Effects of Extraneous Auditory Stimulation on Visual Choice Reaction Time

William J. Wenger

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EFFECTS OF EXTRANEOUS AUDITORY STIMULATION ON VISUAL CHOICE REACTION TIME

by

William J. Wenger

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Faculty of the Graduate College
in partial fulfillment
of the
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EFFECTS OF EXTRANEOUS AUDITORY STIMULATION
ON VISUAL CHOICE REACTION TIME

One of the most available response variables for experimental psychology is speed. The reason is obvious. Every act takes time, and time can be measured. Speed is a useful measure in two ways: as an index of achievement and also as an index of the complexity of the inner process by which a result is accomplished. The more complicated process is assumed to require a longer response time, (Woodworth and Schlosberg, 1954). Reaction time is one such classic response variable based on speed. Achievement in a variety of behavior tasks can be accurately indexed by the measurement of the time it takes to react in the S-R chain of the task. The complexity of the inner process by which a task is accomplished has also been found by Woodworth (1954) to be readily indexed by the magnitude of the reaction time. The particular type of reaction time which has shown itself to be well suited for this purpose is choice reaction time (CRT), a reaction paradigm based on the presentation of two or more reaction stimuli.

A renewed concern about the behavior manifested in CRT experiments has resulted from the recent interest in the intricacies of complex perceptual motor tasks and
informational processings of environmental stimuli. Even though CRT is but a step above simple reaction time, it is more flexible and has more options for experimental analysis. Since the E is not being limited to the single stimulus and response, as in simple reaction time, he is able to pursue a variety of experimental problems with this choice situation. The relationship between extraneous sound and visual choice reaction is one such problem to investigate.

The prospect of intermodal relationships between different sensory channels has been explored repeatedly since man became interested in the scientific analysis of his own behavior. The effect of one sense mode on the performance of another sense mode during simultaneous stimulation has long been an accepted but not necessarily supported hypothesis. What is of special interest to contemporary researchers, in particular the researchers involved in detection thresholds and vigilance performance research, is the effect of non-contingent auditory stimulation. The bulk of past research which examined the intersensory effects of auditory stimulation either has been badly conducted, too complex or too simple. Neither the industrial "distraction" studies nor the basic reaction time experiments have thoroughly examined the simple cognitive subprocesses as found in the CRT paradigm.

The prospect of defining, let alone quantifying, just what temporal subprocesses are taking place in an observer
when he is performing a task has tended to be a no-man's land. Psychophysicologists have traditionally attempted to find out what is happening; but either because of limitations of this young school of science or from following the wrong routes of inquiry, they have been unsuccessful (Harris, 1950). Two subprocess theories, which have been strongly supported by psychophysicologists, have been considered by other researchers to be unsound. Subliminal perception (Goldiamond, 1964) and heightened sensitivity to certain colors under the stimulation of particular sounds (Fisher, 1964 and Kamper, 1965) are two such theories.

The whole problem of dealing with the interactive effects of audition on other sense modes does not adequately seem to fall within the capabilities of psychophysiology science at this time. The particular non-physiological experimental paradigm which is recommended for investigation of the subprocesses of performance is choice reaction time. CRT deals primarily with the measurement of cognitive subprocesses and in so doing may offer to the experimenter readily quantifiable data (Randel, 1968). It is felt then that the sensory interactive effects of extraneous sound on the subprocesses of performance can be best explored through the use of choice reaction time. To thoroughly understand the use of this experimental paradigm its historical development and contemporary utilization must be explored.
HISTORICAL ANTECEDENTS

A theory of Choice Reaction Time (CRT) has its beginning in Donders' (1868) subtraction method and its underlying theoretical postulates. In this method, three types of reactions were postulated: reactions a, b and c. Simple reaction time and the a reaction are identical; it involves a single stimulus and a single response that is to be performed upon presentation of the stimulus. The Donders' b reaction consists of two stimuli having a 1:1 mapping between two responses. This reaction has been the prototype of the standard CRT paradigm. The Donders' c reaction involves two stimuli and a single response to be made upon the presentation of only one of the stimuli.

Donders' theoretical postulates in terms of the a, b and c reactions are described as follows:

Postulate 1: Distinct and independent cognitive subprocesses rather than a single unitary event are performed during the period of time that elapses between the presentation of the stimulus and the subsequent response in the case of the b and c reactions (Doesschate, 1963). In the b reaction these subprocesses consist of, but are not limited to, stimulus categorization (i.e. discrimination) and response selection. In the case of the c reaction,
however, the subprocesses are limited exclusively to stimulus categorization. The importance of this theoretical postulate is two-fold: first that distinct and independent subprocesses are in operation, and second that these subprocesses are completely independent of each other (i.e. they are non-overlapping).

Postulate 2: The critical distinction between the b and c reaction lies in the exclusion in the case of the latter of response selection.

Postulate 3: The b reaction is a synthetic reaction with its component parts being the a reaction, response selection, and stimulus categorization. The addition of these components yields the b reaction. Hence, the period of time consumed by the following subprocesses may be derived by subtraction: stimulus categorization time = c - a, and response selection time = b - c (Woodworth, 1938). This is Donders' explicit statement of the widely known Subtraction Method.

A number of experimental studies have been conducted by Donders to test the adequacy of his theoretical postulates. His experimental results were consistent with this theoretical expectation: the three reactions thus aligned themselves with respect to temporal duration as follows: b, c, a, (Woodworth, 1938). Approximately three decades later, however, Kulpe, Ach & Watt (1968) launched an attack on Donders' third theoretical postulate, the
consequence of which has been an apparent discrediting of his entire theoretical foundations. Using only introspective evidence, they contended that in the case of the a reaction, the subject's reaction was categorized by a higher degree of motor readiness than in the case of the b reaction. This being the case then, the a reaction could not be considered to be a constant and therefore was not capable of providing an estimate of the base time involved in the b reaction (Woodworth, 1938). Furthermore, Kulpe and his associates theorized that a change in processes was subsequent to, as well as predicated on a change of conditions: stimulus categorization, for instance, replaces simple RT, instead of being arithmetically added to it (Boring, 1963). Smith (1968) remarked that the theoretical controversy between Donders and Kulpe revolved around a problem that was quite old in origin, namely, whether specific constants could account for empirically established performance variations in CRT tasks. Donders position was, in essence, that this is indeed the case; whereas Kulpe argued that the performance variations are the consequence of diverse processes having diverse temporal parameters.

It is evident that Kulpe's position sets up severe limitations with regard to the generality of any given CRT theory. The validity of his criticism is subject to question since his assertions are based in their entirety on introspective data.
The relevance of the subtraction method to current CRT theories and its inadequacies with respect to the manner with which it relates to these theories may now be considered. In the first place, the assertion made that Donders' first theoretical postulate which states, in essence, that CRT consists of a series of discrete, non-overlapping subprocesses has not been successfully challenged and that it still forms a valuable foundation for theoretical development. Welford (1960) further elaborated on this foundation. He postulated the existence of three separate control mechanisms in addition to the sensory and effector organs to account for information processing, a perceptual mechanism that is concerned with stimulus categorization, a translation mechanism that deals with response selection and a central effector mechanism concerned with the actual response execution. Further theoretical elaboration on Donders' first theoretical postulate has been made by Morin & Forrin (1963) and Nickerson & Feehrer (1964). They have substituted many :1 (more stimuli than response) and 1: many (more responses than stimuli) mappings for the usual 1:1 stimulus-response mapping. These substitutions represent attempts at theoretical isolation of stimulus categorization (in the case of the many :1 mapping) and response selection (in the case of the 1: many mappings) for purposes of more extensive study. It may be remarked that these approaches have placed primary emphasis on the
nature of the operations involved in the subprocesses of stimulus categorization and response selection.

In the second place, recent theoretical constructs have promoted the validity of the subtraction logic to a greater degree than did Donders (Smith, 1968). Donders had formulated a theoretical model in which stimulus categorization and response selection were postulated to be additive. Recent theories, however, have formulated models that assume the components of a single stage to be additive. The works of Sternberg (1964, 1966) and Christie & Luce (1956), for instance, have contributed to a higher degree of theoretical sophistication by making the assertion that the stimulus categorization stage consists of a number of comparisons occurring in a serial order.
INFORMATION THEORY

The introduction of information theory constructs into the study of CRT for purposes of theoretical refinement, has resulted in increased use of the subtraction logic. The results of relevant studies by Pitts & Switzer (1962), Bricker (1955) and Welford (1960), in which varying amounts of information were transmitted (Ht) may be summarized by the equation: CRT = a bHt (Smith, 1968).

Attempts at interpretation of the denotation of the constants in this equation have resulted in the designation of b to denote an estimate of rate processing and of a to substitute for simple RT. This interpretation closely approximates Donders' theoretical assumption with regard to the composite nature of CRT, namely, that it consists of simple RT to which other stages are added. The studies that have been cited have been primarily concerned with changes occurring in the b constant as a consequence of experimental manipulations, to the exclusion of simple RT. Regardless of the derivation, the logic appears to be subtractive, at least insofar as the various components of CRT are amenable to experimental and conceptual analysis.

The attempt to explain choice-reaction times in terms of communication theory has been examined by recent writers. Such an explanation depends ultimately on an analogy between...
the human subject in a choice reaction experiment and an ideal communication system, and it has been shown in comprehensive reviews by Welford (1960) and Laming (1968) that this analogy cannot be maintained.

With the close interests shown in the analysis of the CRT task, the mechanistic like communication theory is being replaced by the Random Walk model (Laming, 1968). When there are only two alternative signals the decision process can be represented by a random walk between two parallel absorbing boundaries. This is a development of the two-choice model proposed by Stone (1960). When there are more than two alternative signals the geometric representation of the decision process is more complicated (a random walk between curvilinear boundaries) and there are few explicit mathematical results. Both the two choice and multi-choice models have been developed to points at which meaningful comparisons with experimental results can be made. In random walk models such as Laming's (1968), intuitive arguments are used which are illustrated with diagrams. This model should be intelligible to those with only a little knowledge of mathematics. Stone (1960) was the first to suggest the use of the sequential probability ratio test as a model for choice-reaction times. Wald and Waldowitz (1948) have shown that this test is optimal among all statistical tests in the sense of requiring the smallest average size of sample for any given pair of error
probabilities. Stone derived two results suitable for experimental test. First, in a two-choice experiment the distribution of reaction time is the same whether the response is correct or an error. Second, assuming a condition of symmetry, he derived equations relating the mean reaction time and variances conditional on each signal to the probabilities of each sort of error. Finally, under optimal conditions, Stone derived an equation for the unconditional mean reaction time. The sequential probability ratio test is the backbone of the model presented by Laming’s Random Walk theory.

Fitts, Peterson and Wolpe (1963) and Fitts (1966) have made an intuitive empirical use of Stone’s model and Laming (1962), McGall (1963), Edwards (1965), Audley and Pike (1965) and Casterette (1966) have added to the theoretical discussion. Edwards’ contribution is the most distinctive. He has developed a normative Bayesian model for information processing, taking explicit account of costs, pay-offs and prior probabilities, which is applied, among other things, to choice reaction times.

It is apparent then, from the foregoing, that the CRT paradigm has stood up over a century of examinations, Donders’ first theoretical postulate having maintained its theoretical integrity despite the attacks that have been launched against it.
CRT has shown itself to be a synthetic process the components of which render themselves amenable to conceptual and experimental isolation. The rate of information transfer is a constant, and it remains a constant despite variations in the transmission of information (Hyman, 1953). Therefore it seems reasonable that the CRT paradigm can be isolated and reliably recorded to permit exploration of not only the intra-informational variables but perhaps the effects of the environment upon the task.

Environmental stress can be defined as an energy or information which is irrelevant to the requirements of an assigned task, not necessarily as a condition that "feels" stressful (Fitts and Posner, 1967). Defined this way, stress has the same meaning in testing man as it does in testing materials and machines. Stress on a system is varied by changing the information load, temperature, vibrations, and other similar variables. The advantage of so defining stress is that it becomes isolated as an independently quantifiable variable. This definition leaves open the empirical question of just what effect this variable has on human performance. With the renewed interest in man's performance of the CRT task some of the environmental stress variables can be profitably explored. One such variable is sound.
Effects of Sound on Behavior

Laboratory studies of the effects of sound on behavior consider three general categories of auditory effects: transient effects, no effects, and persistent effects. The transient effect is of little practical importance because it is generally agreed by most writers that the sudden onset of a sound may produce a very brief decline in efficiency, but this will disappear as the noise continues (Broadbent, 1958).

It is clear that some sounds are unpleasant, either because of learning or by being naturally aversive. A considerable literature of a rather emotional type exists which argues that noise should be reduced. This literature, which has been comprehensively reviewed by Kryter (1950) and Broadbent (1957), dates back over a century. A majority of the industrial studies and many of the laboratory experiments are badly controlled, and have been adequately criticized by Kryter.

Experiments showing no effects of sound come primarily from war-time research. A majority of the work periods in previous studies were of either short ten minute trials or either long enough, but of objectionable statistical framework. The first group of studies comes from Tufts College (1942), operators were asked to follow a moving target for four hours, a two minute burst of noise
was presented at some time during this period, but the noise did not impair work. When noise was presented toward the end of the period, it tended to improve efficiency, but not significantly so. Subjectively, the operators reported that the novelty of the event relieved the monotony of the long work period. The second set of war-time experiments was done at Harvard (Stevens, 1941) in which a large number of tasks was used. The subjects worked seven hour days, and 115 db noise was presented on some days. The noise used was predominantly low-pitched and was continuous. Counter-balanced days were under quiet conditions. The tasks were all restricted to 15 minutes or less in length, reportedly to maintain motivation. Stevens and his colleagues were evidently not believers in serious effects of quiet noise, designing their experiment so that a steady sound of 90 db was present even in the "quiet" control conditions. This basal noise level was used to prevent sudden sounds from outside the laboratory from reaching the subjects. Certain tests showed no effects of noise. Notable among these were card sorting, target detection, judging distance, vigilance performance, and choice reaction time. The primary restriction of the Harvard study can be found in the use of db noise as quiet and using such short work periods. According to Broadbent (1958) most of the studies which show no effects of noise on behavior consistently fall into the category of: short work periods or noise exposure is short, noise of near 90 db, or the task is one in which there are numerous
predictable moments in which no information will reach the worker.

Psychophysiologica  r e s e a r c h h a s p r o v i d e d e v i d e n c e o f visual effects by auditory stimulation such as London's (1954) report of Russian experiments showing that the sensitivity of central vision to white or blue-green light is improved by a moderate noise background, while sensitivity to red light is impaired. Moderate to high intensity noise has also been shown to reduce the absolute sensitivity of peripheral vision. The limitations to these studies can be found in their dependence on very specific characteristics of both the relevant and the background stimulation. This type of research has been supported by strong evidence but can be criticized because of experimental method and statistical treatment (Ozbayder, 1961), dated (e.g. Ryan, 1940) or inaccessible (e.g. London, 1954). However, the theory of a direct neurological intersensory facilitation should not be discounted: many visual and auditory paths end on the same motoneurones or intercalories; there are fibers from the lateral lemniscus, an auditory path in the brainstem, direct to the superior or visual colliculus. There may also be fibers between the auditory and visual colliculi; and there is on the cortex a tract of fibers between temporal and occipital gyri (Harris, 1950).

Where ambient noise does effect sensory transfer, it may do so by affecting the B measure rather than the d'.
measure (Gregg and Brogden, 1952; Swets, Tanner and Birdsal1, 1961; Symons, 1963). The B measure is an index of the risk the observer is willing to take in stating that a signal is present. The d' measure is an index of an observer's sensitivity, a measure of the detectability of a signal. These two measures have been experimentally explored by Hebb and Broadbent (McGrath, 1960) who suggest that noise affects non-auditory sensory channels indirectly by either arousing or distracting the operator.

The majority of literature analyzing auditory effects comes from either detection threshold studies or vigilance research. The bulk of the literature dealing with any aspect of sensory interaction for detection threshold studies is dated or inaccessible (Mirabella and Goldstein, 1967), though there have been a few more recent studies dealing with the effects of light upon auditory sensitivity. The largest quantity of literature dealing with auditory effects comes from vigilance research. The primary limitation to the vigilance research is that it is interested in monitoring behavior for a relatively infrequent signal. When the S is monitoring a single display and does not have to translate raw data into some other form in order to extract signals, noise produces either no effect or increased detection (Broadbent and Gregory, 1965; Jerison, 1957; Kirk and Hecht, 1963; McGrath, 1960; McGrath and Hatcher, 1961; Pollock and Knaff, 1958; Ware, Kowal and Baker, 1964;
Randel, 1968; Watkins and Feehrer, 1964). A typical experiment showing increased detection was conducted by Kirk and Hecht (1963). These investigators required their subjects to detect a deflection in an otherwise steady beam of light at the center of a cathode ray tube. An exposure to three noise conditions was presented separately for 4 of 12 periods. The effect of white noise, 64 dB, was compared with the effect of steady noises of 64 dB and 61 dB. The fluctuating noise led to better performance than did steady noise.

Where the operator time shares among several independent displays, noise has been shown to decrease detection (Broadbent, 1954; Broadbent and Gregory, 1965; Jerison and Wing, 1957). Broadbent (1954) presented his operators with 20 steam pressure dials whose pointers occasionally moved a fraction of an inch to a new steady-state position, at a signal rate of five per hour over a watch of one and one half hours. The S was required to reset the pointers within nine seconds. It was found that fewer signals were detected under 100 dB than 70 dB noise.

Noise has also been shown to interfere with monitoring one or more displays requiring transformation of the display information (Broadbent, 1958; Jerison, 1954; Teichner, Arees and Reilly, 1963; Woodhead, 1959). Each study, except Woodhead's, used steady noise. Woodhead (1959) employed periodic bursts of noise.
Mirabella and Goldstein (1967) have comprehensively reviewed the effects of noise upon vigilance monitoring behavior and have concluded that a discontinuous or continuous, but varying, noise background improves monitoring performance. This performance is improved if no data processing is called for as well as if only the infrequent vigilance responses are required in the task.

**Auditory Facilitation**

As has been shown in the previous discussion, a variety of auditory stimulations are detrimental to human performance. Most of these sounds are of a transient nature and a subject will normally adjust or adapt to them, regaining a lost proficiency or continue to develop it to a higher degree (Broadbent, 1958). What has also been shown in the previous discussion is that certain auditory sources and other situational variables can act not as a handicap to performance but as a facilitation.

When sound is classified as a particular type of stress it is concluded that people do their best under intermediate conditions of stress (Fitts and Posner, 1967). If all input but the task itself is removed, the individual loses his alertness, becomes bored and performance efficiency is lost. Most industrial tasks just do not supply enough stimulation to maintain interest. It is generally
assumed that one loses alertness after long-continued work
under low stress conditions; therefore it seems quite
apparent that auditory stimulation during a visual-motor
task might very well be a facilitator of performance.

Sensory stimulation of certain types of tasks as a
facilitator is not a new hypothesis. Mackworth (1956) has
suggested that E could improve vigilance performance by
introducing external stimuli in order to avoid a state of
sensory deprivation. This external stimulation could be
irrelevant to the particular task. Deese (1955) has also
suggested this relationship. It has been shown by Magoon
(1952) and others (Lindsley, 1958) that activation of the
RAS (Reticular Activating System) by sensory stimulation
serves to maintain alertness and general arousal. The
facilitating effect of sensory stimulation possibly then
lies in the action of the RAS.

The effects of noise have been postulated by Hebb
and Broadbent (McGrath, 1960) to affect non-auditory sensory
channels indirectly by either arousing or distracting the
operator. The Hebb and Broadbent approaches imply that
noise influences decision and observing responses (Broadbent
and Gregory, 1965; Jerison and Pickett, 1963). What is
important in the approaches of these two researchers is
that they have incorporated both the decision response,
or B effect, and the observing response, the d' effect.
It is not necessarily important to quantitatively analyze either response to determine their related effectiveness. It seems evident, however, that both are affecting the observer's behavior, but is it to a significant degree? Stevens, (1941) in the Harvard studies showed no effect of noise on the CRT task, but as previously discussed, this study is strongly criticized by more recent writers.

Therefore, is there a relationship between human performance, in this case the multi-faceted CRT task, and non-contingent auditory stimulation and if there is, just to what degree? In other words, are we dealing with simply an incidental effect or one of true significant value? What is of interest in this particular case then, is the interactive effects of auditory stimulation versus no auditory stimulation during a standard CRT task.

The hypothesis of this study is that a visual CRT task will be facilitated in the presence of extraneous auditory stimulation. Three auditory effects are of interest in this experimental analysis; intermittent, continuous and quiet. Whether or not there will be an improved performance trend over trials for the intermittent and continuous groups is what is to be determined. It is hypothesized that there will be a significant difference between the effect of intermittent and continuous auditory stimulation and the quiet condition over trials. It is
hypothesized that this difference will take the form of a superior performance during the auditory stimulation conditions whereas a deterioration in performance will take place during the quiet condition. The existence of this superiority will point directly at the presence of auditory facilitation of performance.
METHOD

Subjects

Forty-five introductory psychology students, six of whom were female, were divided into three groups of 15, supplying an equal number of Ss for Group I, Group II and Group III. There were two females in each experimental group.

Apparatus

The Ss sat in an illuminated modified acoustic chamber built of double thick fiberglass insulation and fiber-board which attenuated outside noise by 30-50 db over the audible-frequency range from 100 hz. Extraneous auditory stimulations were presented as continuous and intermittent pure tones generated by a Beltone 15c audiometer and presented binaurally through Monarch ES-600 earphones mounted in semi-plastic cushions. The intensity of the tones in Group I, continuous, and Group II, intermittent, was 70 db at a uniform 1000 hz. In addition, background noise was provided in each condition as well as during the practice trial by the location of an airconditioner motor near the experimental chamber at an intensity of between 35 and 40 db; this was done as a masking attempt for any
sound which was not attenuated by the acoustic chamber or earphones.

All Ss sat at what they considered a comfortable distance from a Lafayette four choice reaction display of four 15 Watt lightbulbs positioned in the center of a small table with the index and middle finger of each hand lightly resting on four typewriter type keys. These keys were mapped in 1:1 correspondence to the four lightbulbs and would turn off the respective light when depressed. The keys required a small amount of pressure and a short travel distance. Reaction times were measured by a Stoelting timer to the nearest hundreds of a second. A counter was started at the onset of the light stimulus and stopped when the S responded to the reaction signal and depressed an appropriate key. The display panel provided the S immediate information feedback after a key press by turning off the light to indicate a correct response, or if the light was not extinguished, the S received the feedback of his error and continued key pressing until successful.

Procedure

The Ss were given standard instructions which equally emphasized speed as well as accuracy in responding. A brief rest period was given after the set of 100 practice trials for all Ss when the Ss were asked if any confusion was taking place and were told that the experimental session was
about to begin. The experimental session in all three situations consisted of approximately 600 trials. Overall testing time lasted between 43 and 45 minutes. The CRT task in the three experimental cases was the same; the correct response to the presentation of a random ordered visual display. The Ss in Group I were exposed to a continuous pulsating tone beating at a steady rate of twice a second. The tone was not turned on or off, but was automatically presented with no db fluctuations. In Group II there were 20 intermittent randomly ordered tones, based upon trial number in lieu of time, which were delivered between trials for a duration of about 150 hundreds of a second. No tone was presented in Group III even though the Ss wore earphones as in the two previous conditions.
RESULTS

Readings taken during the practice and experimental session were averaged into seven CRT scores, each score being an average of 100 trials for the group of 15 Ss. These seven scores are presented in Figure 1. An analysis of variance of the conditions over the seven experimental trial sets revealed no significant differences in mean CRT scores for the three groups during the experiment.

The trial set means of the three different auditory treatments were analyzed using a trend analysis of variance. The test of significance for the auditory effect indicates that the over-all measure of performance for the three groups did not differ significantly. The trial set means did differ significantly. Testing the auditory conditions x trials mean square for significance, F equaled 1.79 with 10 and 210 df. The tabled value of F for 10 and 200 df, at the 0.05 level, is 1.83. The prospect of extraneous auditory effects as proposed in the hypothesis is not then supported; but the prospect of an incidental relationship is suggested. This relationship is suggested by the statistical significance which was nearly reached and by the way the intermittent and continuous curves maintained a constant CRT performance level over trials, as seen in Figure 1.

The following table summarizes the calculations.

25
### TABLE 1
ANALYSIS OF VARIANCE OF AUDITORY EFFECTS ON CRT

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
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<tr>
<td>A: Auditory Conditions</td>
<td></td>
<td>112.60</td>
<td>.72</td>
</tr>
<tr>
<td>Error (a)</td>
<td>42</td>
<td>155.94</td>
<td></td>
</tr>
<tr>
<td>B: Trials</td>
<td></td>
<td>24.50</td>
<td>5.54*</td>
</tr>
<tr>
<td>AxB: Auditory Conditions x Trials</td>
<td>10</td>
<td>7.90</td>
<td>1.79</td>
</tr>
<tr>
<td>Error (b)</td>
<td>210</td>
<td>4.42</td>
<td></td>
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*significant at the .05 level of confidence.
Figure 1. Choice reaction time for the three sound conditions

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DISCUSSION

The main objective of this study was to determine the intermodal relationship between visual CRT and extraneous auditory stimulation. No significant effects were found among the three auditory conditions of continuous, intermittent and quiet and CRT performance. Some possible implications, however, can be drawn if the reader will permit further examination of the results which have not reached an acceptable level of statistical significance.

The first finding of interest is the analysis of the auditory conditions x trials interaction. The obtained F value was 1.79. A value of 1.83 was needed to reject the null hypothesis at the .05 level of confidence. This closeness to rejection level suggests a further examination of the experimental proposal.

An auditory x trials interaction effect was proposed in the experimental hypothesis but was not demonstrated by the experiment. A visual analysis of the graphical results in Figure 1, suggests a decrease in performance efficiency over trials in the quiet condition and implies a constant performance over trials of the continuous and intermittent
conditions. The plotted performance of all three groups seems to be following the expected performance levels as proposed in the hypothesis: an efficient reaction time in the quiet condition immediately after the practice trials quickly was lost; a variability effect which seems to be contributing to the lack of statistical significance. The lengthening of reaction time after the practice trials in the quiet condition may have occurred as a result of observer expectancy changes. On entering the experimental chamber the observer is equipped with a pair of earphones and after what he is told is a practice session, is instructed to prepare for the experimental trials. Diligently attacking his task, the observer develops expectancy relationships from not only the CRT task, but more importantly, from any source which is made available to him in the experimental environment. One source which is made available to him is the presence of earphones; a source which may be exerting a tacit control far greater than expected. The implication of this kind of a relationship is that it has an effect of improving performance by an increased awareness or arousal while monitoring the earphones for something to happen.

In light of findings in the nature of the observer response (Goldiamond, 1954 and Blackwell, 1953), expectancy relationships have become a much more important experimental consideration. What may be important in this experiment is the prospect of an inclusion of sound as a factor into the
expectancy situation. The graphical curves of the two groups which were receiving auditory stimulation were relatively constant over trials and the curve of the group which was in quiet was apparently not. What may have taken place is that the continuous and intermittent curves were being maintained at a constant performance level by the uncertainty created from the environmental implication of an expectancy of something taking place between those sounds being heard and the visual display which was being monitored. This steady state maintenance did not take place in the quiet condition because it was quickly established by the first block of trials that no sound was going to be presented to the subject. In the other two conditions, an ongoing auditory stimulation was present. The expectancy hypothesis as applied to the CRT task and auditory stimulation might very well be resulting in the possible differences of these performance curves.

The instructions delivered to the Ss at the beginning of the experiment may also be exerting a much greater effect than expected. This effect is indicated by the upsurge of the intermittent and quiet curves near the end of the experimental session as seen in Figure 1. The Ss may have been able to determine much better than expected when the experimental session was about to end, and indicated this by a drastic loss in performance. It is felt then that better controlled instructions given to the Ss may have eliminated this unpredicted performance.
Even though statistical significance was not reached, the presence of incidental environmental effects was implied by the experimental results. What new research then is suggested by these incidental effects? Research should be done in which the hypothesized differential expectancies are manipulated as an independent variable. The vigilance research model can, hopefully, be modified to fit the CRT, high response rate, problem. As has been shown, the design of vigilance performance tasks is significantly affected by non-contingent sound. The primary design of the vigilance task which brings about this effect is the long intervals between stimulus presentations. The parameters in the CRT situation which give rise to further research to determine if they are as significantly influential as long vigilance intervals are the following: the use of an absolute quiet condition; a further manipulation of the percentage of intermittent stimuli to actual experimental time; longer experimental sessions, possibly to extinction; the use of pay off matrices to hold constant individual differences; the manipulation of noise levels versus tone levels; and the manipulation of observer expectancy relationships.

The data of this experiment suggest that sound and perhaps other forms of environmental variation will help to maintain CRT performance and avoid its expected performance decrement. There is considerable evidence that excessive environmental stimulation, for example, vibration (Loeb and
Jeatheau, 1958), extremes of temperature (Loeb and Jeatheau, 1958), auditory warning signals (Broerman and Kirk, 1957), and even music will produce a decrease in the performance of many tasks. The presence of these effects suggest a converse effect of a maintenance of the best performance in an optimally stimulated environment and implies the presence of a possible facilitator, as in this case of sound.

Some important conclusions can be drawn from these research findings; the most important is that the CRT task is not necessarily as stable an experimental paradigm as has been thought. Therefore, its use as a parameter by information theorists should be done so with care. In other words, as evidenced from this research, CRT is not as direct a key into inter-cognitive behavior as previously felt by some researchers. The presence of a "numerous factor effect" as proposed by Edwards' (1965) normative Bayesian model would seem to be the key in the analysis of a CRT task as well as any other performance tasks. The nature of the CRT response has also been overinterpreted by researchers. Ever since its development by Donders, there have been tendencies for overinterpretation of CRT simplicity. The important conclusion from this study is that CRT is like any performance task; a subject of the particular and numerous variables which make up its performance environment.
A number of questions raised by this research remain to be answered. Foremost among these are the following: will a manipulation of the amount of noise presented as well as pitch and intensity level prove to have a significant effect upon CRT; can Edwards' (1965) Bayesian model be used effectively enough to design an experimental situation in which auditory stimulation would prove effective; could environmental changes other than sound maintain CRT; if so, which environmental changes are effective; and what is the optimum sensory stimulation program for each?
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APPENDIX

Experimenter Instructions

This is an experiment to see how well you can perform a simple task, or the time it takes you to respond to the onset of a stimulus lights. In front of each light bulb is a corresponding button which will turn it off. Now I am going to want you to respond and turn it off as fast as you can but with as few errors as possible. While you work I want you to wear these earphones. No sound will give you a key to when the lights come on. In fact you might not even hear a sound. For the first few minutes I want you to practice this task and then I will check with you to see if everything is going all right. Are there any questions? If the subject inquired about the length of the experiment, he was told it would take between 40 to 50 minutes.