INTERSENSORY PRESENTATION EFFECTS ON SIGNAL DETECTION UNDER NOISE CONDITIONS

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TABLE OF CONTENTS

LIST OF TABLES

Table | Page

LIST OF FIGURES

Figure | Page

CHAPTER I

THE PROBLEM

Studies of simultaneous stimulation of sensory modalities have been reported for some time in the psychological literature. The sensory modalities studied for the most part have been vision and audition. Generally, experimenters have employed one of two approaches in their design. The first is to present visual stimuli varying about a threshold point and simultaneously stimulate the subject aurally with a tone of specific frequency. The interest here has centered on the effects on visual absolute threshold. The second major design approach represents an expansion on the threshold determination design. In this approach, dissimilar material is also simultaneously presented by means of an additional sensory modality. However, rather than merely an alerting signal, the auxiliary stimulation has meaningful content. This content is dissimilar from the primary stimulus material.

These same two variables, vision and audition, have figured in much research in education. The concern, however, has not been directed toward the study of signal detection and facilitation effects; but, rather, has been one of seeking to identify the particular input channel enabling more efficient presentation as measured by rate of learning.

Though subjected to the longest period of study, the basic question of whether simultaneous stimulation with an auxiliary stimulus results in an enhancing effect on threshold determination has not been satisfactorily resolved. Harris (1948) and Maier, Bevan, and Behar (1961) cite a number of studies reporting effects for which the main conclusion is that a positive enhancing effect on threshold results from simultaneous auxiliary stimulation. Opposing this view are Broadbent (1958) and Licklider (1961) who have summarized much evidence pointing to an inhibitory effect resulting from simultaneous intersensory stimulation.

The detection of a low energy signal appearing against a background of random noise is a vital problem to many psychologists and others concerned with human functioning in complex communication systems of the type being currently developed. Sherwin et al (1961) provided strong support for continued use of the human as a component in any signal detection system with their finding that the human false alarm rate was significantly lower than that of an electronic detector for any given probability of signal detection. False alarm rate, as used by these authors, is a measure expressed by the proportion of the number of times a signal is stated to be present when it, in fact, is not to the times a signal is said to be present when it does appear.

The problem of enhancing the signal detection ability of the human has received increasing concern from engineering psychologists in the last decade as a result of continued progression of complexity in the state of the art in electronic equipment. One of the approaches considered has been the use of additional sensory modalities to increase human performance in signal detection tasks. A number of modalities have been considered, including tactile stimulation (Geldard, 1960). The most commonly considered modalities in electronic communication have been vision and audition. Though vision and audition are the modalities most frequently employed in communication systems, Morgan et al (1963), have indicated that little systematic work has been done in comparing the visual and auditory abilities of the human to accomplish signal detection tasks. This lack of interest of Western psychology in the area of the effects of sensory interaction for vision and audition has been emphasized by London (1954) and Maier, Bevan and Behar (1961).

The contradictory nature of the existing findings, coupled with the relative paucity of research in the area, creates a need for additional research which more systematically establishes conditions under which the many variables involved in intersensory presentation effects on signal detection can be isolated, experimentally manipulated, and evaluated.

Statement of the Problem

It is the purpose of this study to investigate whether simultaneous presentation of signals through more than one sensory modality does in fact result in facilitation of detection. An important accompanying problem under study is whether the nature of the signal input to an additional channel is of importance to the facilitation effect, or whether only the amount of stimulus energy present is of concern. The question asked here can be expressed as follows: Is the facilitation effect merely the result of the cueing function provided by stimulation of the additional sensory channel? Regardless of the nature of the stimulus presented to the accessory sense modality, the presence of the stimulation might serve to alert the observer to the fact that a signal requiring action on the part of the observer was being presented to the primary sense modality. In this manner, the accessory stimulation could provide merely a cue, a signal for action.

Manifest anxiety levels have been shown to have an effect on level of performance in complex stressful tasks (Taylor and Spence, 1952). As the human in a signal detection task could be regarded as performing under varying conditions of stress, degree of sensory facilitation, if any, might reasonably be expected to be influenced by the manifest anxiety level of the operator. The possibility of an interaction between manifest anxiety and signal detection was therefore investigated by preselecting high and low anxious subjects on the basis of scores obtained using the Taylor Manifest Anxiety Scale.

CHAPTER II

A REVIEW OF THE LITERATURE

In a study intended to investigate the effects of simultaneous auditory, olfactory, tactual or pain stimuli upon visual threshold, Hartmann (1933) posited an explanation for the results obtained in terms of a neurological "dual interchange of energy". He reasoned:

> The writer assumes that the activity of any one sense organ does not remain confined there but tends to affect, although in lesser degree, the general plane of excitation of the sensorium as a whole . . . one may suppose that the temporal region is not the only locus of cortical response evoked by an auditory stimulus, but that the remaining brain areas are also aroused, probably through the medium of the so-called association fibers. If, as in this study, the occipital lobe is the primary 'seat' of excitation and the temporal region is also simultaneously thrown into action, a reciprocal exchange of energy occurs in order to preserve neural equilibrium. This would demand that auditory acuity be increased when auxiliary visual stimulation is presented - a consequence which seems probable if the data of this paper be valid (p. 405).

Harris (1948) in a paper presented to the Army-Navy-National Research Council Vision Committee argued that the mechanism responsible for threshold enhancement was neural summation. Neural summation is a phenomenon whereby an increase in sensory intensity results either when two or more stimuli are presented in rapid succession in the case of temporal summation or when two or more stimuli are presented to closely adjacent areas in the case of spatial summation. In either instance the end result can be the enhancement of an otherwise subliminal neural impulse to an above threshold intensity and the resulting propagation of a neural impulse (spike potential).

Prior to a review of the literature in the area of effects of intersensory stimulation it would seem advisable to consider briefly what neurological basis might exist for the position advanced by Harris for interdependence of sensory modalities.

If at one point in the nervous system visual and auditory systems do interconnect, it would be neurologically sound to theorize an influence of one sense on the other. This influence would be manifested through the action of neural summation. It would be equally plausible, within the framework of the neural summation process, to expect that if neural summation between the two senses did occur that this summation would result in an intersensory facilitation effect to some degree.

Helmholtz first described the summation of subliminal stimuli in muscle tissue (Boring, 1950). The phenomenon of summation was shown to function with nerve impulses by Gotch and Burch (1899). Adrian and Lucus (1912), in a paper on summation, suggested the operation of two types of summation. The first a summation of local excitations. Here, a first stimulus is not strong enough to set up a propagated disturbance in the tissue, but produces, instead, at the locus of stimulation an incomplete local change. This change persists for a short time and enables a second stimulus of similar strength to complete the local change and in this way result in a propagated disturbance. The second type of summation suggested by Adrian and Lucus was termed "summation of propagated disturbances". This type of summation was held to be localized at the point of myoneural junction and was held to be due to a second propagated disturbance from the same source of excitation. According to the authors:

> The failure of the first stimulus to cause any visual response in this case (in the case of a propagated disturbance) lies in the fact that between the seat of excitation and the tissue whose response is looked for there lies a region which the first propagated disturbance is unable to pass. The propagated disturbance set up by the second stimulus succeeds in passing this region of block (p. 72).

The type of summation being discussed here was to be described later as synaptic summation (Morgan and Stellar, 1950). In summation of this type, a single propagated disturbance arriving at a neural junction (snyapse) is not sufficiently intense to produce a propagated disturbance in the second neuron across the synapse. The arrival of two or more disturbances at the synapse, either temporally or spatially, results in summation across the synapse leading to establishment of a spike potential in the second neuron. Forbes (1921) was the first to suggest that summation in muscular reflexes was not due to a second response from the same motoneurones, the explanation suggested by Adrian and Lucas, but rather due to other motoneurones which were affected by a central summation of the effects of afferent stimulation. Forbes held the view that:

> Some central mechanism must be excited which continues to transmit impulses to the motor neurones for a long time after the afferent impulses have ceased to come in. We may possibly account for this fact without postulating in the central complex any properties foreign to peripheral conducting paths, if we assume a sufficiently extensive series of branching paths in which conduction is delayed, as it probably is in the synapses. A single impulse might, through extensive branching of the fiber which conducts it, set up other impulses in a large number of central neurones . . . and the synaptic delays in some of the more extensive paths might suffice to account for the observed continuance of the motor response through many seconds (p. 294).

This position of Forbes would provide a possible explanation of intersensory facilitation through neural summation.

In opposition to the conclusions of Forbes, Eccles and Granit (1920) found that after a facilitation stimulus had been terminated, it might still take as long as five seconds for facilitation to subside. The authors felt that this long a time disproved the "delay path" explanation of Forbes. As support for their abandonment of Forbes' explanation, Eccles and Granit called attention to their work with crossed nerves to rectus and vastus medialis as afferents in study of reflex contractions in the vastus medialis of the cat. Stimulation of either nerve alone resulted in no reflex response. When stimulation of the nerve to the rectus ceased the "after-discharge" persisted for 160 microseconds. When stimulation of the nerve to the vastus medialis ceased 75 microseconds before that of the nerve to the rectus the after-discharge was 260 microseconds. Eccles and Granit found that with a larger continuance of stimulation of the nerve to the rectus after concurrent stimulation had ceased it required 4.8 seconds for "sustained facilitation" effects to disappear. The authors pointed to the fact that reinforcing action of one subliminal excitation on the other did not cease when one source of afferent impulses had been terminated. Eccles and Granit concluded, "It is difficult to think that 'delay paths' can be considered when the duration of the after-action is as long as 5 seconds. The excitation of the neurone from one afferent is now able to maintain its supraliminal excitatory state owing to the effect of the previously excited other afferent." (p. 115). They supported instead the position of Sherrington that there is an accumulation of some substance at some locus in the neuron which summates with additional neural excitation to produce an above threshold excitation. As Sherrington's conception was viewed by Eccles and Granit, the accumulation of the substance was able to maintain excitation for some time after cessation of both stimuli. If only one stimulus stopped, the other continued to add the substance at the neuron locus. The rate of addition of the substance alone is unable to result in reaching threshold level, but when added to the amount of substance already present from concurrent stimulation threshold values can be maintained over a longer period of time. In a later study Eccles (1937) described how excitation of a single preganglionic fiber could cause a brief excitatory state in the postsynaptic region of the synapse. This excitatory state was held to spread rapidly but decrementally through the cell body of the neuron by a process which Eccles called a "detonator action". Two or more of these actions, through temporal or spatial summation, were held necessary to bring the excitatory state of the postganglionic fiber to threshold.

In the human nervous system one or more areas do exist in which neural interactions for vision and audition do occur and which might permit this summation process to operate. Ranson and Clark (1963) indicate that there are several points at which the two systems have a very direct connection. As they traverse the midbrain they are in close proximity and do send fibers to the same motor nuclei of the brain stem. In addition to visual and aural pathways ending on the same motoneurones there are fibers from the lateral lemniscus, an auditory path in the brain stem, directly connecting with the superior (visual) colliculus.

Also, there is a tract of fibers in the cortex, the inferior longitudinal fasciculus, connecting the temporal and occipital gyri.

Thus, it would seem that through the summation resulting from simultaneous stimulation of the two senses, a neurological basis could be postulated for the operation of intersensory facilitation.

Historical Background

Evidence for the functional interdependence of the various sense modalities predates knowledge of the summation process in the nervous system. In fact, Hartmann (1934) reports interest concerning the influence of visual stimuli upon auditory functions as early as the year 1669 when an anatomist, Thomasis Bartholinus, reported his findings that partially deaf individuals could hear better in the light than in the dark. More frequently cited (Child and Wendt 1938, Gilbert 1941, and Hartmann 1933, 1934), as the principal forerunner of modern experiments in this area is Victor Urbantschitsch (1888) who reported findings that the sensitivity of the eye to light could be enhanced by simultaneous excitation of the ear. Of this study Gilbert (1941) reports:

> The study . . . attempted to investigate the effects of stimulation in each one of the modalities on the responses of the other modalities - a task never attempted before or since, though it merely made up in scope what it lacked in thoroughness. The results were not very consistent and controls were almost entirely lacking (p. 382).

Even in the light of this criticism by Gilbert, however, Urbantschitsch directed attention to the possibility that simultaneous intersensory stimulation had an effect on visual threshold.

The pioneer work of Urbantschitsch was followed some 20 years later by a study conducted by Heymans (1904) who reported inhibition, not facilitation, as the result of intersensory stimulation. Heymans' study was followed by one performed by Jacobson (1911) who provided further evidence for inhibition as a result of intersensory stimulation.

The inhibition noted by both Heymans and Jacobson was one of weak momentary visual stimuli. The auxiliary stimulus was stronger and was presented simultaneously with the primary stimulus.

In opposition to these findings Hartmann (1933), Newhall (1923), and Thorne (1934) have supported Urbantschitsch's findings that sensitivity of the eye to light could be enhanced by simultaneous stimulation of the ear. Newhall found that presenting a series of five monetary (.1 second) visual stimuli "whose physical value is uniform and approximately at the difference threshold (Gilbert 1941 p. 384)", simultaneously with five clicks resulted in a tendency for more of the visual stimuli to be perceived and to be perceived as brighter than when the visual stimulus was presented alone. Hartmann, working with auditory, olfactory and cutaneous stimuli, found evidence that simultaneous presentation of each with a visual stimulus resulted in a temporary increase in visual acuity.

The major purpose of Thorne's study was to investigate the temporal course of the visual threshold. However, some data were included on the effects of simultaneous stimulation, and from this data Thorne concluded that simultaneous stimulation under certain conditions could facilitate perception of the visual stimulus and result in a lowering of the threshold. Thorne also reported conditions under which he found an inhibitory effect. These conditions were comparable to those reported by Jacobson: under a situation where the auxiliary stimulus was of greater intensity than the primary it assumed the role of figure in a "figure-ground relationship" and exerted an inhibitory effect on the primary stimulus.

Kravkov (1934), who reported in earlier studies finding both a facilitation and an inhibiting effect of an auxiliary stimulus, described an experiment designed to discredit Hartmann's (1933) attack on his earlier studies. Hartmann had stated that his results were "opposed to his (Kravkov's) other finding that a deterioration ensues . . . Not only is the effect uniformly positive; it seems tenatively to be independent of the pitch quality of the auxiliary stimulus (p. 396)."

Faced with this criticism, Kravkov repeated his earlier experiments and verified his results. Of Hartmann's criticism he stated, "we come to the conclusion that neither our experiments (together with those of Gotch and Wilcox), nor the theory expounded in the beginning of the present paper, are disproved by the experiments of G. W. Hartmann (p. 812)." Of Hartmann's experimentation, Kravkov stated, "A close examination of Hartmann's methods of experimenting . . . permits us, however, to call his inferences into question (p. 811)."

Serrat and Karwoski (1936), using the method of constant stimuli and two subjects, reported finding that visual sensitivity was not enhanced by the addition of a simultaneous auxiliary stimulus. They indicated that these findings were somewhat contradictory to expectations based on Kravkov and Hartmann's work. Kravkov and Hartmann both used white squares on black backgrounds and also black squares on a white ground. Both were interested in noticing the effects of an auditory tone stimulus on least noticible interval between squares. Kravkov found an increase in acuity for black squares but a decrease in acuity for the white squares, Hartmann found slight increases in visual acuity under both conditions. Kravkov explained the decrease in acuity with the white squares by making reference to the expansive property of the white patch, the "well known phenomena of irradiation of bright surfaces (Kravkov, 1934 p. 805)." Hartmann explained the increases in visual acuity in terms of a general cortical diffusion from one area to another. Serrat and Karwoski felt that Kravkov's interpretation in terms of areal enlargement might be more reconcilable with their findings than Hartmann's. They held this view on the assumption that sensory interaction might be "of the nature of areal irradiation rather than intensity change" and "may consist in the bringing of new elements into excitation rather than increasing the activity of elements already activated (Serrat and Karwoski, 1936, p. 610)." After making this supposition that size of visual stimulus might be a critical factor, they conceded that their stimulus patch might have been too large to show effects of secondary stimulation due to cortical areal irradiation.

Cason (1936), in a study employing "training of the conditioned response type", investigated whether or not intensity of sensory and associated verbal responses could be modified by apparent intensity changes in a primary stimulus as a result of simultaneous presentation of an accessory stimulus in another sense modality. Training was carried out under four different conditions with visual and aural stimuli as attention stimuli; (1) The subject was instructed only to pay attention to the light and sound as they were repeated together. (2) In addition to paying attention to the light and sound, the subject repeated the words ' light' and 'sound' alternately when the stimuli were presented together. (3) In addition to paying attention to stimuli the subject was instructed to grip hand dynamometers when stimuli were both present and (4) In addition to paying attention, the subject received an electric shock whenever both stimuli were present. The subject was asked, for each presentation series, to judge whether the primary stimulus was the more intense in the first (singular presentation) or second presentation (paired presentation) situation. In each condition the simultaneous visual and auditory responses were evoked a large number of times. Subjects were then tested for the influence of one stimulus on the intensity of the response in the other sense modality. With exception of condition three, which involved an overt motor act, an enhancing effect was found when the auxiliary stimulus coincided with the onset of the main stimulus.

Ryan (1940) in an early review of the literature concluded that research up to 1940 had been concerned with a highly abstract and artificial kind of interaction rather than with "the kind of perceiving of most interest in every day living. The perceiving of objects, scenes, events, and situations (p. 690)." He felt that investigations had been artificially limited to certain aspects abstracted from the total situation and because of this the object of study has been removed from meaningful context. In spite of this criticism he felt that there was sufficient evidence to conclude that there is a positive "dynamic interplay" between sense modalities.

Summary of the Literature

Generally, experimenters have employed one of two approaches in recent studies of the effects of intersensory stimulation. The sensory modalities studied, for the most part, have been vision and audition. The first approach has been to present visual stimuli about a threshold point while simultaneously stimulating the subject aurally with a tone of specific frequency. Interest here has centered on the heightened visual acuity as measured by the effects on visual threshold. The second major design approach has been to present one set of stimulus information visually and a different set aurally. The subject is then tested for comprehension of the two stimulus presentations.

Threshold Determinations

Knox (1945) sought an answer to the question: "Can auditory stimulation alter the critical flicker frequency, that is, can visual flicker be induced by the presence of auditory flicker, under visual conditions which would otherwise give fusion? (p. 139)." Knox found that auditory flicker could enhance visual flicker which was already present but could not produce visual flicker under stimulation conditions normally giving visual fusion.

Little attention was given to the topic of intersensory stimulation in the United States in the immediate post-World-War-II era. However, such was not the case in the Soviet Union. London (1954), in an exhaustive review of Soviet research which contained 506 references reported on Soviet efforts spaning the years 1930 to 1954. Of the studies reviewed, 193 appeared after 1945. The Russian approach has been directed solely at threshold determinations of sense modalities in the presence of auxiliary stimulation. Soviet investigators have studied such topics as the absolute sensitivity of central and peripherial vision, critical flicker frequency, irradiation effects on vision produced by accessory stimulation, and auditory sensitivity. A large majority of the papers report evidence for a positive effect of accessory stimulation. Most work has been concerned with the modalities of vision and audition; however, work employing other sense modalities in relation to threshold determinations has also reported positive results.

Of the Russian work London states:

> It is true that much of the Soviet work on sensory interaction adheres to standards of execution, reportage, and interpretation that would be quite unacceptable to the western researcher. As a matter of fact, even a casual survey of the Soviet literature yields ready evidence of inadequate instrumentation and methodology, scanty detail, and a primitiveness in the statistical treatment of data which makes anything beyond an arithmetic mean a rare encounter.
>
> Nevertheless, western work on sensory interaction has been, in the main, scattered and desultory, whereas in the Soviet Union the subject has been given systematic and sustained attention (p. 531).

In addition to experimental investigations, much Soviet attention has been directed toward theorization. Here the Soviet effort has been less systematic. No intergrated set of relevant explanations has been put forth to cover the threshold modifications observed as a result of application of auxiliary stimulation.

Introducing their study by calling attention to the amount of contradictory evidence in the area of intersensory facilitation, Gregg and Brogden (1952) sought to investigate conditions under which an auxiliary stimulus facilitates or inhibits threshold sensitivity. Two experimental conditions were established, one in which the subject was instructed to report the presence of both the primary (auditory) and the auxiliary (visual) stimulus and one in which only the presence of the primary stimulus was reported by the subject. It was found that threshold sensitivity to the primary stimulus was enhanced when the subject was not required to report the presence of the auxiliary stimulus; however, if verbal report of both stimuli was required, then threshold sensitivity to the primary stimulus was decreased. This finding, that the positive or negative effect of an auxiliary stimulus depended on the nature of instructions given to the subject, was not verified in a later study (Thompson, Voss and Brogden, 1958).

O'Hare (1956) investigated the effects of chromatic change on the audible threshold. He found significant auditory threshold shifts as a result of the chromatic shifts. From this he concluded that chroma was of importance in determining auditory threshold. However, O'Hare's experimental procedure did not exercise adequate control over the variables employed as there was no control over brightness. Effective brightness (a measure of the amount of light emitted from a surface) was allowed to vary from 87.4 foot-lamberts for yellow to 10.9 for red. O'Hare failed to recognize this confounding in his design and used an improper statistical analysis in that in failing to control for brightness he cannot clearly determine whether his results were due to color differences or whether his subjects were responding to the brightness differences alone.

Forrest (1957), in a study inspired by the research of a number of investigators in the area of perceptual defense, sought to determine the effects of auditory familiarity on visual threshold. Using a sample of 15 subjects, a number of nonsense syllables were presented a varying number of times. Frequencies of repetition for four groups of syllables were 200, 25, 5, and 0 repetitions. The finding was that visual threshold was affected by auditory frequency. As Forrest found a fall in threshold which continued over the range of repetitions used, he took exception to the Solomon and Postman (1952) conclusion that the enhancement effect is present only in the lower end of the frequency scale.

Thompson, Voss and Brogden (1958) attempted to extend and clarify the results obtained by Gregg and Brogden (1952). The Gregg and Brogden study held that threshold sensitivity to a primary stimulus was enhanced when the subject was not required to report the presence of an auxiliary stimulus. If verbal report of both stimuli was required then threshold sensitivity was decreased. The earlier investigation had used three light intensities and studied their effects on auditory sensitivity. Thompson, Voss, and Brogden used essentially the same apparatus, but extended the number of light conditions to eight. Support was found for Gregg and Brogden's conclusion that instructions to respond to both primary and auxiliary stimuli results in an inhibitory effect on auditory threshold. However, the study found no support for the second conclusion of Gregg and Brogden: that presentation of an auxiliary stimulus in the absence of instructions to respond to it results in enhanced sensitivity to an auditory stimulus. In contradiction to a number of earlier studies, Thompson, Voss, and Brogden found that the addition of an auxiliary stimulation produced no effect on threshold.

The effects of sensory interaction on critical flicker fusion frequency were studied by Levine (1958). His results supported other research on threshold determination, i.e. simultaneous stimulation resulted in a lowered threshold for fusion.

Criticizing experimental techniques of earlier studies, Özbaydar (1961) designed an experiment to investigate the effects of low (25 foot-candles) and high (100 foot-candles) illumination on audition. In this study the effects of light on absolute, differential and masked auditory thresholds were investigated. To obtain a masked threshold the test tone was masked by white noise. It was found that there was a consistent advantage with high illumination. For each of the three types of threshold measures obtained the mean sensitivity of the subjects was greater in the high illumination condition.

In a very elaborate study of the contralateral relationship between audition and halves of the visual field, Maruyama (1961) supported the phenomenon of intersensory facilitation. He found that application of a tone to one ear heightened visual sensitivity only in the opposite side of the visual field. Illumination of the right visual periphery affected aural threshold for only the left ear. These findings would seem to lend support to the argument for neural summation provided earlier.

Symons (1963) studied the effects of a number of heteromodal stimuli on visual sensitivity. He reported finding that, with the exception of olfaction, all stimuli produced an increase on visual sensitivity. In this experiment a 1,000 cycle-per-second tone 60 decibels above threshold was used as the auditory auxiliary stimulus.

Using a monitoring task as the vehicle for investigation, Klingberg (1963) found a higher probability of detection existed when a combined visual and auditory presentation was made than when all signals were presented via a uni-sensory presentation. In this study one of the results was in disagreement with most other research - better performance was found for auditory stimulation than for visual.

In an attempt to relate conventional signal detection theory to the problem of intersensory stimulation effects, Treisman (1964) studied the extent of shift in detection rate as a function of interstimulus interval. He found that if an accessory stimulus regularily preceded the primary stimulus at a fixed interval then the shorter the interval, the lower the threshold for the primary stimulus. This variation in threshold level was considered in terms of the model of the threshold for the selected task which was provided by application of signal detection theory. With application of this theory, Treisman was able to predict the extent of shifts in detection rate resulting from altering the interstimulus interval from one of relatively long duration to one approximating simultaneous presentation.

In two studies on the effects of white noise on signal detection (Watkins 1964, Watkins and Fechrer, 1964) it was found that detection was better when noise was present only during the observation periods than when constantly present. Unfortunately no presentation condition involving only a visual signal was included for comparison with detection performance under dual presentation conditions. These studies can be compared with the previous studies reported, as the only function served by the white noise was to provide auxiliary stimulation. This is especially true of the intermittent noise condition which was found to result in increased sensitivity for detection of the visual signal.

Simultaneous Presentation of Dissimilar Material

The study of the effects of simultaneous presentation of dissimilar material is the second approach in the literature concerned with intersensory stimulation. Here the object of investigation has not been the end result on threshold determination, but rather the possibility of presenting information through more than one sense modality in an effort to increase human capacity for data handling. Because of the contemporary nature of this orientation it can be inferred that this area of research has occupied the attention of psychologists for a briefer and more recent period of time than has interest in threshold effects. This is in fact the case. The studies appearing under this second approach can be further subdivided into two categories. This categorization is made in relation to the nature and purpose of the accessory stimulation: whether it has content as meaningful as that contained in the primary stimulus, though dissimilar, and requires an independent response; or whether, though meaningful, the purpose of the accessory stimulus is to serve only a cueing function to the primary stimulus.

Accessory Stimulation with Independent Meaningful Content

The first reference in the literature to the simultaneous presentation of dissimilar material appears to be that of Herman and Broussard (1951). Ninety-six subjects were presented with two types of serial order learning tasks, one a tone series and one a picture series using line drawings. The authors found a significantly greater number of trials and errors for learning when the two series were learned together than when either was learned alone. Broadbent (1952) studied the problem of using either an auditory or visual cue to identify the one relevant of two simultaneously presented auditory messages having different content. The finding was that with only an auditory cue to identify the proper message, identification and answer of the correct message was less than 50 per cent. With the addition of a meaningful visual cue the answer rate increased to 70 per cent.

Mowbray (1952) simultaneously presented either an auditory number sequence and a visual alphabet sequence or a visual number sequence and an auditory alphabet sequence. Both alphabet and number sequences had been overlearned in prior single mode presentations. The subject's task was to detect missing elements in the visual or aural sequences when both were presented simultaneously. Mowbray found that there were more errors with alphabet sequences than with numerical sequences for nonsimultaneous presentation. In addition, the subjects exhibited significantly more aural than visual errors with the number sequence. There was no difference between visual and aural errors with presentation of an alphabet sequence. With simultaneous presentation of sequences, the absolute number of errors with auditory material was higher than for visual material. However, when compared with nonsimultaneous performance, there was a large increase in both visual and auditory errors.

In a later experiment the same author (Mowbray, 1953) employed simultaneous presentation, both visually and aurally, of two dissimilar prose passages with varying levels of difficulty. Difficulty level was determined, in part, by the Flesch readability formula. Mowbray reported finding a greater deterioration for easy material than for complex, a finding also claimed in his earlier study. Deterioration was measured on the basis of responses to ten questions asked about each presentation.

Accessory Stimulation as a Cueing Function

Klemmer (1958), in a study designed to investigate time sharing between auditory and visual channels, found some evidence of improvement in performance with simultaneous presentation of coded material to both channels, as opposed to performance with time-sharing or single channel presentation. In this study Klemmer hypothesized that simultaneous presentation could be effective only if the material presented in the separate channels was of the same order of difficulty. Support for his hypothesis was provided with the finding that when difficulty levels of the material being presented in each sensory channel were varied, the enhancing effect of simultaneous presentation disappeared.

Using auditory cues in conjunction with a visual task to indicate the quadrent location of the task on a vertical display surface, Mudd and McCormick (1960) found that visual search time was appreciably lowered by the existance of the auditory cue. Five auditory conditions were employed, and were as follows: (1) The auditory tone was present but was not modulated i.e. - it did not include any cueing dimensions, (2) A direction dimension was included by presenting tone to right (task on right half of display surface) ear or left ear, (3) A frequency dimension added to tone to cue for upper or lower portions of display, (4) A duration dimension added to tone as a cue to location within the display quadrent, and (5) All tonal cue conditions combined. The authors concluded that simultaneous presentation of a cueing stimulus does result in more efficient visual performance.

Adams and Chambers (1962) tested response of the subjects to simultaneous stimulation of two sense modalities. The task was to respond with one hand to a visual stimulus, with the other hand to an aural stimulus. The concern in this investigation was whether the responses with simultaneous stimulation would be the same as when each stimulus was presented separately and required a one-hand response. The experimental results showed a superiority of bisensory over unisensory responding when the stimulus was certain. When the stimulus was uncertain, for example a red or green light used instead of a white light, the response times were inhibited instead of enhanced.

In the only study in this topical area which used infrahuman subjects, Smith and Bird (1964) measured responsiveness of chicks to combinations of visual and auditory stimuli. Their findings were that all groups studied showed greater improvement in approach behavior when auditory and visual stimuli were presented together than when either stimulus was presented separately.

Anxiety and Effects of Anxiety on Performance

Psychologists investigating the effects of anxiety on performance have obtained results more in agreement than is true for findings relating to the effects of simultaneous stimulation of sensory modalities. It is generally concluded that anxious subjects perform less well than nonanxious subjects on more complex problems. The Taylor Manifest Anxiety Scale has been the instrument most widely used to measure anxiety in the studies reviewed. In fact, this instrument has become perhaps the best known and most widely used of the current scales for measuring anxiety.

Taylor and Spence (1952), using the scale developed by Taylor (1953), showed that in a serial learning task the number of errors made was much greater for the anxious subjects than for the nonanxious for difficult choice points, for the easiest choice points: the anxious subject made fewer errors than the nonanxious.

Montague (1953), using three verbal learning tasks in which difficulty was varied by manipulating intralist similarity and association value of nonsense syllables, tested anxious and nonanxious subjects on the number of trials required to learn to criterion. His results supported the earlier findings of Taylor and Spence - anxious subjects performed less well than nonanxious on the difficult list but surpassed them on the easy list.

Using a test instrument of their own design Kaye, Krischner, and Mandler (1953) studied the effects of test anxiety on memory span in a group test situation. Differential effects of anxiety levels in group testing were observed which were in agreement with earlier findings obtained under individual testing conditions: the low anxiety group performed significantly better than the high anxiety group. In this study 28 memory span tests were used and included 10 number series, 10 mixed number and letter series, and 8 word lists. Ramond (1953) used a series of stimulus words to which the subject could respond with either of two given response words. The response words were selected so that one was relatively high in an initial response hierarchy and the other relatively low — i.e., stimulus word: tranquil, response words: serene (high), rugged (low). Performance was observed on two different kinds of presentations: (1) the stronger of the two responses was correct, and (2) the weaker of the two was correct. He obtained results in line with the majority findings: nonanxious performed better on the more complex task (condition 2) than did anxious subjects.

Korchin and Levine (1957) used three subject groups in a verbal learning situation: (1) low anxious college students, (2) high anxious college students, and (3) subjects selected from a hospital psychiatric patient population. Again the results supported earlier findings. The high anxious performed less well on the more complex tasks.

Makres (1961) used a discrimination learning task in a test of the Taylor-Spence (1952) hypothesis on the interaction of anxiety level, drive, and learning task complexity. Taylor and Spence held that with a simple task increased drive produced a higher level of response for higher anxious subjects than for low anxious. As task complexity increased, competing response tendencies were introduced, and establishment of a higher drive level resulted in poorer performance for high anxious subjects than for low anxious. The discrimination learning task used by Makres involved an apparatus on which subjects had to learn light-switch combinations. In the test phase, subjects had to master altered light-switch combinations. The inference was made that interference of stimulus response connections made in original learning would be greater for high anxious subjects during the test phase. The results obtained by Makres upheld the general finding with regard to anxiety and performance. High anxious subjects performed less well than low anxious on complex tasks.

Discussion of the Review

Fitts (1951) brought the issue of intersensory stimulation into a meaningful context for engineering psychology. He discussed the need for systematic investigations of combined visual and auditory displays and concluded, "the judicious combination of visual and auditory displays in various kinds of tasks remains however, an interesting, if relatively unexplored, possibility (p. 1314)."

In reviewing the literature just cited one can readily agree with London's (1954) conclusion that research on sensory interaction has been rambling and inconsistent. The relatively few studies in the area have not provided much more definitive answers than were available from the pioneering work of Urbantschitsch (1888).

While the literature cited would seem to favor the position that simultaneous stimulation does have a positive enhancing effect on threshold determination, there are enough findings of an inhibitory effect to leave the question of facilitation very much unsettled. This can be exemplified by Harris (1948) who, after reviewing the literature, concluded that intersensory facilitation was both logical and probable and by Licklider (1961) who opposed the Harris position in summarizing evidence supporting his conclusion of an inhibitory effect resulting from intersensory stimulation.

On reflection the research reporting the use of dissimilar material may not be as unsettled as it initially appears. Klemmer (1958) provided what may prove to be the clue to a more complete understanding of the results in this area. In his study he controlled for the difficulty level of the dissimilar material employed. Under these conditions he found an enhancing effect of simultaneous presentation. This effect disappeared when the difficulty levels of the respective stimulus materials were varied.

Questions Pertinent to the Problem

This research is concerned with two areas of concentration, the first being an investigation of the effects of intersensory stimulation on performance of a signal detection task. The second problem area is that of the importance of the nature of the signal input to the auxiliary channel. As a result of review of the literature cited, the following specific questions were developed in relation to these problems. 1) Is visual presentation of identical stimuli superior to auditory presentation? In seeking answer to this and the following questions, superiority of a presentation condition is established by subject performance in a signal detection task in which immediate recall of the correct order of presentation of a digit series is the dependent measure. 2) Will simultaneous presentation of a meaningful auditory stimulus plus a visual cue result in better performance than auditory presentation alone? 3) Will performance with a simultaneous meaningful visual stimulus and an auditory cue be better than for vision alone? 4) Does simultaneous presentation of the same stimulus to both vision and audition facilitate detection and recall? Does this condition result in the best performance of any presentation condition? 5) Is performance under simultaneous presentation of a meaningful visual stimulus and an auditory cue better than for simultaneous presentation of a meaningful auditory stimulus and a visual cue? 6) Is performance of high anxious subjects different from that of low anxious subjects? Will the low anxious perform better?

CHAPTER III

METHOD

Subjects

Approximately 850 students at Oklahoma State University enrolled in courses in Introductory Psychology were tested by means of the Taylor Manifest Anxiety Scale (TMAS) to obtain the required number of subjects in each anxiety condition. Sample items from the TMAS are shown in Appendix A. Only volunteer male students were used as subjects and were run on an individual basis at times convenient to the subject. Nineteen subjects were used for each anxiety level. Sample size was chosen in part on the basis of distribution statistics obtained in a pilot study. Figure 1 shows the position and range of the two student groups superimposed on a frequency polygon of subject scores used by Taylor (1953) as normative data for her scale. Subjects selected for the low anxious group were those scoring between 0 and 10 on the TMAS. High anxious subjects had scores between 26 and 30. No student having a lie score above 7 was chosen as a subject.

Apparatus

The experimental apparatus consisted of three basic units: (1) slide projector, (2) tape recorder with headphones, and (3) projection screen. A schematic of the equipment configuration appears in Appendix

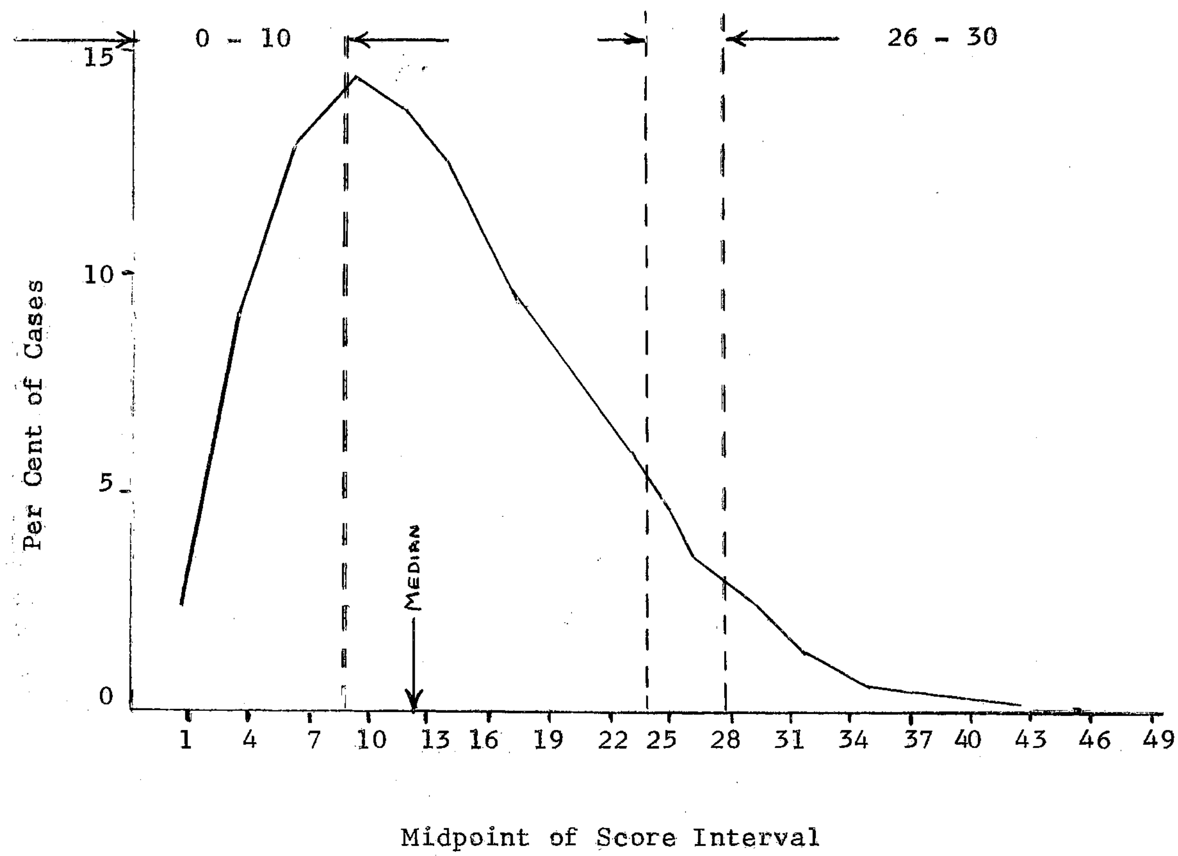

Fig. 1 - Frequency Polygon of TMAS Scores for 1971 Students Used as Normative Group by Taylor (1953) with Experimental Subject Groups Indicated (0-10 Low Anxious, 26-30 High Anxious).

B.

Black and white 35 millimeter photographic slides were prepared for visual presentation of the random numbers used in the experiment. Each slide had one white digit centered on a dark grey field. Digit style adhered to Air Force-Navy Design (AND) 10400 (Baker and Grether, 1954). The numbers were 2.25 inches in height and had an aspect ratio (the ratio expressed by the height, width and stroke width of the number) of 8:6:1.

An Ansco slide projector equipped with a Sylvania CZA 500 watt lamp was used to project the slides. Exposure duration was 500 milliseconds.

A Wollensak model 1570 monophonic tape recorder was used to provide both the instructions to the subject and the auditory portion of the stimulation. The voice portion of the tape was recorded at 70 $\pm$ 5 decibels. White noise, used as background for the aural stimulation conditions, was held constant at 70 decibels (Referent: .0002 dyne per square centimeter). A General Radio Company model 1551-C sound level meter equipped with a Shure model 98108 non-directional microphone was used to control decibel level of the recording. A complete script of the recorded material appears in Appendix C. The taped auditory cueing tone used in condition 4 of the experiment was 440 cps tone, the standard musical "A".

Air Force type H-157/AIC headphones were worn by both the subject and the experimenter.

A standard "Da-lite versatol deluxe" projection screen was used in conjunction with the projector.

Experimental Design

A 2 x 5 factorial arrangement having repeated measures over subjects was used for the experimental design. Factor A was anxiety level and was tested at two levels, low anxious and high anxious. Factor B was the treatment plans with B_1 = visual presentation, B_2 = auditory presentation, B_3 = the combined presentation of meaningful visual and auditory stimuli, B_4 = the combined presentation of a meaningful visual stimulus and an auditory cue, and B_5 = the combined presentation of a meaningful auditory stimulus and a visual cue.

The stimuli presented were a number of digit series. These digits were randomly selected unit digits arranged in series progressing from three to ten digits.

The dependent variable in this study was the number of digit series of increasing length which could be correctly reproduced in the order presented.

In this experiment the necessity of counterbalancing order of presentation of the treatment plans was given careful review. When a learning effect carries over from one treatment to another, the order of presentation of treatments should be counterbalanced to eliminate this source of biasing in the data. Though immediate recall of a random digit series was used as the response measure in this experiment, the major concern was not in recall per se, but, rather, in arriving at a measure of the ability of the subject to recognize correctly the degraded stimulus under the various conditions of presentation. Each recognition condition of the experiment was felt to be sufficiently different, i.e., each involved either a different sensory modality or different type of stimulus in the same modality, to a degree which would not cause one to suspect the existence of a practice effect carrying over from condition to condition. Winer (1962) advocates counterbalancing when practice effects are suspected, but presents a strong caveat regarding the appropriateness of a repeated-measures design when one is forced to counterbalance.

In an attempt to provide credibility to the assumption of absence of a practice effect between conditions of the experiment, the writer performed an analysis of variance for recognition scores obtained by the subjects for the initial series of three digits presented in each of the five experimental conditions. A summary of the results of this analysis together with raw scores of the subjects are presented in Appendix E. The data summary table and the summary of the analysis of variance indicate a significant effect of presentation condition coupled with a distribution of results which would not be anticipated if performance were being enhanced by the effects of practice. The writer concluded that the assumption of no confounding effects due to practice was a tenable one.

Procedure

Prior to beginning the main experiment the projector was set in an out-of-focus condition. The resolution of the projected stimulus was degraded to the point where the probability of detecting the presence and providing correct recognition of the stimulus was equal to that for an auditory presentation of the same number. The required setting was empirically determined from the responses of five subjects who did not participate in the main experiment. This procedure was followed to provide a visual detection-recognition problem of compatable difficulty with auditory stimulus presentations. The point of focus determined in this manner was used for all subjects in the experiment. To obtain the maximum degree of standardization in the experimental situation, conversation with the subject prior to the experiment was limited to an introductory greeting. The subjdct was informed that complete instructions for the experiment were contained on the experimental tape. He was requested to sit on the designated chair and don the headphones. All further instructions to the subject were prerecorded and appear in Appendix C.

The auditory stimuli were prerecorded on the tape and presented to the subjects by means of headphones. The headphones were worn throughout the experiment. Wearing the headphones during the visual as well as the aural portions served two purposes: (1) damping any extraneous aural stimuli during the visual phase of the experiment, and (2) making the environmental stimulus conditions as uniform as possible for all phases of the experiment. To compensate for any unmeasured hearing defects in the subjects the intensity of aural input to the headphones was adjusted to each subject's preference. Two subjects requested a change from the established setting of 4 on the volume control of the recorder.

The sequencing of the visual stimuli for condition 1, 3 and 4 was controlled by the experimenter. Digit series were sequenced at the fastest machine speed. At this setting, the sequence of presenting a digit, i.e., advancing from a no-projection condition to projection of a particular digit and return to a no-projection condition, was completed in 1800 milliseconds. Actual exposure time of the digit was 500 milliseconds. The insertion of a masked slide after each digit series in a projector magazine allowed the experimenter to effectively blank the screen after each series presentation simply by advancing the magazine to the next position.

The projector fan motor was allowed to run at all times during the experiment in order to provide a more uniform background noise.

When the subject was seated and the headphones were in place, room lights were extinguished and the recorder started. The instructions section of the recorded tape informed the subject of the nature of the experiment, described the five experimental conditions, and told the subject what response was expected of him. He was then instructed to raise his hand if he did not understand the procedure and the recorder would be stopped and his questions answered.

The recorded experiment then moved to the trial series preceding condition 1 (visual presentation of the digit series). After presentation of the trial series, the subject was again instructed to raise his hand if he didn't understand the procedure. The tape then began condition 1. The first series presented was a series of three digits, the same length as the trial series. In this, and in all digit-series presentations, the subject was never exposed to more than one digit at once. Each digit was sequentially exposed until all of the digits in the particular digit series had been presented. After presentation of this first series, the subject had 15 seconds to repeat the numbers before the next digit series appeared. Each digit series was increased in length by one number. Longer digit series were presented until the subject failed to repeat the series correctly. At this point condition 1 ended. The recorder was stopped at the point of subject failure and the tape moved to the end of the recorded condition by means of the rapid advance control. After a one minute rest the subject was exposed to condition 2. The procedure just outlined was repeated for each of the remaining presentation conditions.

Condition 2 entailed only the auditory presentation of the series of digits through headphones. Condition 3, the presentation of the digits visually and aurally at the same time. Condition 4, a visual presentation of the digits coupled with the sounding of the 440 cps tone through the headphones at the time each digit appeared on the screen. Condition 5, an aural presentation of the digits through the headphones with the projection of a visual stimulus pattern (the letter X) at the time the digit was read to the subject.

In all presentation conditions of the experiment the subject had fifteen seconds to repeat the digit series just presented before another digit series appeared. The subject was given a one minute rest after each presentation condition. The duration of the complete experiment was 35 minutes. The response measure employed was correct recall of the digit series in the order presented. Thé subject's responses were recorded on a data sheet by an observer who assisted the experimenter.

CHAPTER IV

RESULTS

In this section the results of the statistical analyses of the data are presented. An analysis based on a 2 x 5 factorial arrangement with repeated measures on the second factor, the stimulus factor, was the major statistical technique employed. The five levels of the stimulus factor involved visual and auditory stimulation which were presented in the following manner: (1) meaningful visual stimulus alone, (2) meaningful auditory stimulus alone, (3) combined presentation of meaningful visual and auditory stimulus, (4) combined presentation of meaningful visual stimulus and an auditory tonal cue, and (5) combined presentation of meaningful auditory stimulus and a visual cue.

To justify the use of a repeated-measures design it is necessary to defend the assumptions underlying the design. The repeated-measures design makes the assumptions of homogeneity of variance, homogeneity of covariance and equality of covariance.

A test of the assumptions of homogeneity of variance and equality of covariance was made by means of Hotelling's T^2 test (Winer, 1962). This test showed the absence of any significant departure from homogeneity or equality (.01 level). Homogeneity of variance was also verified by application of Hartley's F max test (Winer, 1962). Winer (1962) indicates that, if an experimenter questions the homogeneity of covariance in the underlying population, a method developed by Greenhouse and Geisser (1959), which avoids assumptions about equal covariances in the pooled variance-covariance matrix, may be used. Critical values for within-subject tests using the Greenhouse and Geisser method are shown in Table I. Even with the more conservative, negatively biased test the effects of presentation conditions, as shown in Table II, remained statistically significant.

The criterion measure employed in this study was correct recall of a digit series in the order presented. The numerical score assigned to the subject was the actual number of series correctly recalled. With this system of scoring a subject getting all series correct would receive a score of 8. In this experiment a range of scores from 0 to 7 was obtained. Figure 2 gives the mean scores for each presentation condition by anxiety level. Inspection of the histogram indicates that, with the exception of condition 4, low-anxious subjects showed better performance than did the high-anxious. However, as reflected by the analysis-of-variance summary in Table II, this difference in performance between low and high anxious subjects was not a real difference, i.e., these two groups were not statistically different. The obtained F ratio for the comparison of differences between these groups was 2.1517 (Table II). A minimum value of 4.12 is required for significance at the .05 level of confidence.

The summary of the analysis of variance depicted in Table II indicates that the effect of the condition of stimulus presentation was real and that the statistical significance obtained was far beyond the .01 level.

TABLE I

CRITICAL VALUES FOR WITHIN SUBJECT TESTS

Hypothesis	Conservative Test	Ordinary Test
$6^2b = 0$	$F_{.01}\ (1,36) = 7.41$	$F_{.01}\ (4,144) = 3.46$
$6^2ab = 0$	$F_{.01}\ (1,36) = 7.41$	$F_{.01}\ (4,144) = 3.46$

TABLE II

SUMMARY OF THE ANALYSIS OF VARIANCE

Source	df	SS	MS	F
Between Subjects	37	107.874	2.91551	
A (Anxiety Level)	1	6.084	6.08400	2.1517
Subjects Within Groups	36	101.790	2.82750	
Within Subjects	152	264.000	1.73684	
B (Presentation Condition)	4	164.874	41.21850	64.5896
AB	4	7.231	1.80775	2.8328
B x Subjects Within Groups	144	91.895	.63816	
Total	189	371.874		

Conservative F Values

$F_{.01}$ (1,36) = 7.41

$F_{.05}$ (1,36) = 4.12

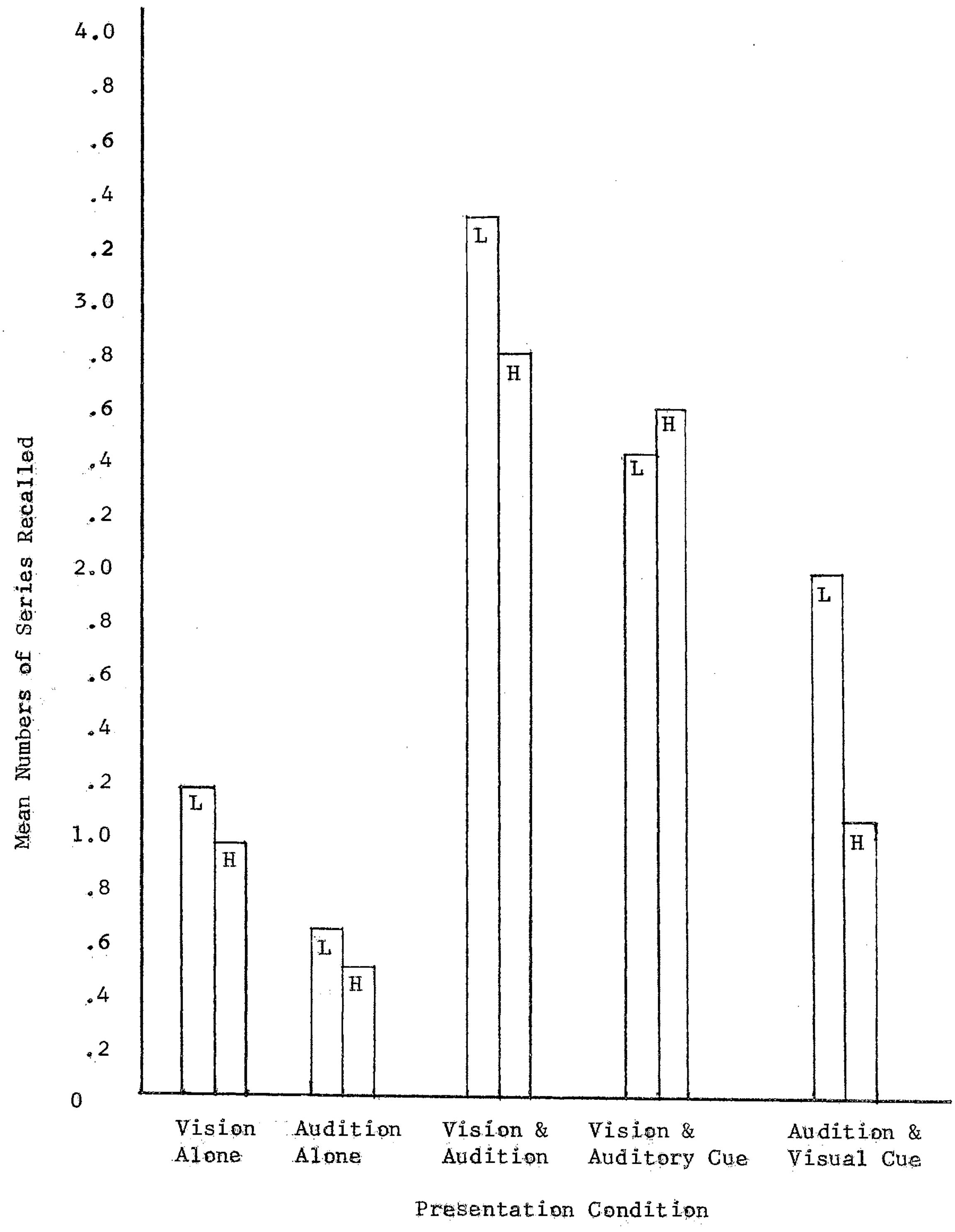

Fig. 2 - Mean Number of Series Recalled for High and Low Anxious Subjects Under Each Presentation Condition (L = Low Anxious, H = High Anxious).

With the existence of statistical differences between presentation conditions established, the individual conditions were compared to obtain information on the pattern of differences that occurred. Two main approaches were employed to make these comparisons: (1) a least significant difference (LSD) analysis (Steel and Torrie 1960), and (2) the Student-Newman-Keuls test of differences between all possible means (Winer 1962). With the LSD the critical value required for a significant difference is .4315. For all comparisons the obtained values ranged from .4737 to 2.5263. As the LSD is less conservative than the Student-Newman-Keuls method, the latter test was also run. The results are given in Table III. It can be seen from the pattern of asterisks that with the exception of the comparison between conditions 1 and 5, all of the comparisons made were significant.

The patterning of the differences reflected in Table III provides evidence for a positive answer to the question of whether the simultaneous presentation of both visual and auditory meaningful stimuli results in the best performance of any presentation condition. It can be readily seen that the highest mean response occurred under Condition 3. This same conclusion is reached when an orthogonal contrast is made of Condition 3 with all other conditions. This contrast appears in Appendix D.

For single presentation modes, an answer was sought to the question of whether visual presentation would be significantly different from, and superior to, auditory presentation. Both the LSD and the Student-Newman-Keuls tests would permit the conclusion that the visual presentation mode was superior to the auditory mode.

TABLE III

STUDENT-NEWMAN-KEULS TEST ON PRESENTATION CONDITION MEANS

	II	I	V	IV	III
Ordered Means	.5526	1.0526	1.5263	2.5263	3.0789
II		.5000	.9737	1.9737	2.5263
I			.4737	1.4737	2.0263
V				1.0000	1.5526
IV					.5526

Truncated Range		2	3	4	5
r = (K, 144)		.4810	.5460	.5850	.6123

II		*	*	*	*
I				*	*
V				*	*
IV					*

A further question investigated in this study was whether the simultaneous presentation of a meaningful auditory stimulus plus a visual cue would result in better performance than for auditory presentation alone. The difference between means here was .9737. With the obtained order of ranking of means a difference of .5460 was required for significance. Thus, these data indicate that simultaneous presentation of a meaningful auditory stimulus plus a visual cue does result in better performance. A similar significant difference resulted from the comparison of a visual stimulus alone with a simultaneous meaningful visual stimulus and auditory cue.

Presentation of a visual stimulus accompanied simultaneously by an auditory cue led to better performance than did presentation of a meaningful auditory stimulus and a visual cue. The obtained mean difference was 1.000, whereas a minimum value of .4810 was required for a significant difference.

From inspection of the summary data in Table II it can be seen that the AB interaction, though nonsignificant, has a sizable F ratio. As a result, it was decided to isolate the factors contributing most to this interaction tendency. It was not possible to make the assumption that the treatment plans were equally spaced along a psychological continuum. For this reason, the usual procedure of a trend analysis (Winer, 1962) could not be followed. In place of a trend analysis, separate analyses of variance comparing the various presentation conditions were made. Through this procedure it was found that conditions 4 and 5, each of which involved the combination of a meaningful stimulus and a cue, were interacting with anxiety level of the subjects in a manner which served to balance out the effects of anxiety on performance. No other conditions showed this interaction. The summary of the analysis of variance for conditions 4 and 5 is shown in Table IV.

TABLE IV

SUMMARY OF ANALYSIS OF VARIANCE FOR CONDITIONS 4 AND 5

Source	df	SS	MS	F
Between Subjects	37	59.947		
A	1	2.579	2.5790	1.618
Subjects Within Groups	36	57.368	1.5936	
Within Subjects	38	44.000		
B	1	19.000	19.0000	36.708
AB	1	6.368	6.3680	12.303
B x Subjects Within Groups	36	18.632	.5176	
Total	75	103.947		

Conservative F Values

$F_{.01}$ (1,36) = 7.41

$F_{.05}$ (1,36) = 4.12

CHAPTER V

DISCUSSION

The present investigation was conducted with the purpose of testing the effects of simultaneous presentation of signals of different modalities on detection under noise conditions. This problem assumes theoretical importance in the design of complex communications systems where human performance must be dealt with as one of the system limitations. In such a situation the system designer seeks a method for maximizing the performance of the human component in the system. Both Fitts (1951) and Morgan et al. (1962) have discussed in some detail the need for experimental data to provide definitive statements regarding the effect of multisensory inputs on human performance.

This investigation has provided strong support for the position that human detection and recognition under noise conditions may in fact be improved through the simultaneous use of more than one sensory channel to relay information to the brain. That the simultaneous presentation of the same information both visually and aurally results in better performance than any other presentation condition is reflected in the data presented in Table III and Appendix D.

This research sought an answer to the question of whether any condition involving simultaneous presentation of information by means of more than one sensory modality would result in better performance than that obtained for a single channel presentation. A comparison of values given in Table III shows that any form of simultaneous presentation does result in significantly better subject performance. Unfortunately, the nature of the results does not permit a definitive statement with regard to an important accompanying problem concerning intersensory facilitation, i.e. the question of whether the nature of the signal input to an additional channel is of importance to the facilitation effect or whether only the presence of a stimulus is important. The comparison of treatment conditions presented in Table III would seem to indicate that with multisensory presentations the nature of the signal input is of prime importance. However, in the design employed in this investigation the amount of information presented to the subject under each condition was not rigidly controlled. An experiment where this control is effected, perhaps through the application of information theory in an attempt to equate information presented in Condition 3 (where both meaningful visual and aural stimulation is present) with that in Conditions 4 and 5 (where only one sensory modality receives a meaningful stimulus), is required to provide evidence directly related to this problem. A design of this type has, to date, apparently not been employed. The closest would appear to be the work of Klemmer (1958) in which dissimilar material was used but controls for level of difficulty were exercised. He found some evidence for improvement in subject performance under simultaneous presentation conditions.

The prediction that performance of high-anxious subjects would be significantly poorer than that of low-anxious subjects was formulated on the basis of strongly documented experimental results reported in the literature (e.g., Taylor and Spence, 1952; Ramond, 1953; Markes, 1961). This prediction was tested in null-hypothesis form and the data showed that the null hypothesis could not be rejected. Thus, the results of this study do not confirm the majority-finding with regard to the effect of anxiety level on performance. Review of the data and the experimental variables suggests certain explanations for this lack of consonance with the results of other studies. First, the possibility exists that the complexity of the task may have been overestimated. The nature of the instructions given the subjects (Appendix C) may not have resulted in a situation regarded by the subjects as sufficiently complex or stressful to result in exhibition of situational anxiety. A second, and it seems to the writer more plausible, explanation is that the subjects chosen for the high anxious group were not functioning in a range far enough removed from the median to be susceptable to the disrupting effects of anxiety on complex performance tasks. The choice of a more extreme group than the one depicted in Fig. 1 may have more adequately demonstrated the interrelation between anxiety, stress and complexity demonstrated by earlier researchers. It is probable, however, that the group selected would be more typical of the high-anxious people in the population encountered in complex communications systems. Taylor (1953) has indicated an increasing positive relationship between high-anxious scores on the TMAS and clinical judgment of either neurotic or psychotic requiring therapy. The median TMAS score for the group judged either neurotic or psychotic was approximately 34, a figure which would be at the 98.8 percentile for the normative group used by Taylor. Thus, individuals above the upper limit of a score of 30, used in the experiment, would probably not be assigned to positions in complex communication systems, or, if assigned, would not survive in the job.

The question of the underlying physiological basis for facilitation as a result of intersensory stimulation was considered earlier in this paper (Chapter II). The fact that this experiment has shown that any simultaneous stimulation of visual and auditory receptors leads to better performance than any stimulation of a single sense seems to lend further support to the position advanced by Harris (1948), which views the mechanism responsible for the enhancing effects of intersensory stimulation to be neural summation.

Suggestions for Future Research

The present results suggest the need for additional research in two areas in order to provide definitive answers sought to the questions posed by the problem investigated in this study. The first area addresses itself to a problem of theoretical importance: "Is the facilitative effect of simultaneous presentation due to the nature of the signal itself or merely a function of the amount of stimulus energy present?" A design incorporating, perhaps, information theory would be required in this instance to control the variables involved.

The second area of research suggested by this study is one of a more practical, applied-research nature. The range of anxiety might be expanded to include all levels represented on the Taylor Scale. The point at which performance in a signal detection-recognition task representative of performance required in complex communication systems is adversely affected by anxiety level could be empirically determined and used in conjunction with selection and assignment procedures.

CHAPTER VI

SUMMARY AND CONCLUSIONS

The purpose of this research was to investigate the effects of simultaneous presentation of identical signals by means of more than one sensory modality on a detection-recognition task. An important accompanying problem was whether the nature of the signal input to an accessory channel is of importance to sensory facilitation or whether only the presence of a stimulus is important. A review of pertinent research indicated the area of study was one for which research had been scattered and unsystematic. The relatively few studies in the area have provided no definitive answer to a number of relevent questions. As a result of the review, the following questions were developed: 1) Is visual presentation of stimuli superior to auditory presentation? 2) Will simultaneous presentation of a meaningful auditory stimulus plus a visual cue result in better performance than auditory presentation alone? 3) Will performance with a simultaneous meaningful visual stimulus and an auditory cue be better than for vision alone? 4) Does simultaneous presentation of the same stimulus to both visual and auditory receptors facilitate detection and recall, and, does this condition result in the best performance of any presentation condition? 5) Is performance under a simultaneous presentation of a meaningful visual stimulus and an auditory cue better than for a simultaneous presentation of a meaningful auditory stimulus and visual cue? 6) Is performance of high anxious subjects different from that of low anxious subjects?

To investigate these questions 38 subjects, separated into two equal groups of high and low anxious on the basis of scores on the Taylor Manifest Anxiety Scale, were individually exposed by means of a repeated measures design to each of five presentation conditions. The presentation conditions used were: vision alone, audition alone, combined presentation of meaningful visual and auditory stimuli, combined presentation of meaningful visual and auditory tonal cue, and combined presentation of meaningful auditory and visual cue. All stimulus presentations were made under noise conditions.

The major findings were: 1) For single mode presentations, vision was supperior to audition. 2) Simultaneous presentation of a meaningful auditory stimulus plus a visual cue resulted in better performance than experienced with audition alone. 3) Performance was enhanced as a result of the addition of a simultaneous auditory cue to a visual stimulus. 4) Simultaneous presentation of identical visual and aural stimulus material enhanced signal detection-recognition performance and this condition resulted in performance superior to any other presentation condition. 5) Performance was improved with the simultaneous presentation of a meaningful visual stimulus and an auditory cue more than with a meaningful auditory stimulus and a visual cue. 6) There was no difference in performance between high and low anxious groups. It was suggested that the anxious group used may not have been sufficiently removed from the population median for effects of differential anxiety to be displayed within the framework of the task complexity involved in the experiment.

An attempt was made to relate the findings to Harris' theoretical position of neural summation as an explanation of intersensory facilitation. The discussion of the results was followed with suggestions for future research, both of a theoretical and an applied nature.

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APPENDIX A

SAMPLE ITEMS FROM THE TAYLOR MANIFEST ANXIETY SCALE

I am often sick to my stomach (True)*

I blush as often as others (False)*

At times I lose sleep over worry (True)*

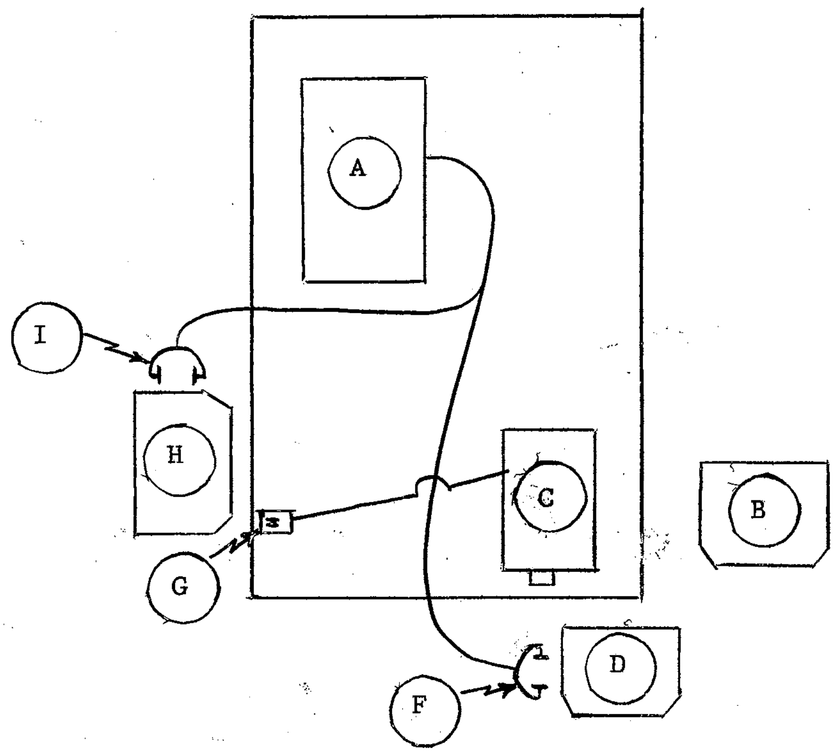
I wish I could be as happy as others (True)*

I am more self-conscious than most people (True)*

I am very confident of myself (False)*

* The response given in parentheses is that scored as anxious.

APPENDIX B - SCHEMATIC OF EQUIPMENT CONFIGURATION



A - Tape Recorder

B - Data Recorder

C - Slide Projector

D - Subject

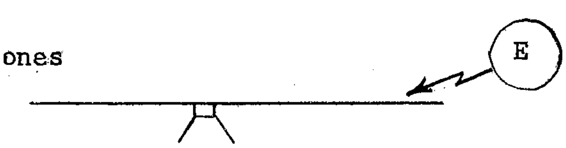
E - Projection Screen

F - Subject Headphones

G - Projector Control

H - Experimenter

I - Experimenter Headphones



APPENDIX C

TAPE SCRIPT

The experiment in which you are about to participate is concerned with one's ability to detect visual and auditory signals under noise conditions.

As you listen to these instructions, indicate to the experimenter if you would like the volume adjusted for more comfortable listening.

In this experiment you will be asked to repeat a series of numbers in the same order in which they have been presented to you.

In the experiment the numbers will be exposed to you under each of five conditions:

Condition 1 - The numbers will be projected onto the viewing screen.

Condition 2 - The numbers will be heard through the headphones.

Condition 3 - The numbers will be seen and heard at the same time.

Condition 4 - The numbers will be projected onto the viewing screen and at the same time they are projected you will hear a tone through the headphones.

Condition 5 - The numbers will be heard through the headphones and at the time they are heard a visual stimulus will be projected onto the screen.

In each condition the numbers will be presented to you one at a time. Do not repeat the numbers aloud until you are asked to do so.

The presentation will start with a series of three numbers and will continue to the point at which you cannot repeat the numbers correctly. When this point is reached, the experiment will move to the next condition and repeat the procedure. This process will continue until you have been exposed to each of the five conditions.

In the experiment you will find that you have some difficulty in seeing or hearing the numbers. In the case of the visual presentation the numbers will appear fuzzy. In the case of the auditory presentation you will hear a constant background noise through the headphones. This is intentional and is part of the experimental design.

The headphones will be worn throughout the experiment. Do not remove them until told to do so by the experimenter.

Before starting the experiment you will be given some practice series of three numbers to show you what to expect in the experiment.

On the center of the screen you will see an X. This indicates the area in which all of the numbers will appear.

I will now project a series of three numbers. After the numbers have been projected you will be asked to repeat the numbers aloud which you have just seen projected. Be sure to continue looking at the same area of the screen.

You will have approximately 15 seconds to repeat the numbers before another presentation series appears.

If you do not understand the procedure, raise your hand and the recorder will be stopped at this point.

( )[1] - Please repeat the numbers you have just seen.

---

[1]Parentheses with no material contained between the brackets indicate that the digits were presented visually only. The tape contains an unrecorded space equal in running time to the period of time required for projecting the digit series.

( ) - Please repeat the numbers you have just seen.

If you don't understand the procedure raise your hand and the recorder will be stopped.

The experiment will now begin.

( ) - Please repeat the numbers you have just seen.

( ) - Please repeat the numbers you have just seen.

.
. [2]
.

This ends condition 1 of the experiment. We will now have a one minute rest before moving to condition 2 of the experiment. In condition 2 you will hear the numbers but will not see them.

I will now read a series of three numbers. After the numbers have been read, you will be asked to repeat the numbers aloud which you have just heard. You will have approximately 15 seconds to repeat the numbers before another presentation series starts. If you do not understand the procedure, raise your hand and the recorder will be stopped at this point.

2 7 9 - Please repeat the numbers you have just heard.

3 4 1 - Please repeat the numbers you have just heard.

If you don't understand the procedure, raise your hand and the recorder will be stopped.

---

[2] The particular experimental condition being presented on tape was played to the point of subject failure. At this point the recording was stopped. Through the use of the rapid advance control, the tape could be positioned at the point at which the instructions stated - "This ends condition ___ of the experiment". This adjustment was made possible by having the script used by the experimenter for monitoring keyed for tape footage. At the end of each experiment, the tape was rewound and the counter reset to zero if adjustment was required.

Condition 2 of the experiment will now begin.

.
.
.

This ends condition 2 of the experiment. We will now have a one minute rest before moving to condition 3. In condition 3 of the experiment you will see and hear the numbers at the same time.

2 7 9 - Please repeat the numbers you have just heard.

3 4 1 - Please repeat the numbers you have just heard.

If you don't understand the procedure, raise your hand and the recorder will be stopped. Condition 3 of the experiment will now begin.

.
.
.

This ends condition 3 of the experiment. We will have a one minute rest before moving to condition 4. In condition 4 of the experiment you will see the numbers projected. At the same time they are projected you will hear a tone through the headphones.

( ) - Please repeat the numbers you have just seen.

( ) - Please repeat the numbers you have just seen.

If you don't understand the procedure, raise your hand and the recorder will be stopped. Condition 4 of the experiment will now begin.

.
.
.

This ends condition 4 of the experiment. We will now have a one minute rest before moving to the final condition of the experiment. In condition 5 you will hear the numbers through the headphones and at the same time you hear them, a visual stimulus pattern will be projected onto the screen.

2 7 9 - Please repeat the numbers you have just heard.

3 4 1 - Please repeat the numbers you have just heard.

If you don't understand the procedure, raise your hand and the recorder will be stopped. Condition 5 of the experiment will now begin.

.
.
.

This ends the experiment. Thank you very much for your cooperation. Through your efforts, you have contributed much to the success of the experiment. You may now remove the headphones.

APPENDIX D

RAW SCORES - RECOGNITION DATA AND ANALYSIS-OF-VARIANCE SUMMARY

TABLE D-1 - LOW ANXIOUS SUBJECTS

Presentation Condition

Subject Number	I	II	III	IV	V	Total
1	3	1	3	3	2	12
2	3	2	3	3	2	13
3	2	1	3	3	2	11
4	2	2	3	3	3	13
5	2	2	3	3	3	13
6	3	0	3	3	2	11
7	2	2	3	3	2	12
8	3	2	3	3	3	14
9	3	0	3	3	0	9
10	1	2	3	3	3	12
11	3	2	3	3	2	13
12	3	1	3	3	1	11
13	2	3	2	3	2	12
14	3	1	3	3	2	12
15	3	2	3	3	1	12
16	2	0	3	3	2	10
17	2	0	3	3	2	10
18	2	2	2	2	2	10
19	2	0	3	3	0	8
	47	24	55	56	36	218

TABLE D-2 - HIGH ANXIOUS SUBJECTS

Presentation Condition

Subject Number	I	II	III	IV	V	Total
1	3	0	2	3	2	10
2	3	0	3	3	1	10
3	2	2	3	3	0	10
4	3	2	3	3	2	13
5	2	2	3	3	2	12
6	1	1	3	3	2	10
7	2	1	3	3	2	11
8	2	2	2	3	2	11
9	2	3	3	3	2	13
10	2	2	3	3	2	12
11	2	0	3	3	2	10
12	3	3	3	3	3	15
13	3	0	3	3	2	11
14	2	2	3	3	3	13
15	3	2	3	3	3	14
16	3	2	3	3	2	13
17	2	0	3	3	2	10
18	2	0	2	2	2	8
19	3	3	3	3	2	14
	45	27	54	56	38	220

TABLE D-3 - A x B SUMMARY TABLE

(RECOGNITION SCORES)

Presentation Condition

	I	II	III	IV	V	Total
Low	47	24	55	56	36	218
High	45	27	54	56	38	220
Total	92	51	109	112	74	438

TABLE D-4

SUMMARY OF ANALYSIS OF VARIANCE

Source	df	SS	MS	F
Between Subjects	37	20.695		
A (Anxiety Level)	1	.021	.021	.0366
Subjects Within Groups	36	20.674	.57427	
Within Subjects	152	127.600		
B (Presentation Condition)	4	68.348	17.0870	41.861
AB	4	4.52	.11300	.2768
B x Subjects Within Groups	144	58.770	.40818	
Total	189	148.295		

Conservative F values

$F_{.01}\ (1,36) = 7.41$

$F_{.05}\ (1,36) = 4.12$

APPENDIX E

RAW SCORES - DIGIT SERIES CORRECTLY REPRODUCED

AND A x B SUMMARY TABLE

TABLE E-1 - LOW ANXIOUS SUBJECTS

Presentation Condition

Subject Number	I	II	III	IV	V	Total
1	3	1	5	4	2	15
2	0	2	4	2	3	11
3	0	0	3	1	0	4
4	0	1	4	3	4	12
5	2	1	3	3	3	12
6	1	0	3	2	2	8
7	1	0	3	2	1	7
8	3	0	5	3	3	14
9	2	1	2	2	1	8
10	1	1	4	2	3	11
11	3	0	5	3	4	15
12	2	0	2	2	1	7
13	1	1	4	2	2	10
14	2	1	4	3	1	11
15	2	1	4	3	3	13
16	0	0	1	2	1	4
17	0	0	2	3	1	6
18	0	2	2	1	2	7
19	0	0	4	3	1	8
	23	12	64	46	38	183

TABLE E-2 - HIGH ANXIOUS SUBJECTS

Presentation Condition

Subject Number	I	II	III	IV	V	Total
1	3	1	2	3	1	10
2	2	0	4	3	0	9
3	1	0	2	2	0	5
4	1	0	4	2	1	8
5	0	0	3	3	3	9
6	0	0	2	2	1	5
7	0	0	1	1	0	2
8	0	0	2	2	1	5
9	0	1	2	2	0	5
10	0	0	2	3	0	5
11	1	0	2	2	0	5
12	1	2	3	3	2	11
13	1	1	5	2	1	10
14	2	1	3	4	3	13
15	2	1	3	4	3	13
16	1	0	2	3	2	8
17	0	0	3	3	0	6
18	0	0	1	1	0	2
19	2	2	7	5	2	18
	17	9	53	50	20	149

TABLE E-3 - A x B SUMMARY TABLE

Presentation Condition

	I	II	III	IV	V	Total
Low	23	12	64	46	38	183
High	17	9	53	50	20	149
Total	40	21	117	96	58	332

VITA

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