Auditory	Auditory	9.33	17.58	35.32	43.80

TABLE 28

Summary Of The Analysis Of Variance Of The Modal Instructions, Modal Conditions, And Intervals Data For Study 4.

Knowledge And Lack Of Knowledge Of The Mode Of Response Instruction Conditions; Visual Standard-Visual Response, Visual Standard-Auditory Response, Auditory Standard-Visual Response, Auditory Standard-Auditory Response Modal Conditions; 9, 17, 35, And 44 Second Intervals.

Source	d.f.	M.S.	F	P
Modal Instructions (I)	1	10.13	0.81	NS
Error	5	12.55		
Modal Conditions (C)	3	180.01	13.82	$<.05$
Error	15	13.03		
Intervals (In)	3	12212.94	1420.22	$<.05$
Error	15	8.60		
I x C	3	6.98	2.97	NS
Error	15	2.34		
I x In	3	1.07	0.76	NS
Error	15	2.80		
C x In	9	18.96	5.85	$<.05$
Error	45	3.24		
I x C x In	9	4.22	1.44	NS
Error	45	2.93		

TABLE 29

Neuman-Keuls Test Of Mean Differences For The Visual Standard-Visual Response, (VSVR), Visual Standard-Auditory Response (VSAR), Auditory Standard-Visual Response (ASVR), Auditory Standard-Auditory Response (ASAR) Modal Conditions In Each Interval For Study 4

9 Second Interval

	VSAR	ASAR	VSVR	ASVR
	9.14	9.33	9.56	11.05
9.14		0.19	0.42	1.91
9.33			0.23	0.72
9.56				0.49
11.05				

17 Second Interval

	ASAR	VSVR	VSAR	ASVR
	17.58	17.65	17.94	20.07
17.58		0.07	0.36	2.49
17.65			0.29	2.42
17.94				2.13*
20.07				

35 Second Interval

	VSAR	VSVR	ASAR	ASVR
	34.93	35.31	35.32	39.89
34.93		0.38	0.39	4.76*
35.31			0.01	4.58*
35.32				4.59*
39.89				

44 Second Interval

	VSAR	VSVR	ASAR	ASVR
	41.05	43.55	43.80	49.27
41.05		2.50	2.75	8.22*
43.55			0.25	5.72*
43.80				5.47*
49.27				

*$p < .05$

Reference to the summary of the analysis of variance (Table 27) also illustrates that judgements made under the knowledge of the mode of response condition did not differ significantly from those made under the lack of knowledge of the mode of response condition in the auditory and visual modes.

Summary

Reproduction of intervals under conditions of knowledge of the mode of response did not differ from reproductions under conditions of lack of knowledge of the mode of response.

Discussion

In terms of Cohen's model of the 'internal clock', the lack of significant difference between judgements made under conditions of knowledge and lack of knowledge of the mode of response suggests that the 'clock' has no cognitive responsibility in the processing of temporal information in a way that corresponds to a certain mode. That is, if withholding the knowledge of the mode of response does not significantly affect the estimations made, then the suggestion would be that the 'internal clock' does not need this information. Rather, the 'internal clock' is mechanical in function and processes the temporal information as it is directed by external factors (calibrating monitors). These factors calibrate the frequency of pulsation by the variable pacemaker which in turn provides the standard with which we measure durations.

An admitted weakness in the design of this experiment is that it does not enable us to be sure of the precise effect of

receiving spoken instructions in two different positions in the processing sequence. However, the lack of significant difference between the instruction conditions suggests that the effect of the spoken instructions was minimal.

CONCLUSIONS AND DISCUSSION

The objective in this final chapter is to discuss the general implications of these experiments as they relate to the explanation of processing of the temporal information through a hypothetical 'internal clock' proposed by Cohen (1965). In view of the number of experiments involved, a summary will precede the discussion. This summary is presented in the form of a series of conclusions which, within the limits of the experiments, the results seem to warrant.

Conclusions

1. The effects of a background sound on judgements of visual temporal stimuli, made using the methods of verbal estimation, operative estimation, and reproduction, can be adequately explained by Cohen's model of the 'internal clock' in a manner that suggests that the background sound increases the rate of functioning of the 'clock' system. The effect of the background sound was such that:

(a) When the background sound was present in the standard stage of temporal processing under the method of verbal estimation, the judgement of the interval was greater than if there was no background sound present in this stage. This effect occurred only when the background sound was applied in the standard stage for the 14, 38, and 47 second intervals.

(b) When the background sound was present in the judgement stage of temporal processing under the method of operative

estimation, the judgements of 14, 38, and 47 second intervals were shorter than if there was no background sound present in this stage. This effect occurred only when the background sound was applied in the judgement stage of temporal processing.

(c) When a background sound was present in the standard stage of temporal processing under the method of reproduction, and there was no background sound present in the judgement stage, the reproduction of an interval in this condition was longer than a reproduction of the same interval made with the background sound absent in the standard and judgement stages.

(d) When a background sound was absent in the standard stage of temporal processing under the method of reproduction and present in the judgement stage, the resulting reproduction was shorter than one made of the same standard without the background sound present in the judgement stage.

2. Lack of knowledge of the method of response (verbal estimation or reproduction) during the standard stage of temporal processing may cause the accuracy of judgements made in both the auditory and visual modes to decline in a manner that results in the judgements being shorter than those made with these methods and modes in conditions of knowledge of the method of response before the standard was presented. The lack of consistent significance, however, necessitates further research.

3. The cross-modal difference in temporal perception between the auditory and visual modes was such that auditory reproductions of visual standards were shorter in duration than visual reproductions

of the same standards. Also, visual reproductions of auditory standards were longer than auditory reproductions of these standards. In terms of the 'internal clock' these results suggest that the auditory temporal stimuli cause the 'clock system' to increase its rate of functioning. This increased rate of functioning was consistent throughout the processing of the modal temporal information by the 'clock'. This in turn suggested that the modal difference was a direct result of the different modes and their effect on the 'internal clock' as calibrating monitors rather than a result of inner 'clock' factors. It should be noted that the strength of these conclusions are based on a combination of a limited number of significant differences in the original analysis and the aposteriori finding that the direction of the differences was consistent and significant. This in turn suggests further research on this point.

4. Knowledge and lack of knowledge of the mode of response does not play an imporant part in the modal difference found between the auditory and visual modes in the method of reproduction. This suggests that the 'internal clock' is rather mechanical in function and simply processes the temporal information in a way determined by the stimulus conditions.

Discussion

Thus the conclusions suggest that the 'internal clock' analogy is not only a useful way of theorizing about man's ability to estimate time, but it also provides a valid guideline in terms of explaining and relating time estimation results. Although

the basic definition of this clock is still not established in physiological terms, the mechanistic definition, as provided by Cohen (1965) and used in explanations of time estimation ability by Bindra and Waksberg (1956), is further extended. This 'mechanistic clock' however requires definition in terms of the functions it carries out, and the effects of other variables on its functioning.

In view of the results of Study 1, it would seem that this pulsating 'clock system' can be, and is affected by external influences in a manner that either increases or decreases its pulsating frequency. This variable pulsating frequency would be the cause of the effects noted in terms of a background sound on the judgements of visual intervals made using the methods of verbal estimation, operative estimation and reproduction. This suggests that the explanation of the different estimations made under the three methods can be attributed to one underlying system, and not two or three as suggested by Clausen (1950), and Ochberg, Pollack, and Meyer (1965).

The illustration that a hypothetical 'internal clock' can explain the different time estimation results made under the three methods of psychochronometry leads to the next step, which is to delineate the characteristics of this clock. A major point of concern is the 'cognitive responsibility' of this clock. That is, to what extent is this clock a simple mechanistic processing system, as suggested by Cohen (1965), or to what extent does this 'internal clock system' play a role in the cognitive direction of the temporal processing that corresponds to the different methods and modes used

in time estimation? Studies 2 and 4 both suggest that the 'internal clock' plays no active role in the manner of processing that corresponds to the method and mode, other than to channel the temporal information as it is directed by outside stimulus conditions. Study 3 further suggests this, as the modal difference found between the perception of auditory and visual temporal stimuli was consistent throughout the different processing stages of the 'clock', and thus was not due to one particular facet of the 'clock system'. Therefore the 'internal clock' would seem to be a simple 'mechanistic' system capable of providing the individual with a means of measuring durations against a standard base.

This further raises the question of how the individual reads the 'internal clock', i.e., how does the individual turn the temporal information into a form such that it is in cognitive terms? This basic question remains the most difficult. When durations are experienced the interval is usually given a verbal label, whether it is needed or not. This label serves as a referent point for the memory of the interval. However, in this research, it was stressed to the subjects that there was to be no counting or application of verbal labels to the durations perceived, unless specifically requested. Although there was some difficulty experienced initially all subjects arrived at reasonably accurate estimates of the intervals without using the verbal cues. This would suggest that the individual is able to read this 'clock system' without using the verbal labels. The manner in which this is done needs further study.

Although it has been illustrated that Cohen's 'internal clock' model may provide an explanation of time estimation ability, it cannot be too strongly stressed that this is just a hypothetical model designed to explain and integrate the essential features of subjective time. It provides a base and a means from which to organize research. It must never be forgotten that a 'model' in the sense in which the term has been used throughout the present work, is but a simplified structuring of reality which presents supposedly significant features or relationships in generalized form. It is a highly subjective approximation to reality, and in testing its validity we must constantly use care to avoid finding only those facts which seem to fit the model and shutting our eyes to those that contradict it. The conclusions reached in this study suggest that man's time estimation ability results from one underlying system which seems rather mechanical in nature. Research, however, should go beyond the hypothetical model in further attempts to delineate the causal basis of man's time estimation ability.

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APPENDICES

APPENDIX A

SCHEDULE FOR EACH SUBJECT AND ORDER OF PRESENTATION OF STUDIES

TABLE A1

SCHEDULE FOR EACH SUBJECT

Subject	Session One	Session Two
1	7:20 A.M.	3:40 P.M.
2	8:00 A.M.	2:00 P.M.
3	8:40 A.M.	12:00 Noon
4	10:00 A.M.	4:00 P.M.
5	11:20 A.M.	3:00 P.M.
6	1:30 P.M.	5:00 P.M.

TABLE A2

ORDER OF PRESENTATION OF STUDIES

Subject	Block	Session One	Session Two
1	I	Study 2	Study 4
	II	Study 1	Study 3
2	I	Study 1	Study 4
	II	Study 2	Study 3
3	I	Study 1	Study 4
	II	Study 2	Study 3
4	I	Study 2	Study 3
	II	Study 1	Study 4
5	I	Study 1	Study 3
	II	Study 2	Study 4
6	I	Study 2	Study 3
	II	Study 1	Study 4

APPENDIX B

SCHEMATIC DIAGRAM OF THE APPARATUS AND PHOTOGRAPH OF THE RESPONSE PANEL

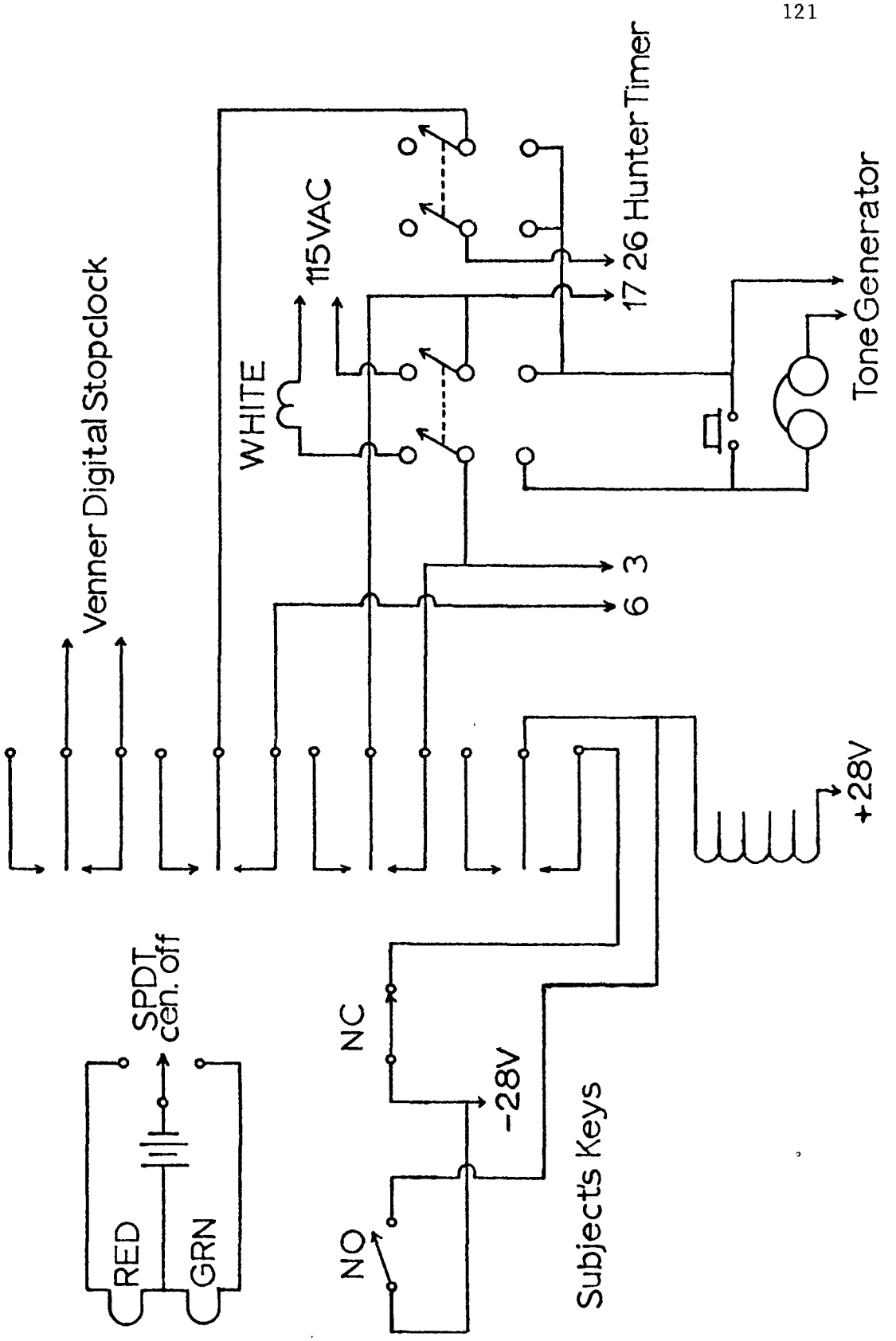

FIGURE B1 A Schematic Diagram Of The Apparatus.

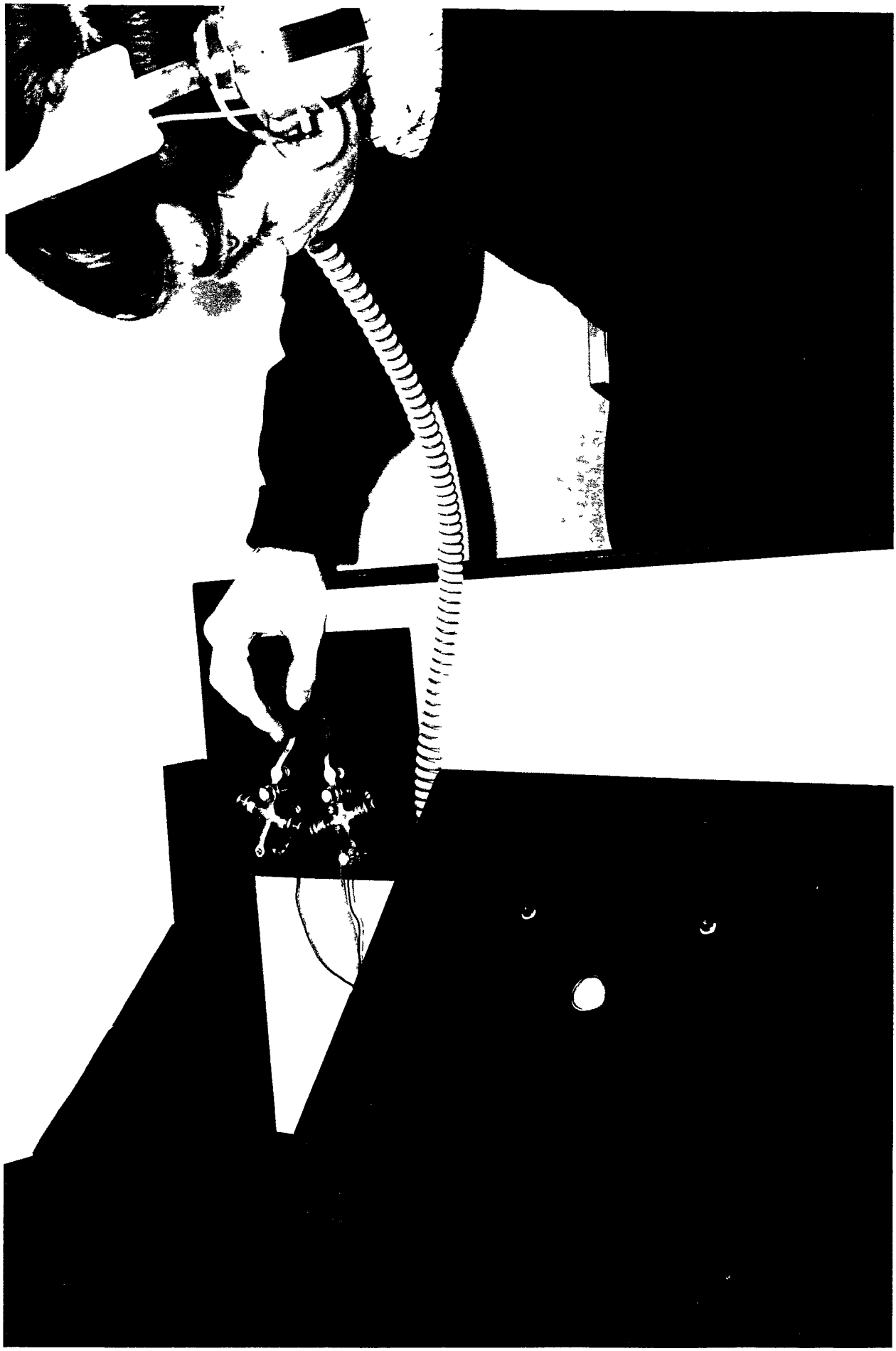

FIGURE B2 Subject's Side Of The Control Panel.

APPENDIX C

COUNTERBALANCED PRESENTATION OF METHODS AND SESSIONS AND THE AVERAGE JUDGEMENT FOR EACH SUBJECT IN EVERY CONDITION FOR STUDY 1

TABLE C1

COUNTERBALANCED ORDER OF PRESENTATION OF METHODS AND THE TOTAL NUMBER OF SESSIONS FOR STUDY 1

Subject	Counterbalanced Order Of Methods			Number of Sessions
1	Reproduction	Operative Estimation	Verbal Estimation	24
2	Reproduction	Verbal Estimation	Operative Estimation	24
3	Verbal Estimation	Operative Estimation	Reproduction	24
4	Operative Estimation	Verbal Estimation	Reproduction	24
5	Operative Estimation	Reproduction	Verbal Estimation	24
6	Verbal Estimation	Reproduction	Operative Estimation	24

TABLE C2

MEAN JUDGEMENT FOR EACH SUBJECT IN EVERY BACKGROUND SOUND CONDITION AND INTERVAL FOR THE METHOD OF VERBAL ESTIMATION.

Subject	Interval	Background Sound Conditions*			
		BB	BN	NB	NN
1	3	2.60	2.65	2.45	3.00
	14	10.80	10.25	10.25	11.00
	38	29.50	27.70	26.25	26.95
	47	34.35	33.25	32.35	32.70
2	3	3.10	3.00	2.90	2.95
	14	12.20	11.50	9.10	9.20
	38	31.20	34.90	27.30	28.30
	47	39.50	38.00	33.40	33.50
3	3	3.64	3.80	2.60	2.95
	14	18.70	18.90	16.60	16.10
	38	39.10	40.10	34.70	32.40
	47	45.10	48.20	44.30	43.00
4	3	3.70	3.05	2.65	2.95
	14	9.50	10.20	8.50	8.40
	38	28.90	30.50	25.20	22.20
	47	33.30	33.20	30.00	29.50
5	3	3.80	3.00	2.90	2.90
	14	12.50	12.00	12.10	11.80
	38	31.00	29.70	26.50	26.50
	47	39.30	39.90	33.10	33.10
6	3	5.70	5.90	4.60	4.90
	14	18.40	19.90	14.30	15.90
	38	37.70	41.90	34.10	36.20
	47	47.80	43.30	37.30	38.00

* BB - Background Sound Standard-Background Sound Judgement
BN - Background Sound Standard-No Background Sound Judgement
NB - No Background Sound Standard-Background Sound Judgement
NN - No Background Sound Standard- No Background Sound Judgement

TABLE C3

AVERAGE JUDGEMENT OF EACH SUBJECT IN EVERY BACKGROUND SOUND CONDITION AND INTERVAL FOR THE METHOD OF OPERATIVE ESTIMATION

		Background Sound Condition			
Subject	Interval	BB	BN	NB	NN
1	3	2.84	3.33	2.89	3.26
	14	15.31	17.44	14.63	18.13
	38	47.41	50.60	44.18	54.34
	47	59.34	65.18	57.06	62.86
2	3	2.48	2.41	2.72	2.67
	14	15.23	16.50	15.45	17.72
	38	42.12	44.43	42.82	43.59
	47	51.64	53.80	54.39	51.75
3	3	2.85	3.25	2.92	2.91
	14	14.45	15.23	13.90	14.67
	38	38.08	38.07	38.23	38.46
	47	44.99	48.40	42.16	46.73
4	3	2.05	2.47	2.00	2.16
	14	20.47	24.10	18.54	24.12
	38	56.56	57.58	58.29	59.77
	47	68.78	75.68	65.70	78.77
5	3	2.80	2.96	3.03	3.41
	14	20.51	21.62	20.45	27.30
	38	51.84	58.35	47.88	57.98
	47	68.81	70.94	64.76	80.64
6	3	1.85	2.19	1.62	2.15
	14	20.23	21.71	21.50	20.93
	38	42.56	45.62	41.43	44.82
	47	52.22	56.86	52.94	58.98

* BB- Background Sound Standard-Background Sound Judgement
BN- Background Sound Standard-No Background Sound Judgement
NB- No Background Sound Standard-Background Sound Judgement
NN- No Background Sound Standard-No Background Sound Judgement.

TABLE C 4

AVERAGE JUDGMENT OF EACH SUJBECT IN EVERY BACKGROUND SOUND CONDITION AND INTERVAL FOR THE METHOD OF REPRODUCTION

Subject	Interval	Background Sound Condition			
		BB	BN	NB	NN
1	3	2.80	2.99	2.56	2.42
	14	14.96	18.08	17.04	14.50
	38	41.63	40.86	44.10	38.08
	47	47.34	47.13	45.94	48.57
2	3	3.27	3.76	3.25	3.27
	14	14.71	15.81	12.75	15.49
	38	37.38	42.91	34.20	35.96
3	3	2.77	3.05	2.53	3.17
	14	14.34	15.61	13.11	15.32
	38	34.65	42.99	35.03	41.02
	47	45.77	47.10	45.08	45.94
4	3	2.43	3.36	3.40	3.48
	14	14.18	16.13	15.85	14.19
	38	31.01	42.40	37.83	35.46
	47	43.47	49.97	47.75	45.22
5	3	2.10	2.64	2.53	2.95
	14	16.75	17.40	15.80	15.87
	38	42.53	45.14	37.29	41.53
	47	47.67	54.11	43.31	53.34
6	3	2.83	3.41	3.19	3.01
	14	17.49	19.70	17.54	16.99
	38	34.33	40.46	33.75	36.00
	47	46.51	50.41	40.31	40.82

* BB- Background Sound Standard-Background Sound Judgement
BN- Background Sound Standard-No Background Sound Judgement
NB- No Background Sound Standard-Background Sound Judgement
NN- No Background Sound Standard-No Background Sound Judgement.

APPENDIX D

GROUPED DATA FOR STUDY 2

TABLE D 1

AVERAGE JUDGMENT FOR EACH SUBJECT IN EVERY INTERVAL, METHOD, AND KNOWLEDGE, (KS) AND LACK OF KNOWLEDGE (NKS) INSTRUCTION CONDITION IN THE VISUAL MODE

			Interval			
			7	19	28	42
1	Verbal Estimation	KS	5.60	16.30	22.10	32.80
		NKS	6.40	13.10	20.40	27.20
	Reproduction	KS	7.47	20.70	32.93	47.33
		NKS	7.37	24.57	34.02	49.68
2	Verbal Estimation	KS	5.10	13.80	23.20	33.80
		NKS	4.10	12.20	20.00	29.90
	Reproduction	KS	7.63	18.00	29.38	42.17
		NKS	5.99	14.02	26.07	46.72
3	Verbal Estimation	KS	6.33	20.30	28.20	41.45
		NKS	5.74	16.85	26.20	38.04
	Reproduction	KS	6.88	19.14	29.30	41.46
		NKS	6.13	18.04	25.87	45.64
4	Verbal Estimation	KS	7.30	19.30	28.40	37.50
		NKS	7.40	21.00	23.00	34.50
	Reproduction	KS	8.84	22.81	26.02	39.37
		NKS	8.21	24.10	27.74	35.31
5	Verbal Estimation	KS	5.70	15.60	22.00	40.00
		NKS	5.60	13.20	18.30	32.60
	Reproduction	KS	6.35	17.54	27.44	40.47
		NKS	6.50	16.17	25.25	39.90
6	Verbal Estimation	KS	6.60	18.80	28.40	42.10
		NKS	7.40	17.60	25.30	39.80
	Reproduction	KS	7.27	18.21	26.87	41.52
		NKS	6.50	16.39	26.40	36.52

TABLE D 2

AVERAGE JUDGMENT FOR EACH SUBJECT IN EVERY INTERVAL, METHOD, AND KNOWLEDGE (KS) AND LACK OF KNOWLEDGE (NKS) INSTRUCTION CONDITION IN THE AUDITORY MODE

Subject	Method		Interval			
			7	19	28	42
1	Verbal Estimation	KS	5.10	13.50	20.40	33.60
		NKS	4.60	12.60	16.40	28.20
	Reproduction	KS	6.46	17.89	29.87	43.69
		NKS	5.98	18.79	26.64	44.32
2	Verbal Estimation	KS	5.10	15.60	24.40	34.30
		NKS	4.20	13.50	17.30	31.00
	Reproduction	KS	5.86	17.83	28.33	41.77
		NKS	4.77	15.27	28.01	38.49
3	Verbal Estimation	KS	7.10	19.10	27.30	42.20
		NKS	6.35	20.10	24.90	39.40
	Reproduction	KS	7.34	19.98	27.39	41.11
		NKS	6.50	16.83	25.12	37.82
4	Verbal Estimation	KS	6.30	21.20	28.20	39.00
		NKS	6.20	22.70	25.00	35.00
	Reproduction	KS	7.65	21.22	31.29	46.21
		NKS	6.28	20.91	33.18	37.98
5	Verbal Estimation	KS	6.20	15.80	22.90	37.70
		NKS	5.20	14.60	19.80	30.45
	Reproduction	KS	6.89	19.70	28.58	45.45
		NKS	7.09	18.37	24.86	39.67
6	Verbal Estimation	KS	6.10	16.70	21.90	34.30
		NKS	5.40	12.90	20.40	31.60
	Reproduction	KS	6.45	19.03	27.14	42.39
		NKS	6.04	19.62	25.00	40.30

TABLE D3

THE MEAN DIFFERENCE BETWEEN THE STANDARD AND THE JUDGEMENT FOR EACH SUBJECT IN EVERY INTERVAL, METHOD, AND KNOWLEDGE (KS) AND LACK OF KNOWLEDGE (NKS) INSTRUCTION CONDITION IN THE VISUAL MODE.

Subject	Method	Instruction Condition	Intervals			
			7	19	28	42
1	Verbal Estimation	KS	1.40	2.70	5.90	9.20
		NKS	0.60	5.90	7.60	14.80
	Reproduction	KS	0.47	1.70	4.93	5.33
		NKS	0.37	5.57	6.02	7.68
2	Verbal Estimation	KS	1.90	5.20	4.80	8.20
		NKS	2.90	6.80	8.00	12.10
	Reproduction	KS	0.63	1.00	1.38	0.17
		NKS	1.01	4.98	1.93	4.72
3	Verbal Estimation	KS	0.67	1.30	0.20	0.55
		NKS	1.26	2.15	1.80	3.96
	Reproduction	KS	0.12	0.14	1.30	0.54
		NKS	0.87	0.96	2.13	3.64
4	Verbal Estimation	KS	0.30	0.30	0.40	4.50
		NKS	0.40	2.00	5.00	7.50
	Reproduction	KS	1.84	3.81	1.98	2.63
		NKS	1.21	5.10	0.26	6.69
5	Verbal Estimation	KS	2.30	3.40	6.00	2.00
		NKS	1.40	5.80	9.70	9.40
	Reproduction	KS	0.65	1.46	0.56	1.53
		NKS	0.50	2.83	2.75	2.10
6	Verbal Estimation	KS	0.40	0.20	0.40	0.10
		NKS	0.40	0.40	2.70	2.20
	Reproduction	KS	0.27	0.79	1.13	0.48
		NKS	0.50	2.61	1.60	5.48

TABLE D4

THE MEAN DIFFERENCE BETWEEN THE STANDARD AND THE JUDGEMENT FOR EACH SUBJECT IN EVERY INTERVAL, METHOD, AND KNOWLEDGE (KS) AND LACK OF KNOWLEDGE (NKS) INSTRUCTION CONDITION IN THE VISUAL MODE.

Subject	Method	Instruction Conditions	Intervals			
			7	19	28	42
1	Verbal Estimation	KS	1.90	5.50	7.60	8.40
		NKS	2.40	6.40	11.60	13.80
	Reproduction	KS	0.54	1.11	1.87	1.69
		NKS	1.02	0.21	1.36	2.32
2	Verbal Estimation	KS	1.90	3.40	3.60	7.70
		NKS	2.80	5.50	10.70	11.00
	Reproduction	KS	1.14	1.17	0.33	0.23
		NKS	2.23	3.73	0.01	2.51
3	Verbal Estimation	KS	0.10	0.10	0.70	0.20
		NKS	0.65	1.10	3.10	2.60
	Reproduction	KS	0.34	0.98	0.61	0.89
		NKS	0.50	2.17	2.88	4.18
4	Verbal Estimation	KS	0.70	2.20	0.20	3.00
		NKS	0.80	3.70	3.00	7.00
	Reproduction	KS	0.65	2.22	3.29	4.21
		NKS	0.72	1.91	5.18	4.02
5	Verbal Estimation	KS	0.80	3.20	5.10	4.30
		NKS	1.80	4.40	8.20	11.55
	Reproduction	KS	0.11	0.70	0.58	3.45
		NKS	0.09	0.63	3.14	2.33
6	Verbal Estimation	KS	0.90	2.30	6.10	7.70
		NKS	1.60	6.10	7.60	10.40
	Reproduction	KS	0.55	0.03	0.86	0.39
		NKS	0.96	0.62	3.00	1.70

TABLE D5

SIGN TEST COMPARING THE DIRECTIONAL DIFFERENCES OF THE MEAN JUDGEMENTS IN THE KNOWLEDGE (KS) AND LACK OF KNOWLEDGE OF THE METHOD OF RESPONSE INSTRUCTION CONDITIONS

Sign Test Formula

$$Z = \frac{(X \pm .5) - 1/2N}{1/2\sqrt{N}}$$

Method	Number Of Comparisons	Direction of Differences Of Instruction Conditions	Frequency Of Difference	Sign Test P Values
Verbal Estimation	48	NKS < KS NKS > KS	42 6	< .05 *
Reproduction	48	NKS KS NKS > KS	35 13	< .05 *

TABLE D6

SIGN TEST COMPARING THE MEAN ACCURACY SCORES IN THE KNOWLEDGE (KS) AND LACK OF KNOWLEDGE OF THE METHOD OF RESPONSE INSTRUCTION CONDITIONS

Method	Number Of Comparisons	Direction of Differences Of Instruction Condition Accuracy Scores	Frequency Of Difference	Sign Test P Values
Verbal Estimation	48	NKS > KS	45	< .05
		NKS < KS	2	
		NKS = KS	1	
Reproduction	48	NKS > KS	37	< .05
		NKS < KS	11	

APPENDIX E

GROUPED DATA FOR STUDY 3

TABLE E1

AVERAGE JUDGMENT OF EACH SUBJECT IN EVERY INTERVAL AND MODAL CONDITION* FOR STUDY 3

Subject	Interval	Modal Conditions			
		VSVR	VSAR	ASVR	ASAR
1	9	8.65	9.34	7.97	8.73
	17	17.33	19.04	16.22	17.25
	35	39.28	43.15	37.75	36.34
	44	45.44	50.92	45.32	44.09
2	9	9.67	7.20	11.47	9.69
	17	18.48	18.05	18.63	16.36
	35	35.59	33.83	41.37	36.34
	44	45.74	45.45	47.97	41.81
3	9	8.56	8.76	10.58	9.41
	17	17.41	14.11	20.10	17.65
	35	33.26	33.73	38.54	36.06
	44	43.02	41.11	47.23	44.43
4	9	11.87	9.43	11.17	8.63
	17	18.11	16.69	17.81	16.80
	35	31.71	34.25	37.42	38.37
	44	41.87	37.45	43.12	43.52
5	9	9.86	8.77	11.68	9.20
	17	17.49	14.44	18.20	16.57
	35	33.85	31.49	40.37	29.33
	44	42.56	39.30	46.20	43.21
6	9	8.65	8.26	10.03	8.85
	17	17.54	18.04	19.85	16.98
	35	35.57	32.63	37.87	35.13
	44	46.40	40.34	46.65	41.99

*Visual Standard-Visual Response (VSVR), Visual Standard-Auditory Response (VSAR) Auditory Standard-Visual Response (ASVR), and Auditory Standard Auditory Response (ASAR) Modal Conditions.

TABLE E2

SIGN TEST COMPARING THE DIRECTIONAL DIFFERENCES OF THE MEAN JUDGEMENTS IN THE MODAL CONDITIONS OF STUDY 3

Sign Test Formula

$$Z = \frac{(X \overset{+}{-} .5) - 1/2\ N}{1/2\ N}$$

Stage of Modal Variation	Number of Comparisons	Direction of Difference of Combined Modal Comparisons	Frequency of Differences	Sign Test P Values
Standard	48	Auditory > Visual Auditory < Visual	36 12	< .05
Standard And Judgement	24	Auditory ASVR > VSAR ASVR < VSAR	 20 4	< .05
Judgement	48	Auditory < Visual Auditory > Visual	33 15	< .05
No Interaction	24	ASAR > VSVR ASAR < VSVR	11 13	NS

APPENDIX F

GROUPED DATA FOR STUDY 4

AVERAGE JUDGMENT OF EACH SUBJECT IN EVERY INTERVAL AND MODAL INSTRUCTION CONDITION* FOR STUDY 4

Subject	Interval	Modal Instruction Conditions							
		xVSVR	VSxVR	xVSAR	VSxAR	xASAR	ASxAR	xASVR	ASxVR
1	9	9.48	9.72	8.48	9.97	9.71	8.84	9.65	9.77
	17	18.04	17.41	20.28	18.84	17.65	17.56	17.87	17.97
	35	37.18	35.75	38.96	40.68	38.16	40.16	37.54	38.49
	44	45.72	46.25	45.30	42.10	47.12	45.71	45.50	53.45
2	9	9.41	8.95	11.02	8.45	9.46	11.28	11.64	10.90
	17	18.47	16.08	17.92	14.75	18.66	16.09	21.48	19.48
	35	37.69	34.11	36.36	35.00	35.60	33.42	41.56	42.62
	44	43.04	43.00	39.68	36.90	43.26	44.41	51.40	51.15
3	9	9.95	8.72	9.48	8.11	9.38	8.97	12.33	9.99
	17	17.56	19.19	18.43	16.57	17.09	15.86	19.96	20.83
	35	35.98	30.24	32.29	31.88	34.66	30.91	38.16	38.15
	44	42.12	42.42	43.99	39.57	44.49	39.42	47.91	45.41
4	9	10.13	10.11	10.57	9.13	9.17	8.12	11.92	12.79
	17	17.91	19.74	18.00	20.49	17.18	19.31	22.23	22.08
	35	35.58	37.24	36.63	35.75	37.61	1.14	40.94	50.04
	44	41.95	44.30	38.63	41.81	40.88	42.49	53.34	56.42
5	9	9.39	10.27	9.29	9.19	9.53	9.61	11.68	10.15
	17	17.23	18.60	18.01	18.67	18.06	19.03	20.63	20.33
	35	38.77	36.92	33.27	34.18	34.61	38.37	39.58	40.94
	44	45.45	45.67	43.02	43.38	46.50	44.58	50.07	51.79
6	9	8.55	10.01	8.33	7.69	9.38	8.47	11.07	10.75
	17	15.79	15.81	16.49	16.86	19.46	14.98	19.45	18.23
	35	34.23	30.04	32.00	32.16	38.45	30.79	37.63	33.03
	44	45.59	37.12	38.66	39.57	44.12	42.65	40.80	44.05

* xVSVR-Modal Instruction-Visual Standard-Visual Response.
VSxVR-Visual Standard-Modal Instruction-Visual Response.
xVSAR-Modal Instruction-Visual Standard-Auditory Response.
VSxAR-Visual Standard-Modal Instruction-Auditory Response.
xASAR-Modal Instruction-Auditory Standard-Auditory Response.
ASxAR-Auditory Standard-Modal Instruction-Auditory Response.
xASVR-Modal Instruction-Auditory Standard-Visual Response.
ASxVR-Auditory Standard-Modal Instruction-Visual Response.