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NOISE AND HUMAN PERFORMANCE

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ance on various tasks during exposure to the sound reveal no relation between
rformance and noise conditions. A study is reported of individual differences of
ed annoyance of various sounds between males and females, with females showing
ore variability. A third experiment is reported on effects of noise in
ation with another stressor (fatigue), revealing no significant differences
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NOISE AND HUMAN PERFORMANCE

SUMMARY

One of the objectives of the investigation as proposed was to determine the relationship between the "meaning" of a sound and performance on various tasks during exposure to the sound. Several approaches were used (reported in Experiment I of this report). Results in all studies were negative in the sense that no significant relationships were found to exist between task performance and noise conditions.

Another objective of the investigation was to study individual differences in response to noise. In experiment II comparisons were made between male and female subjects in terms of their perceived annoyance of various sounds. Of particular interest in this study was the difference in variability of response of the males and females with the latter showing much more variability. This study is currently being written up for publication.

In experiment III, the effects of noise in combination with another stressor (fatigue), on a complex psychomotor task was investigated. Subjects were tested under several noise and fatigue conditions. No significant differences between conditions were found.

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EXPERIMENT I

Introduction

Previous experimenters have usually referred to the noise in their experimental situations as "unwanted sound." This is the definition used by Berrien (1946) and Kryter (1950) in their respective summary publications. More recently, noise has also been defined (Burrows, 1960) as "sound without task relevant information."

When referring to sound in such a manner, observed effects have usually been explained with reference to the intensity and duration of the stimulus, and how these variables were related to arousal.

McBain (1961) proposed that such an explanation of effects ignored the subjective value which the sound may have had for each listener. A certain amount of meaning is associated with every stimulus to which we attend. The "intelligibility" of a sound refers to the specific meaning that it may have for a listener. With the use of "white noise" experimenters have assumed that there was no useful meaning for the sound, and that duration and intensity were the only variables of importance. While it may be true that some loud sounds have no meaning when originally heard, there is a strong possibility that they acquire a meaning because of the inherent unpleasantness of very intense sounds.

Several experimenters (Broadbent, 1958a; Wijting & Smith, 1969; and Jerison, 1959) have examined the effect of presenting a task in noise, followed by the same task in silence. They have suggested that the detrimental effect observed in the quiet condition was due to the style of performance which was developed by the subject for use in the noisy session. Those aspects of the task which were affected by the sound (the sound which caused a performance decrement) are similarly affected upon presentation of the original task without the sound.

Although not directly related to research concerning the effects of noise upon performance, an investigation reported by Welford, Brown and Gabb (1950) illustrates that the learning of a style of performance for a specific task, under less than optimal conditions, can influence the style of performance on a later re-test.

Flight personnel were presented with a psychomotor-mental task combination. Those persons who had just returned from a "hard flight" performed more poorly than any of the "easy flight" personnel. The poorest performer in the unfatigued group was better than the best performer in the fatigued group. These results would be expected when comparing a fatigued group's and a rested group's performance levels on a difficult task. However, the experimenters tested the same individuals later on the same task, after some period of rest. The "hard flight" personnel still failed to reach a level of performance comparable with the other, "easy flight" subjects.

The style of performance learned in the first session did not significantly improve in the second, rested session.

An unexplored possibility concerning the difference in performance upon re-testing, after a task has been learned in noise, is the effect of the same noise (used in the first session) on the re-test performance. Differences in performance might well be due to the interaction of the noise and the style of performance learned initially. Re-tests have not involved a re-presentation of the sound stimulus, probably due to the definition of noise that the experimenters were using. Only when the "intelligibility" of the noise (McBain, 1961) is considered does it become apparent that the style of performance in the first of several sessions may have given meaning to the sound, or that the unpleasantness of a high intensity sound may have made the sound, at any level, unpleasant in itself if heard again. By increasing the intelligibility of the sound, detrimental performance effects may result, due to increased distraction from the task.

Terris and Rahhal (1969) indicate that psychological stressors may serve as cues to performance style in such situations. Thus, if a noise is very intense and consequently unpleasant, it may develop some level of meaning, and if heard again at a lower intensity, performance may be impaired due to the sound's distracting qualities which are related to the meaning. Or, if the sound is not of sufficient intensity to be inherently unpleasant, it may acquire a meaning due to the associations between it and the style of performance associated with it.

If the apparent meaning of a sound (to the experimenter) does not correspond exactly with the actual meaning of the sound (to the listener) then performance effects cannot be accurately interpreted. The information associated with the sound is the actual meaning. A sound may be quite low in meaning (apparent) to the experimenter and quite high in meaning (actual) to the listener.

To assess the ease of establishing meaning for a sound, the first experiment in this series of investigations concerns the effect of low level sound (under different experimental situations) upon paired-associate learning. McLean (1969) observed that performance on this task was significantly different between groups. In McLean's study, while the group exposed to noise (85dB) performed more poorly initially, taking longer to learn and remembering fewer associates immediately after the session concluded, this group performed much better than the control group upon re-testing one day later. McLean suggests that what is learned in arousing, noisy conditions is learned more poorly than if learned in quiet, but it is remembered longer. Similar findings, discussed within the framework of perseverative consolidation, have been observed by Kleinsmith and Kaplan (1963, 1964).

Experiment I involved four studies. The first investigation concerned the degree of association between experience and a sound.

In this situation the sound stimulus was held constant and the task was varied. This is the inverse of Broadbent's (1958a) procedure which held the task constant and varied the noise conditions. The experimental paradigm involved two steps: (1) the establishment of associations for the sound, the same task being presented under different noise conditions, and (2) a test of these associations.

In the second investigation an unpleasant environmental stimulus (electrocutaneous stimulation, or "shock") was paired with the sound previously used, to assess the meaning which the sound acquired due to its association with shock, as measured by differences in performance. If the electrocutaneous stimulation was considered unpleasant, the sound which was simultaneously presented should have served as a cue to the unpleasant experience when the sound was heard by itself.

The third and fourth studies of Experiment I were designed to determine whether a novel sound, to which an "unpleasant" meaning had been associated, would have any effect on a complex performance task.

Methods

Stimulus Preparation

Because the noise used in Experiment I was required to have no initial meaning to listeners, and to be novel, white noise was not used as the stimulus. To define such a novel, meaningless sound, a number of sounds were recorded, which the experimenter believed would fit these restrictions. These sounds were then evaluated by listeners.

Fifteen volunteer subjects were used for the sound evaluation. Each subject, individually, listened to each of the sounds during a 30-minute test session. After each presentation of a given sound, the following questions were asked of the subject before a new sound was presented.

1. Can you recognize the sound? For example, is it a motorcycle?
2. What does it sound like? For example, if you can't recognize it, does it sound like something you do recognize, such as a police siren?
3. Does it remind you of anything? For example, does it remind you of a person, an event, a place?
4. Have you heard the sound before? For example, have you heard it in stores or in school?
5. Does it mean anything to you? For example, an air raid siren means something to you, or the sound of breaking glass means something to you.

The sounds each lasted from 10 seconds to 25 seconds, and were played backwards on the tape recorder.

Of the 22 different sounds, only two were not recognized, bubbles in an aquarium and a dripping faucet. No listener indicated that he had ever heard anything like the bubble sound, while several people had heard the dripping faucet sound, but could not identify it.

This indicated that the sound of bubbles, when played backwards, was novel to most listeners and was quite low in actual meaning to them. It was selected for use as the novel sound in Experiment I.

Data Analysis--Use of the Covariate

The Maudsley Personality Inventory (Eysenck, 1959) was used to measure subjects on the dimension of introversion-extraversion. This single measure was used because previous research (Broadbent, 1958b; and Cohen, 1968) indicated that extraversion was an important personality factor to be considered in noise investigations, and because evaluations of the MPI indicated that the introversion-extraversion factor accounted for most of the numerous "other named" dimensions of personality measured by other paper-and-pencil tests (Buros, 1965).

Each of the analyses which involved the examination of subject performance over time utilized the analysis of covariance (Winer, 1962), with the extraversion score as the covariate. This technique permits statistical control of variability. It allows an experimenter to consider such factors as experience or personality as covariates, and to remove their contribution to the overall variability of the performance measures being considered. Any reliable differences can then be attributed directly to the influence of the variables under investigation.

STUDY 1

Methods

Subjects

Subjects in Study 1 of Experiment I were 40 male, volunteer college students, screened for normal hearing and normal (20/20 to 20/40 Snellen) or corrected-to-normal vision. Each subject was paid for his participation.

Performance Task

A series of 10 paired associates were used, each comprised of a 3 letter (consonant-vowel-consonant, or CVC) nonsense syllable to the left and a number to the right. The CVC's were selected from the 0% association value group presented in the Handbook of Experimental Psychology (Stevens, 1951, p. 544). Numbers were assigned to each CVC in a random, non-replacement order, using the numbers 0 through 9.

The associates were:

YUF	0	CEF	5
WUH	1	GUQ	6
TOV	2	XAT	7
LAJ	3	ZOJ	8
QAP	4	SIJ	9

The associates were photographed on 35 mm color slide film, using precut black letters on a white background, no border surrounding the white background. The slides were presented with a Lafayette Instrument Company "Constant Illumination Tachistoscope." Subjects were seated 12 feet from the screen and the image was approximately 20° above a straight-ahead line of sight. All CVC's were to the left and all numbers to the right in each complete pair. CVC's presented alone were in the same relative position as when presented with a number.

The slides were arranged in four separate orders, the series repeating itself every four trials. Each trial consisted of 20 slides. The series for each trial began with a CVC by itself, displayed for 2 seconds, followed by the pair (the CVC and the corresponding number), also displayed for 2 seconds.

Procedure

All subjects were tested alone. Before starting the paired-associates, each subject filled out a Maudsley Personality Inventory (MPI) form. Upon completion, the initial instructions were read to him.

He was then asked to remove his watch, to be sure he was comfortably seated, and to wear an electrocutaneous stimulator electrode.

When the complete instructions were concluded, the room lights were turned off and the session began. Each subject was presented with the first 20 slides (the first set of the ten paired-associates) with no responses allowed. Following this practice trial the series continued and subjects called out the appropriate number when they were presented with a CVC by itself. The experimenter recorded the response, and the latency (from onset of the stimulus slide to the subject's vocalized response). If more than one response was made, only the first was recorded.

Upon completing three successive trials correctly the session was stopped and the subject told to report for a different experiment the following day, at the same time.

Instructions for the second day were given when the subject again reported to the experimental room.

Testing was done during the day and early evening hours. The length of each day's session was variable, depending upon the number of trials necessary for a subject to reach the criterion of three successive correct trials.

On Day 2 the slides were started with the first CVC of the second set, the same performance measures being taken as on Day 1. Upon reaching a criterion of three successive correct trials the session was stopped and the subject was released from the experiment.

Noise Conditions

On Day 1, 20 of the subjects learned the paired-associates while listening through earphones to the tape recording of "bubbles backwards," played at 75 dB(A). The other 20 subjects wore the earphones, but performed the task in quiet (50-55 dB(A)).

Subjects had been randomly assigned to one of four groups for the re-test on Day 2. Each of the original groups was divided. Ten of the subjects performed the Day 2 task in the quiet condition, and the other 10 in the sound condition. The combinations of conditions were: Noise-Noise, Noise-Quiet, Quiet-Quiet, and Quiet-Noise.

Results

Number of Trials to Criterion

Using the number of trials necessary to reach a criterion of three successive correct trials, an analysis of covariance was performed using the extraversion score from the MPI as the covariate. A 4 x 2 (noise conditions x day of measurement) model, with repeated measures on the day-of-measurement factor was used. Results of this analysis are presented in Table I, and illustrated in Figure 1.

Table I

Summary of the Analysis of Covariance of the number of trials to criterion on Day 1 and Day 2. The extraversion score from the MPI is the covariate. (Study 1, Experiment I)

Effect (adjusted for covariate)	SS	df	MS	F
A (Noise condition)	195.463	3	65.154	2.711
Subjects within Groups	841.072	35	24.030	
B (Day of measurement)	4500.011	1	4500.011	266.241**
AB (Noise x Day interaction)	92.495	3	30.831	1.824
B x Subjects within Groups	608.503	36	16.902	

**significant at the 0.01 level

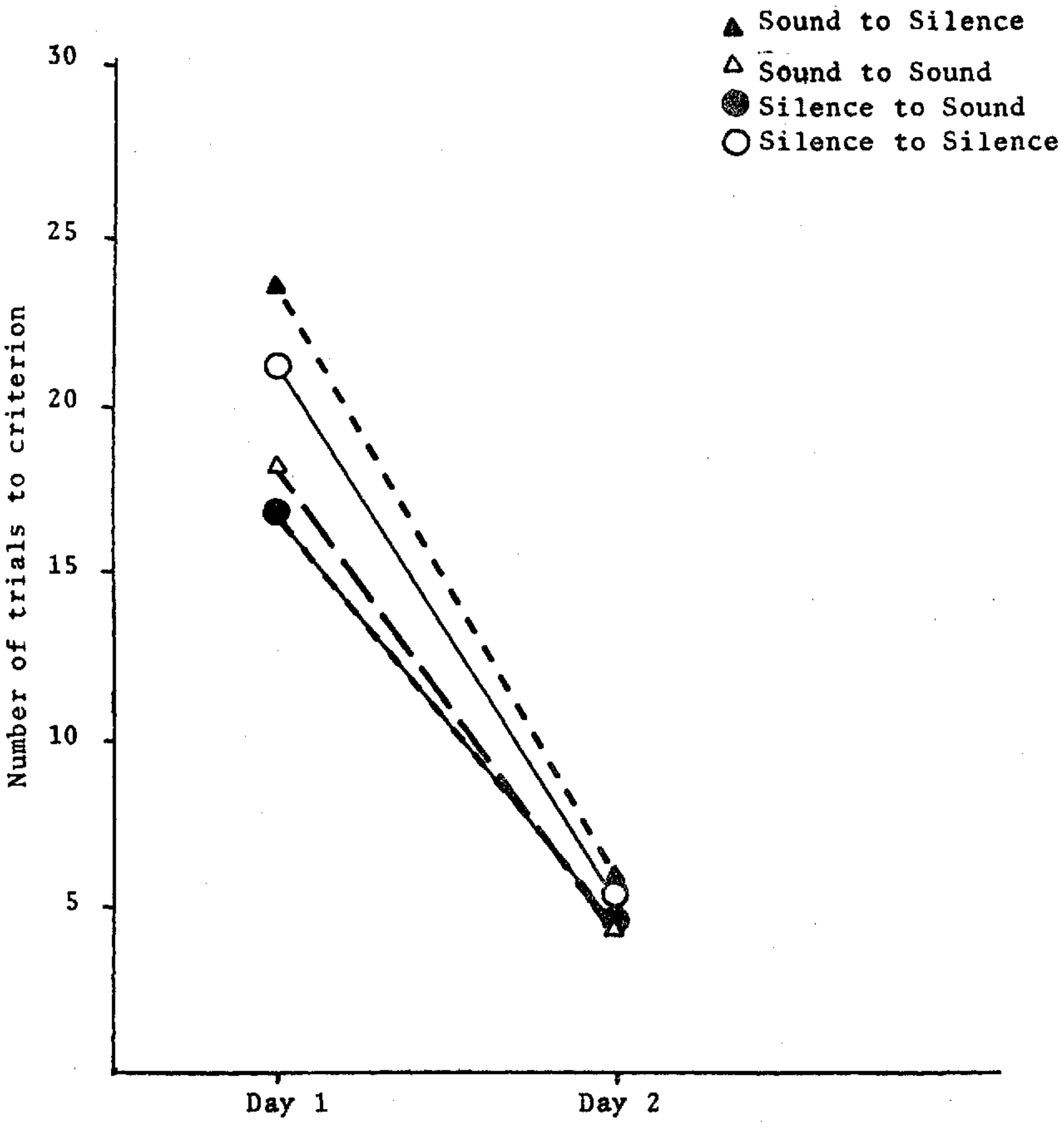


Figure 1

Number of trials to a criterion of
3 correct in a row, Day 1 and Day 2.

Learning did occur over time, as indicated by the significant trials effect, less time being required to reach the learning criterion on Day 2 than on Day 1. There was no difference between groups, and no group by trial interaction.

Latency

Latency for each response was used to determine a mean latency for those trials having a complete set of 10 responses. Because each subject took a variable number of trials to reach the learning criterion, the covariance analysis was performed considering only the last trial for each day, and the first recall trial on Day 2. A 4 x 3 (noise conditions x trial) analysis of covariance model with repeated measures on the trial factor was used, using the extraversion score from the MPI as the covariate. Results of this analysis are presented in Table II, and illustrated in Figure 2.

The significant trials effect indicates that the mean latency changed over time, but the lack of a noise effect or a noise by time interaction indicates that there were no over-all differences between groups or between groups over time.

Number Recalled

Subjects, when presented with the same task on Day 2, were required to vocalize their responses to each CVC stimulus from the first set of 10 associates displayed (correct responses were not displayed during this trial). Each subject's score consisted of the number of correct responses to the first 10 CVC stimuli. These scores were analyzed using a 4 x 1 (noise x trial) analysis of variance. The results are presented in Table III.

No significant differences between groups were observed, and the recall rate was 90% correct.

Table II

Summary of the Analysis of Covariance of the mean latency time for the last criterion trials of Day 1 and Day 2, and the first trial of Day 2. The extraversion score from the MPI is the covariate. (Study 1, Experiment I)

Effect (adjusted for covariate)	SS	df	MS	F
A (noise condition)	0.039	3	0.013	0.650
Subjects within Groups	0.720	35	0.020	
B (Trials)	0.460	2	0.230	38.333**
AB (Noise x Trial interaction)	0.081	6	0.013	2.166
B x Subjects within groups	0.433	72	0.006	

**significant at the 0.01 level

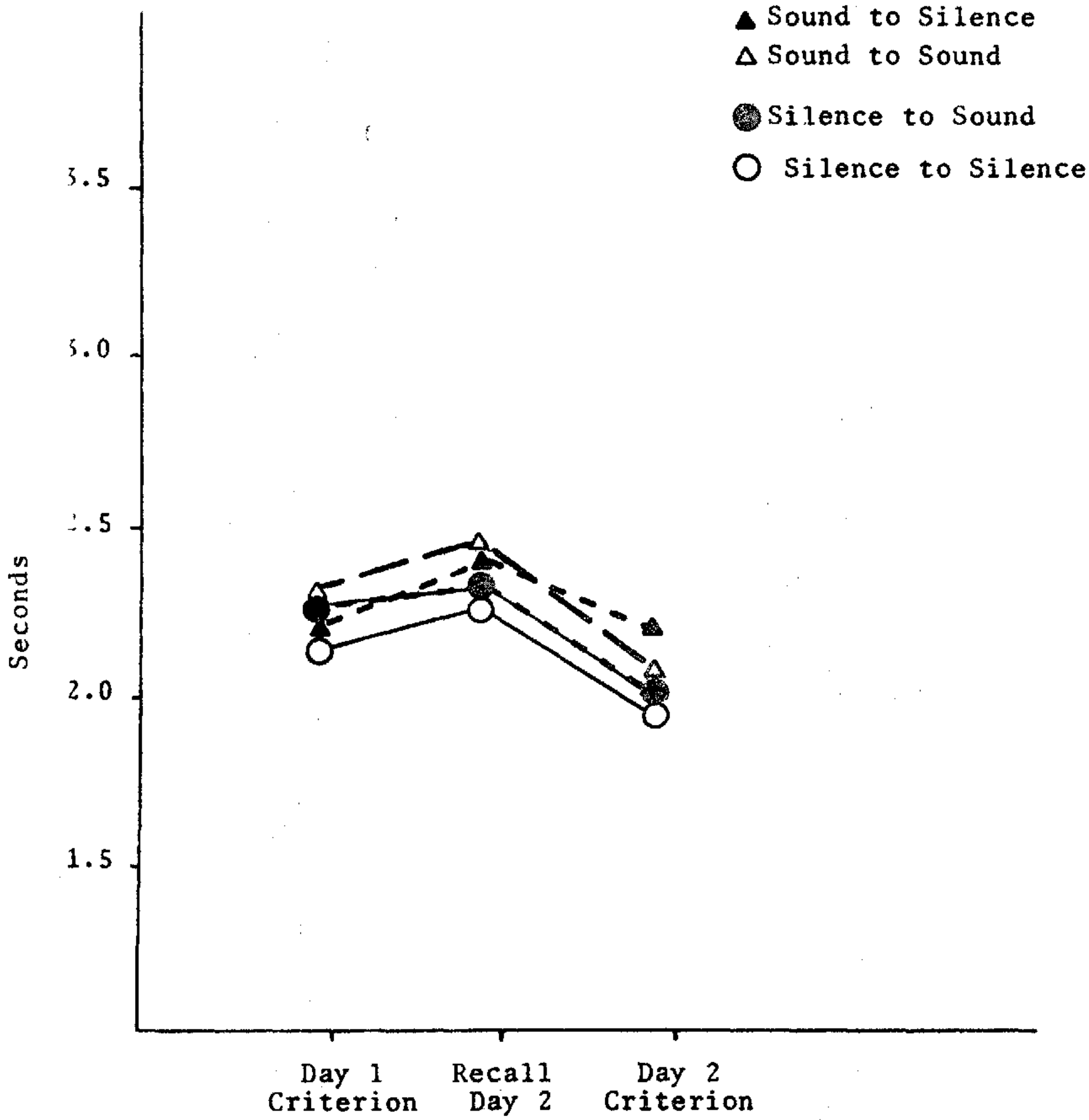


Figure 2

Latency time for responses to paired associates on the last trial of each day, and first trial of Day 2.

Table III

Summary of the analysis of variance of the subjects' recall scores on Trial 1 of Day 2.
(Study 1, Experiment I)

Effect	SS	df	MS	F
A (Noise condition)	1.3	3	0.43	0.401*
error	38.6	36	1.07	
Total	39.9	39		

*not statistically significant

STUDY 2

Methods

Subjects

Subjects in the second study were 40 male, volunteer college students, screened for normal hearing and normal (or corrected) vision. None of these subjects had participated in the first study, and none had any experience on paired-associates tasks. Each subject was paid for his participation.

Performance Task

A different set of 10 CVC's was prepared for the second study. This was done to insure that the list used for the first study would not be known by the second set of subjects through conversations with members of the first subject set. The CVC's were again selected from the 0% association group in Handbook of Experimental Psychology (Stevens, 1951).

The associates were:

GAX	0	MEF	5
DAX	1	VEC	6
CIJ	2	JEX	7
ZIL	3	ZEQ	8
QOB	4	YEM	9

Procedure

The procedure used was identical with that of the first study with the exception that electrocutaneous stimulation was involved. This stimulation was delivered through a concentric electrode worn on the right side of the subject's neck. The electrode, which was built within a 1 1/2 inch square of clear plastic, was positioned with one corner of the plastic base touching the lowest portion of the vertical ramus of the mandible, and the electrode itself resting over the sternocleidomastoid muscle.

Pulses were transmitted at a frequency of 10 per second, each lasting 20 milliseconds, at a voltage level of 100. Current level was initially set at 50 milliamperes, and was reduced during the experimental session for those subjects who complained of a "burning" sensation. The basis for selecting these limits of stimulation was the response of several pilot subjects to various stimulation levels. These pilot subjects had indicated the level at which their reaction changed from "pleasant vibration" to an unpleasant, but not painful or burning, "shock."

The electrocutaneous signals were generated by an electronic stimulator. To protect the subject from accidental shock, the signal was passed through a stimulus isolation unit, which placed a limit upon the maximum voltage actually transmitted through the electrode.

The presence of electrocutaneous stimulation during the task was not amenable to control by any subject response, except removal of the electrode. No subject exercised this option.

Noise Conditions

On Day 1, all of the subjects learned the paired-associates while receiving electrocutaneous stimulation. Twenty subjects received no sound on Day 1, while 20 other subjects received "bubbles backwards" through their earphones. The decibel level was again set at 75 dB(A).

Half of the group which received shock and sound on Day 1 received shock and sound on Day 2, half did not. Half of the group which had heard no sound on Day 1 received shock but no sound on Day 2, while the other half received neither shock nor sound. Thus, the treatment conditions for Day 1 to Day 2 were: Shock-Sound to to Shock-Sound; Shock-Sound to Sound Only; Shock Only to Shock Only; and Shock Only to No Shock-No Sound.

Results

Number of Trials to Criterion

The same model as used in the analysis of covariance for Study 1 was used in Study 2. Results of this analysis are presented in Table IV.

As Table IV indicates, there were no differences between groups on the basis of the number of trials to criterion on Day 1 and Day 2. The significant differences between the days-of-measurement indicate that learning did take place, the number of trials necessary to reach the learning criterion being substantially less on Day 2 than on Day 1.

Comparing Figures 1 and 3, the illustrated day-of-measurement effects for Studies 1 and 2 appear to be nearly identical. The addition of electrocutaneous stimulation (as an unpleasant stimulus) or the replacement of sound stimulation with electrocutaneous stimulation did not produce any differences between groups in the number of trials to the learning criterion.

Latency

The same model as used in the analysis of covariance for Study 1 was used in Study 2. Results of this analysis are presented in Table V, and illustrated in Figures 4 and 5.

Differences between groups were observed when comparing the latencies between groups (after adjustment to the covariate). The

Table IV

Summary of the analysis of covariance of the number of trials to criterion on Day 1 and Day 2. The extraversion score from the MPI is the covariate. (Study 2, Experiment I)

Effect (adjusted for the covariate)	SS	df	MS	F
A (Noise condition)	47.792	3	15.930	0.237
Subjects within groups	2357.161	35	67.347	
B (Day of measurement)	4929.816	1	4929.816	142.377**
AB (Noise x Day interaction)	24.694	3	8.231	0.238
B x Subjects within groups	1246.525	36	34.625	

**significant at the 0.01 level

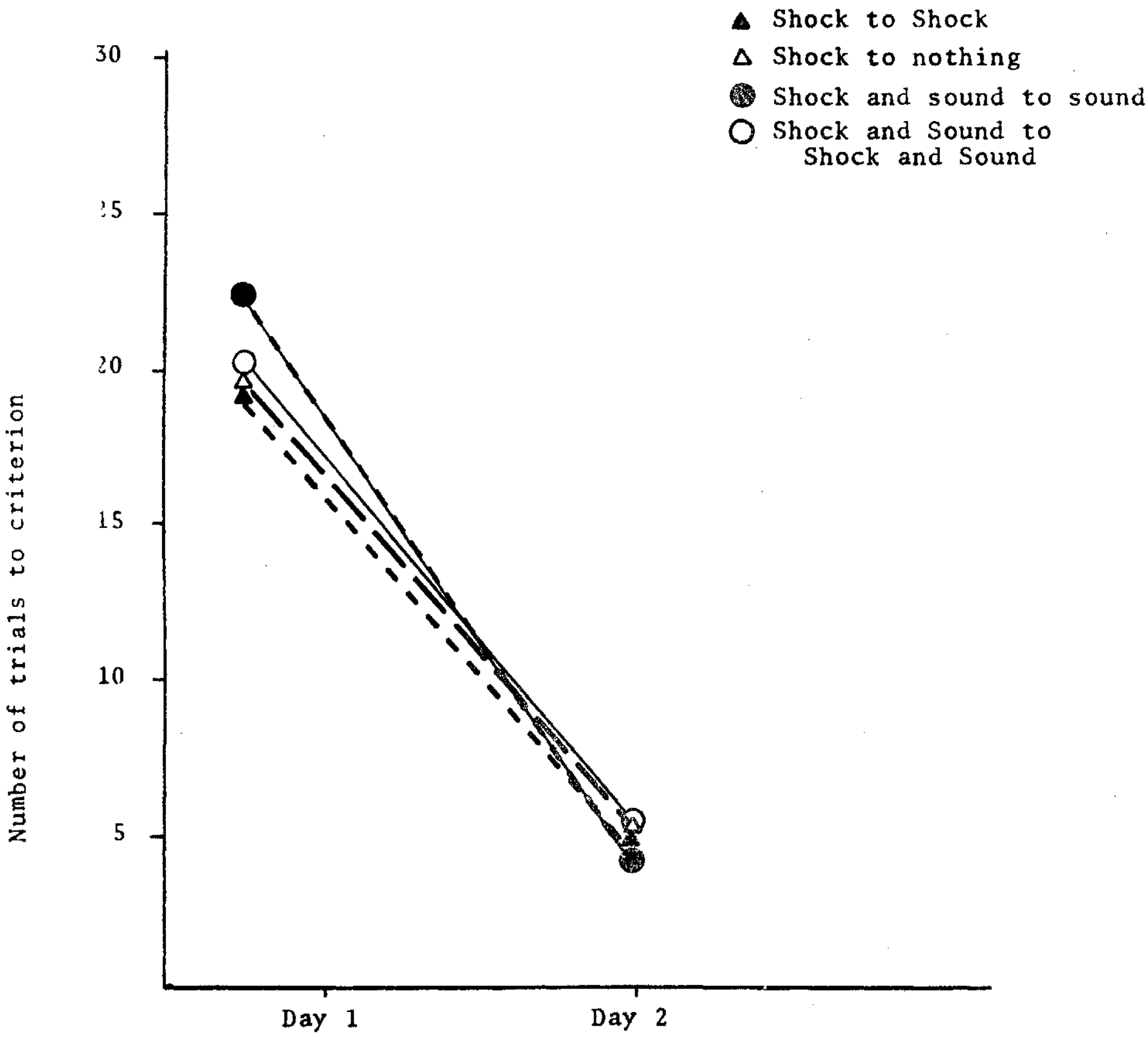


Figure 3

Number of trials to a criterion of
3 correct in a row, Day 1 and Day 2.

Table V

Summary of the analysis of covariance of the mean latency time for the last criterion trial of Day 1 and Day 2, and the first trial of Day 2. The extraversion score from the MPI is the covariate. (Study 2, Experiment I)

Effect (adjusted for the covariate)	SS	df	MS	F
A (Noise conditions)	0.213	3	0.071	3.736*
Subjects within Groups	0.677	35	0.019	
B(Trial)	0.500	2	0.250	83.333**
AB (Noise x Trial)	0.030	6	0.005	1.667
B x Subjects within groups	0.200	72	.003	

*significant at the 0.05 level

**significant at the 0.01 level

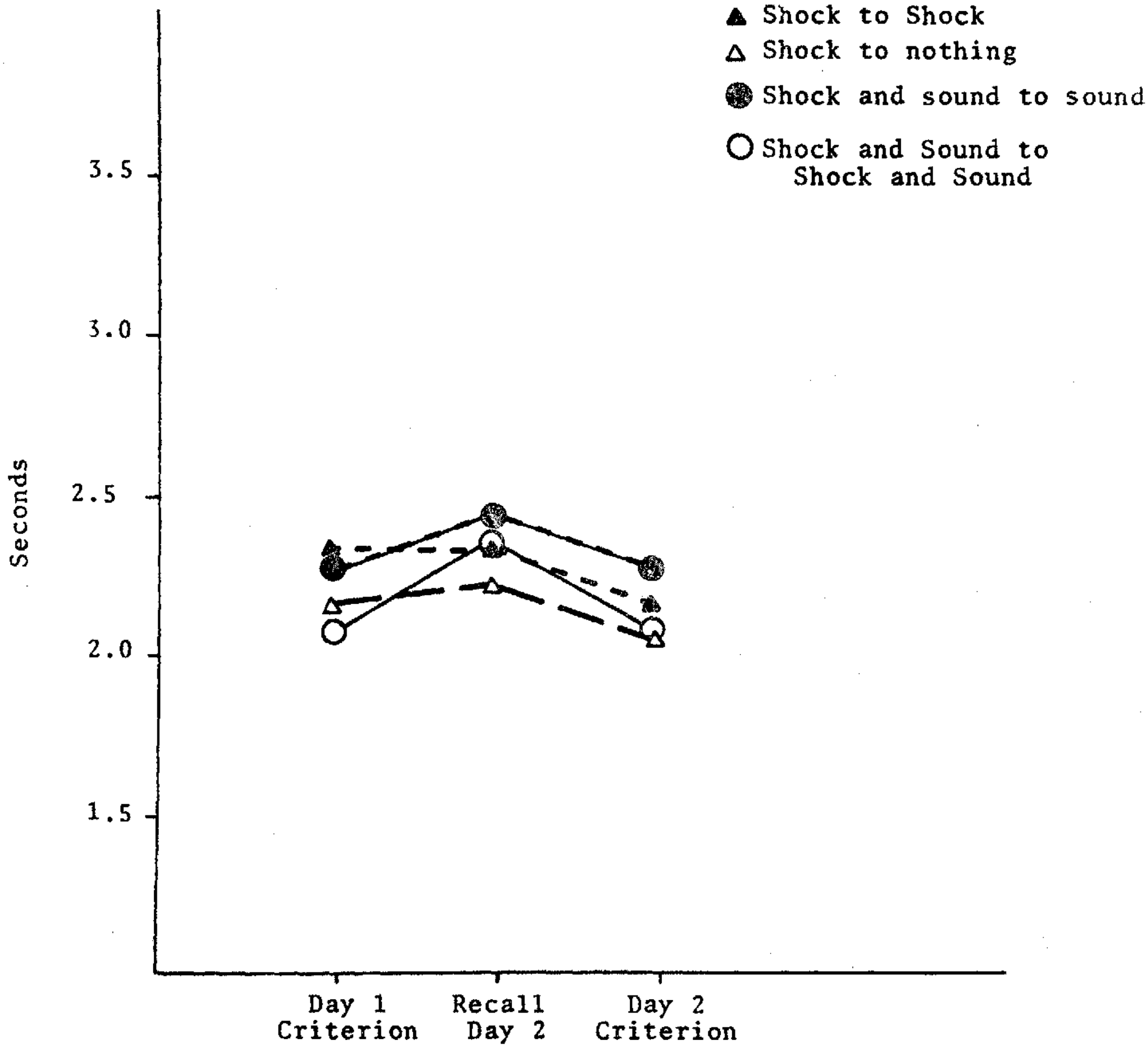


Figure 4

Latency time for responses to paired associates on the last trial of each day, and first trial of Day 2.

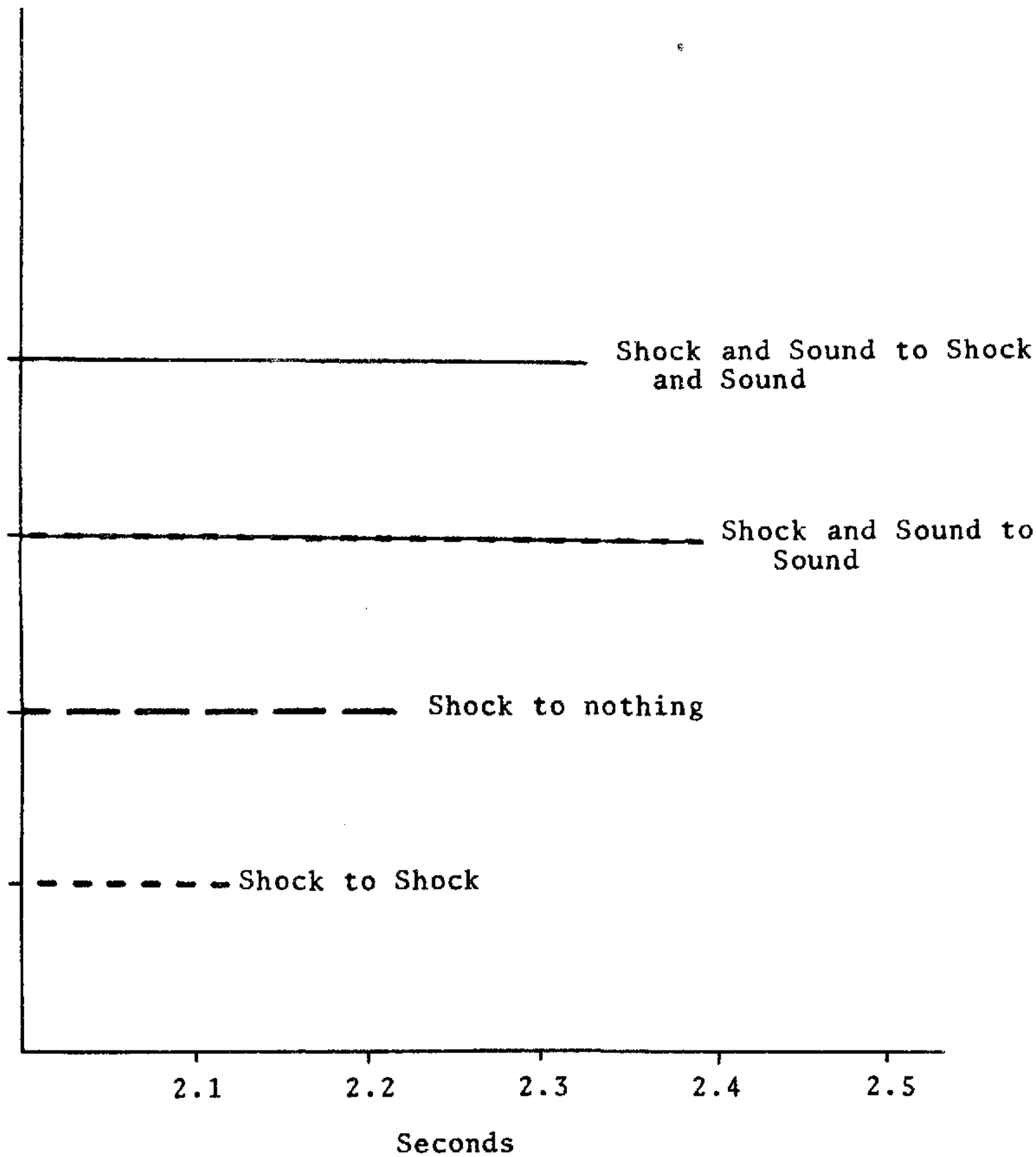


Figure 5

Mean latency time for each group to respond to paired associate stimuli.

differences in latencies for the different trials being considered (Table V) appear similar to the differences observed on this factor in Study 1.

As illustrated in Figure 5, the groups which received electrocutaneous stimulation and sound had longer over-all response times, as compared to the groups which received electrocutaneous stimulation but no sound.

Table VI presents the mean extraversion (E) scores (Winer, 1962, p. 604) for each experimental group. This row of scores is labeled Mean E-score. The mean latency scores, adjusted for the influence of the covariate, are listed in the last row of the table.

Number Recalled

Analysis of subject recall scores was performed using the same analysis of variance model as in Study 1. Results of this analysis are presented in Table VII.

The recall rate between groups did not vary, the overall recall rate being 85% on Trial 1, Day 2.

Table VI

Adjusted mean latency time by group, based upon the statistically significant A main effect from Table IV.

Adjusted Group Scores

b = 0.03 (within cell regression coefficient)

	Shock to Shock	Shock to nothing	Shock-sound to sound	Shock-sound to shock-sound
A_y	328	281	258	257
A_y - Group	47	0	-23	-24
Mean $score_x$	2.27	2.22	2.32	2.25
Adjusted mean $score_x$ (latency time)	2.13	2.21	2.39	2.33

Table VII

Summary of the analysis of variance of the subjects' recall scores on Trial 1 of Day 2. (Study 2, Experiment I)

Effect	SS	df	MS	F
A (treatment condition)	4.5	3	1.50	0.738*
error	73.4	36	2.03	
Total	77.9	39		

*not statistically significant

STUDY 3

This study was designed to determine whether a novel sound, to which an "unpleasant" meaning had been associated by means of electric shock, would have any effect on a complex motor task.

Subjects

Thirty male college students were used as subjects. Ten of these had taken part in Study 2 where they had been exposed to the condition involving electric shock while listening to a sound which, initially, was meaningless. The other subjects had not taken part in the previous studies.

Procedures

The ten subjects who had taken part in Study 2 were assigned to one experimental group while the remaining 20 subjects were assigned to two other groups of ten subjects each. Subjects were tested for a 30 minute period on a two dimensional compensatory tracking task. Subjects in two of the groups (including the group made up of subjects from Study 2 who had been exposed to the sound when paired with shock) were exposed to the "novel" sound played at 95 db(A) while subjects in the third group performed on the tracking task under a no-noise condition.

Results

Analysis of variance revealed that no significant differences existed between the three groups on tracking measures of root-mean square error, absolute error, constant error or time off target.

STUDY 4

Subjects

Subjects were 80 male students ranging in age from 19 to 24 years with a mean age of 20.2 years. All subjects had 20/20 vision (corrective lenses were allowed) and normal hearing in both ears. Subjects were volunteers and were paid for their participation.

Procedures

Subjects were assigned to four groups of 20 subjects each. Subjects in each of the groups were exposed to a pre-test condition described below and then tested on a target detection task. The film utilized in two of the pre-test conditions was a documentary dealing with the atomic blasts at Hiroshima and Nagasaki and, based on previous research, had been shown to be highly stressful and emotion arousing. The noise utilized was continuous white noise at 105 dB(A) generated by a Grason-Stadler, model 901B, noise generator and presented to subjects by means of Superex Stereo headphones.

Subjects in Group 1 (20 subjects) were presented with the film and the noise in a pre-test condition. A pre-test condition lasted for 15 minutes total time. Ten of the subjects were then later tested on the target-detection task under the noise condition and ten under the no-noise condition (ambient noise with headphones in place) which was about 55 dB(A).

Subjects in Group 2 viewed the film under the no-noise condition and were then divided into two groups to be tested on the target detection task under either noise or no-noise. Subjects in Group 3 were exposed to noise in the pre-test condition but viewed no film while subjects in Group 4 received no-noise and no film.

A one hour delay was interspersed between the pre-test session and the test session. Two subjects were exposed to the pre-test condition and tested on the target detection task simultaneously.

Target Detection Task

The target-detection task involved presentation of a series of 35 mm slides. Subjects were asked to record whether or not the slides contained a critical target which consisted of a different letter among a background of identical letters, e.g., an R among B's, an X among Y's, etc. Both target and non-target slides appeared in the series. All slides contained 32 background letters. In the target slides, one of the background letters was replaced with a target letter. The background letters used were B, C, E, F, O, R, X and Y, and the target letters for each background condition were R, O, F, E, C, B, Y and X respectively.

Target slides appeared on an average of once in every two slide exposures. Thus, of a total of 56 slides presented to the subjects, 28 were target slides and 28 were non-target slides. Both target and background letters were randomly located in the display area, and in each slide the positions of the letters were different. During testing, a slide was exposed for 0.7 seconds with an inter-slide interval of 2.5 seconds. White light illuminated the screen during the inter-slide interval at a brightness comparable to the brightness of the slide.

The inter-slide interval served as a response interval for the subjects. During this time, if a subject had detected a target on the slide previously observed, he was required to record the observance of the target by placing a check mark on a booklet page corresponding to the number of the slide, in the series in which he observed the target. If no target was detected for that slide, the subject simply skipped the corresponding booklet page and went on to the next page.

Each subject was provided a booklet containing 56 pages, each page having a circle drawn on it and each circle divided into four quadrants. Thus, there was one booklet page for every slide in the series. By requiring that the subject place a check mark, on the booklet page, inside the quadrant corresponding to the quadrant on the slide in which a target appeared, a measure of the number of errors of commission made by each subject was recoverable as well as the number of correct detections he made. Thus, the number of correct detections and errors of commission served as the dependent variables.

Subjects were seated one on either side of the projector and 10 feet from the projection screen in a typical classroom seat provided with a writing-arm. The projector was located 13 feet from the projection screen.

The slides used in the investigation were photographed in the Human Factors Laboratory using a Bell and Howell Canonet camera, model QL 25, and then commerically processed.

The slides, when projected at the distance given above, displayed a circular field 2 feet in diameter and 4 feet from the floor. This resulted in a visual angle for both subjects of 11° 36'. The background letters were 1" in height, and subtended a visual angle of 29'.

Results

Analysis of the data (univariate and multivariate analysis of variance) revealed no significant differences in performance between any groups.

EXPERIMENT II

Introduction

The effects of environmental noise on man's behavior has been, and is now, of considerable interest to both industry and government. Perhaps the two most favored methods of studying these effects have been either to request a subjective report from a person, inquiring as to the annoyance which is produced by a noise, or to give the individual a task to perform, while exposing him to a noise, and then measuring his efficiency, or performance, on that task.

In the latter case, conflicting reports and research studies have been forthcoming for over four decades. Researchers such as Broadbent (1954, 1957), Grimaldi (1958), and Jerison (1959) have reported detrimental effects of noise upon performance. Other researchers, such as Gilmer (1971), Super, Braasch and Shay (1947), Kryter (1970), Park and Payne (1963), Sanders (1961), Teichner, Arees and Reilly (1963) and Warner and Heimstra (1971, 1972, 1973) have reported either equivocal results or no evidence of a detrimental noise effect.

A problem occurs, however, when it is noted that these two measures of the effects of noise, rated annoyance and task performance often do not agree as to the importance of a noise in question. In response to this situation, Broadbent (1957) states:

> In such cases of disagreement, the hardheaded industrialist or soldier will usually prefer the measure of proficiency. Yet this is perhaps a shortsighted view. Complaints of annoyance by noise may well correlate with other forms of verbal behavior, such as legal action, which will have a cash value.
> (p. 10-1)

Broadbent's point is crucial. Although one may rate a noise as being very annoying, there may be no apparent shift in the individual's performance on a task. However, the fact that the noise is very annoying to the person is not something that should be ignored. The significance of noise as a source of annoyance has not been overlooked by governmental agencies, such as the National Institute of Occupational Safety and Health, viz. the Occupational Safety and Health Act, who have expressed concern over the possible relationship between noise and the "mental health" of workers.

Accepting the premise that the annoyance characteristics of noise are important, the next question is: How can the level of annoyance created by an environmental noise be evaluated?

Factors involved in the absolute level of rated annoyance caused by any environmental noise are complex and varied. Considerations as to loudness, pitch, intermittency, localization, meaning and appropriateness of sounds all play a part in the rating of annoyance. In order to delineate a clear-cut area for investigation, only the specific category of the effect of noise intensity upon rating of annoyance was treated in the present investigation.

It is obvious that, due to individual differences, not everyone will rate the annoyance of the same noise equally. However, it has been generally agreed that as the intensity of a noise increases, the more likely it is to produce annoyance in the listener, as this has been the convention in laboratory findings and seems to be supported in field studies as well (Broadbent, 1957). Rating the annoyance caused by a noise intensity is possible in two ways. First, a noise may be presented to a subject and the subject asked to rate the annoyance by indicating a position on a numerical, or verbal, scale representing an annoyance continuum. Since the subject has no real input into the system, this method is considered the "open-loop" method of annoyance rating. In other instances, some level of annoyance may be specified and a subject asked to adjust the intensity of a noise to a point judged as annoying as indicated by the given level. Since, in this case, the subject does have input into the system, this method of annoyance rating constitutes the "closed-loop" method.

This investigation utilized both methods in an attempt to evaluate their relative efficiency and perhaps to select one as having the greater utility.

In light of the fact that women are becoming involved in more occupations traditionally served by men and consequently are more likely to be exposed to higher intensities of noise, the effects of noise intensity on annoyance level in women as well as, and separate from, men should be of interest to personnel and selection people. For this reason, this investigation was also designed to study sex differences in noise annoyance rating.

Research has shown that there is no discriminable difference in mean annoyance ratings between the sexes (Bregman and Pearson, 1972). However, there has been no effort to determine if a difference exists in the variability of rating between men and women. Since girls, particularly in their adolescence, are typically exposed to noises of less variation and intensity than are boys, it seems tenable that young women might not have formulated such relatively stable judgments concerning noise annoyance as young men. If such were the case, one possible result might be that a difference would occur between the noise annoyance rating variabilities of men and women. In view of this, the present investigation was also designed to determine if there is, indeed, any difference in the variability of noise annoyance rating between the sexes.

In summary, the present investigation attempted to evaluate the merits of the closed and open-loop methods of noise annoyance rating, as well as seeking information relating to sex differences in noise annoyance rating and variability of rating. It was hypothesized that: 1) concurrent with Bregman and Pearson's findings, there would be no difference in mean annoyance rating between men and women, 2) there would be a difference in the variability of rating across sex, and 3) the closed-loop rating system would yield results that were in agreement with those typical of the open-loop method of noise annoyance rating.

Method

Subjects

Forty undergraduate students from the University of South Dakota at Vermillion were used as subjects. Of these, 20 were male and 20 were female. These subjects were selected from approximately 50 applicants on the basis of their responses on a questionnaire. Of particular consequence in selection were responses to questions relating to hearing capability, drug usage, and prior experience, if any, in similar investigations.

All 40 subjects fell between the ages of 19 and 25, with the mean age being 20.7 years (21.1 for the males and 20.3 for the females). Each subject received five dollars for his or her participation.

The Noise Annoyance Sensitivity Scale (NASS)

The development and initial work with the NASS took place in a series of pilot studies conducted at the Center for Acoustical Studies, North Carolina State University at Raleigh. The scale, as used in this investigation, is described in depth by Pearson and Hart (1968) and in some detail below.

The NASS makes use of a rating scale technique consisting of 25 scale positions. Figure 1(A) shows the NASS as used in test session one. Each of the 25 scale positions on the NASS was assigned a numerical weighting, with the position indicative of the least annoyance weighted the lowest, and the position indicative of the highest level of annoyance weighted the greatest. The actual numerical weights ranged from 1 to 25. Figure 1(B) shows the NASS with its corresponding numeric scale values.

During one phase of testing, referred to as "open-loop" testing, subjects were asked to listen to several noises and rate the level of annoyance induced by each. The rating of each noise involved placing a check mark at the position on a NASS indicative of the level of annoyance produced by the noise. Subjects could mark any of the nine descriptive expressions on the scale or any of the 16 points between expressions. The result was a 25-point continuum covering the range of expected responses elicited by the noise presentations. Scoring the NASS was simply a matter of recording the numerical weighting associated with the rating scale position checked by the subject.

--	Unbearable and intolerable	25	--	Unbearable and intolerable
-		24	-	
-		23	-	
--	Extremely annoying	22	--	Extremely annoying
-		21	-	
-		20	-	
--	Very annoying	19	--	Very annoying
-		18	-	
-		17	-	
--	Quite annoying	16	--	Quite annoying
-		15	-	
-		14	-	
--	Annoying	13	--	Annoying
-		12	-	
-		11	-	
--	Moderately annoying	10	--	Moderately annoying
-		9	-	
-		8	-	
--	Somewhat annoying	7	--	Somewhat annoying
-		6	-	
-		5	-	
--	Slightly annoying	4	--	Slightly annoying
-		3	-	
-		2	-	
--	Noticeable but not objectionable	1	--	Noticeable but not objectionable
	(A)			(B)

Figure 1.

The Noise Annoyance Sensitivity Scale (NASS); (A) as seen by subjects (B) with corresponding numeric score values.

The NASS used during the second phase of testing (called "closed-loop" testing) bore a high degree of structural integrity to the NASS of Figure 1. It was constructed on a 16-inch by 28-inch rectangle of heavy, blackened cardboard. The nine descriptive expressions were lettered, black on a white background, in capital letters one-fourth inch in height (resulting in a visual angle of 0°30' for the subject, who was positioned 30 inches from the scale). The 16 points resolved between the descriptive expressions were manifest as 3/16-inch by 1/2-inch white rectangles equally spaced between the descriptive expressions, and indented to the right of same by one inch. The 25 scale positions were equally spaced at one-inch intervals.

Rather than the subject indicating a level of annoyance by placing a pencil mark on one of the scale positions, as was the case for the open-loop testing, the investigator delineated a position on the scale by turning on any one of 25 panel lights, one panel light occurring to the left of each of the 25 scale positions.

Therefore, in the open-loop testing, the NASS provided the means of recovery for measures on annoyance rating. However, in the closed-loop testing, the NASS was used as a means of delivery of assigned annoyance level.

Procedure

Because implementation of the closed-loop method was somewhat dependent upon the results of the open-loop method, two test sessions were conducted. The first session tested the subjects under the open-loop method of annoyance rating, and the second session tested the subjects under the closed-loop method.

Test Session One: Subsequent to the screening of the prospective subjects, and elimination of those determined ineligible, arrangements were made providing for the administration of test session one to the 40 subjects selected for participation.

Because of the limited space available in the experimental room, it was necessary to test the subjects in two groups of 20 each. The first group was comprised of the female subjects, while the second group included the 20 males.

As each group of subjects arrived at the laboratory, they were greeted by two assistants and then shown to the experimental room where they were seated. Recorded music was provided over a sound system in order to aid in promoting a relaxed atmosphere.

When all subjects had been seated, the music was discontinued and NASS booklets and Maudsley Personality Inventories (MPI's) were distributed, one each per subject. Subjects were then asked to follow the instructions provided on the face of the MPI. Having completed the MPI, the subjects were read a set of instructions concerning test session one.

Essentially, subjects were asked to rate the annoyance of four noise conditions. These were made up of white noise at 100, 90, 80 and 70 decibels. Each of the four noise conditions, which are described in more detail below, was presented 12 times during test session one with the resulting 48 presentations scheduled randomly. The observed annoyance of each of the 48 trials was rated on a separate NASS, the scales being consecutively numbered from 1 through 48.

The first eight noise presentations were comprised of two each of the four noise levels. These trials were not included in the data analysis, as they were probably affected by a warm-up phenomena, noted in pilot work with the NASS by Bregman and Pearson (1972).

The presentation schedule for the 48 noise stimuli was cyclic, with on on/off ratio of 15 seconds and 15 seconds. The interstimulus interval provided ample time to complete the rating of the noise annoyance and proceed to the next page in the booklet.

Prior to the presentation of each of the noise stimuli, one of the assistants announced the sequential number of that stimuli. This was intended to prevent subjects from becoming confused and, as a result, getting their ratings out of sequence with the noise presentations. For both groups, not a single such occurrence transpired.

With the conclusion of test session one, all materials were collected from the subjects and they were told that they would be contacted by phone in order to schedule them for test session two. The subjects were then read a short set of dismissal instructions and then released.

The female group of subjects was tested on a weeknight, the test session beginning at 7:00 p.m. The male group was tested the following weeknight at the same time. Total experimental time for each group was 30 minutes.

In summary, the independent variable in test session one was noise intensity. Four levels of intensity were used: 100, 90, 80 and 70 dB(A), slow. (All decibel measures reported herein are based on the reference pressure of .00002 Newtons per meter squared.) The program material presented at the above intensities was white noise in the 70 to 10,000 Hz. spectrum.

Although white noise does not occur frequently in exoteric laboratory environments, it has the advantage in research of this type in that it embodies low associative meaning for most people.

The two dependent variables involved in test session one were mean noise annoyance rating and rating variance. A mean rating was taken on each of the four noise conditions for each subject as was the variance associated with the mean ratings for each group. Recovery of both measures was permitted by the use of the NASS, as described above.

<u>Test Session Two</u>: Some computations on the subject's annoyance ratings of test session one were prerequisite to initialization of test session two. Each subject, as will be recalled, rated the annoyance level of four noise treatment conditions in test session one. These ratings were scored, numerically, and a mean annoyance rating score was obtained for each of the four noise treatment conditions. After rounding to the nearest integer, what remained were four integer scores, per subject, representing four positons on the NASS which, in turn, represented that subject's mean level of annoyance generated by each of the four noise treatment conditions of test session one. These four assigned annoyance levels became the independent variable for test session two.

Each of the four assigned annoyance levels was presented 12 times during test session two, resulting in a total of 48 trials. Presentations were randomized. Subjects were tested on an individual basis during test session two.

Upon arrival at the laboratory, the subject was shown to the experimental room where he was seated directly in front of the instrumented NASS. The experimenter then briefed the subject on test session two procedures by reading him a set of prepared instructions.

Essentially, the subject was told that his task consisted of adjusting the intensity of the white noise eminating from his headset until he felt that it was as annoying as was indicated by the illuminated position on the instrumented NASS. When such an adjustment was reached, the subject was instructed to press his response button, thus indicating his completion of the adjustment and terminating that trial.

The volume control provided the subject made it possible for him to vary the intensity of the audio program material from a low of 55 decibels (A), slow, to a high of 115 decibels (A), slow.

Again, the presentation of the noise was cyclic, with an on/off ratio of 15 seconds and 15 seconds. However, in test session two, the subject was allowed as many stimulus intervals as needed to make his adjustment.

At the end of each trial, the subject's decibel adjustment was recorded, the NASS light was extinguished, and a new light on the NASS was illuminated, followed by delivery of the audio program material back to the subject's headset. This, then, was the trial-by-trial sequence of events in test session two.

As in test session one, the first eight annoyance levels given each subject were comprised of two each of the four assigned levels used. And again, these were not included in the data analysis as they may have been influenced by the warm-up phenomena.

Following the 48th trial, the subject was again read a short set of dismissal instructions, removed from the experimental room, payed, thanked and dismissed.

Total experimental time for the subjects in test session two varied according to the adjustment times of each subject, but at no time was it less than 20 minutes nor more than 35 minutes.

Testing on session two began one week following test session one. Subjects were tested during the hours from 8:00 a.m. to 7:00 p.m., depending on their availability. Seven days were required to complete test session two.

In summary, then, the independent variable in test session two was assigned noise annoyance level. Four levels of annoyance were determined for each subject based on the subject's four mean annoyance ratings of test session one.

As in test session one, two dependent variables were under investigation in test session two. First was the level of noise, in decibels (A), slow, selected by each subject as representative of an assigned annoyance level. Second was the variance, by sex, of these decibel levels. Methods of recovery for both of these measures are discussed in the apparatus section.

Apparatus

In both test sessions, the audio program material was generated by a Grason-Stadler noise generator, model 901B. A Bruel and Kjaer precision sound level meter, type 2203, was utilized for all acoustic measurements.

In test session one, the signal output from the noise generator was interfaced through a programmable interrupt device to an Acoustic Research stereo amplifier. (Acoustic Research makes only one model of stereo amplifier at this writing.) This amplified audio signal was then input to two Acoustic Research AR-5 speaker systems. With the aid of the sound level meter, four points of adjustment on the output control of the stereo amplifier were located and marked. These settings corresponded to the four levels of noise intensity used as independent variables for test session one. A Lafayette interval and repeat-cycle timer, model 400B, provided the interrupt function, delivering the necessary intra- and inter-stimulus intervals for the audio program material--specifically, 15 seconds each.

The experimental room used during test session one was 15 by 17 1/2 feet and had a 10-foot ceiling. The AR-5 speaker systems were located at one end of the room, 12 feet apart and 5 feet off the floor. The room was acoustically "hard," with no windows, no carpeting, plaster walls and ceiling, and a concrete floor. The subject's chairs were the standard "classroom" type, wooden with a laminate writing arm attached, and were arranged symmetrically about the experimental room. Air conditioning was available for temperature maintenance. Lighting, provided by a dual, 10-foot, overhead fluorescent lighting array, although not quantitatively measured, was deemed adequate for the rating task.

Analysis of the room's acoustics revealed that there was no apparent shift in sound environment, as a function of locus, with the exception of locations directly in front of the two speaker systems. In accordance with these findings, no subjects were located in these areas.

Because subjects were run on an individual basis in test session two, a smaller experimental room was advantageous. As a result, testing was conducted in a room 17 by 8 feet. Furnishings consisted of a subject's chair, of the same type noted earlier; the instrumented NASS; a pair of Superex stereo head-phones, model ST-PRO-B; and a response box.

The response box contained a volume control, used by the subjects to make intensity adjustments on white noise presented through the headset, and a push-button used to indicate when he had completed adjustment.

The headset was used for sound reproduction in test session two because, with only one subject participating at a time, there was no need to present the audio program material in a free-field manner. Use of the head-phones also eliminated need for the Acoustic Research stereo amplifier, as the Grason-Stadler noise generator was capable of driving the headset to intensity levels in excess of those required.

A second Grason-Stadler noise generator, of the same model, was located in the experimental room. This noise generator was interfaced to an Acoustic Research AR-5 speaker system and provided background noise at 55 decibels (A), slow. This not only aided in providing some degree of environmental acoustic homogeneity, but also assisted in masking noises eminating from outside the experimental room.

The Lafayette interval and repeat-cycle timer was again enlisted to provide intra- and inter-stimulus intervals for the audio program material. As in test session one, the intervals were both 15 seconds. During the intra-stimulus interval, the subject could make adjustments on the intensity of the program material. When the subject felt that he had made the proper adjustment, he depressed the push-button provided on the response box. This had the effect of switching the program material from his headset to an identical headset in the control room. This control-room headset was mechanically interfaced with the Bruel and Kjear sound pressure level meter via a Bruel and Kjear artificial ear attachment, type 4152. Thus, when the subject completed his adjustment and pressed his response button, the intensity of the audio program material, as heard by the subject, was directly measurable on the sound pressure level meter.

Ag in, lighting in the experimental room was not quantified, but was considered as adequate. Air conditioning was again provided.

Data Analysis

Test Session One: The data obtained during test session one consisted of the noise rating responses and the MPI Extroversion-Introversion and Neurosis scores (E and N scores, respectively).

For reasons discussed earlier, the first eight annoyance ratings made by each subject in test session one were not retained as usable data. Thus, what did remain for each subject were 40 annoyance scores, 10 each on each of the four levels of the independent variable. The mean annoyance score for each subject across these four noise levels was calculated. These mean annoyance scores served as one of the dependent variables for test session one.

These data conformed to a two-way analysis of variance with repeated measures along one dimension (also called a one-between and one-within design). Sex was the between-subject variable, while the four noise conditions were repeated within subjects. This design permitted examination of the two main effects and the sex-by-noise intensity interaction.

The above analysis concerned itself with differences in mean annoyance scores. Of equal interest was the variance, between the sexes, associated with these scores. This was the second dependent variable in test session one.

In order to test for significance along this variable, it was necessary to gain some measure of the overall variance in rating scores by sex. What was needed, statistically, was a measure of the Mean Square within cells at factors A_1 and A_2, males and females, respectively. The following expression yielded these data:

$$\text{Mean Square within cells at } A_j = \frac{\text{Sum of Squares within cells at } A_j}{\text{the appropriate df}}$$

where:

$$\text{Sum of Squares within cells at } A_j = \text{Sum of Squares } (S/A_j) + \text{Sum of Squares } (BxS/A_j)$$

A test for the equality of these two variances was accomplished by use of the test criterion: $F = S_1{}^2/S_2{}^2$, where $S_1{}^2$ was the larger mean square (Snedecor and Cochran, 1969). With these data, the associated degrees of freedom were 76 and 76.

An overall mean and standard deviation was calculated on the MPI E and N scores for the males and for the females.

Test Session Two: The data obtained during test session two consisted of measurements, in decibels, of noise intensities selected by each subject as representative of four assigned annoyance levels.

Decibels are based on a logrithmic relationship, rather than a linear, equal-interval one. For this reason, the data collected in test session two had to be subjected to a linear transformation before further parametric analysis was possible.

The linear, equal-interval transformation used was such that the decibel measurements were converted into a pressure, in Newtons per square meter. Pressure is a linear function and is therefore amenable to parametric statistical analysis. The transformation followed the equation:

$$\text{Pressure} = (.00002\ N/m^2) \times 10^{\frac{\text{dB (observed)}}{20}}$$

As indicated earlier, the first eight subject responses, in test session two, were not retained for analysis. What remained, then, were 40 decibel measurements per subject, 10 each on each of the four levels of the independent variable. Following transformation, the mean pressure for each subject, across these four levels, was calculated. These mean pressures served as one of the dependent variables for this test session.

The same analysis of variance design as used for the mean annoyance scores in test session one was used on the pressure scores obtained in test session two. The data layout was identical as was the between-subject variable, sex. However, of course, in test session two, the within-subjects variable was assigned annoyance level.

Similarly, the second dependent variable in test session two was the variability, between sexes, associated with the pressure scores. Testing for significance along this variable was identical to the corresponding test used for annoyance rating score variance in test session one.

A mean pressure score for the males and for the females was calculated across the four levels of the independent variable. These means, along with the variance of the means, were then transformed back to a decibel score. It was then possible to calculate any statistical difference resulting from rating of annoyance in a closed-loop vs. an open-loop system. In other words, the subjects generated an average noise annoyance rating for four noise intensity levels. These mean ratings were then fed back to the subjects who were required to define decibel levels as annoying as the mean ratings. The degree to which these two methods of determining one's noise annoyance sensitivity agreed was testable using the Student's t statistic.

Results

All statistical tests calculated on data from test session one and two were tested against an alpha level of .05 percent.

Test Session One

Figure 2 shows the relationships found between noise intensity level and mean annoyance rating, by sex. This information is also presented, numerically, in Table 1. Figure 3 shows these mean annoyance ratings in relation to the NASS.

The results of the analysis of variance computed on these mean annoyance ratings are given in Table 2. As could be expected, a strong difference was observed between the ratings of the four noise intensities. There were no significant differences, however, between the mean annoyance ratings across sex or as a result of the sex-by-noise intensity interaction, as hypothesis number one predicted.

Figure 4 shows the variance, by sex, associated with the noise annoyance ratings. These data are also tabulated in Table 3. When the overall F est for significance was computed on the variance of the ratings, between sexes, it was found to be significant at the $p < .001$ level, $F = 1.99$. This finding was also in agreement with its corresponding hypothesis, number two. As a result, pair-wise comparisons, computed on the variance associated with the annoyance ratings at each of the four noise intensity levels were calculated. Results of these comparisons are shown in Table 4. All were significant with the exception of the variances produced across sexes at 100 decibels.

Educational and Industrial Testing Service of San Diego, publishers of the MPI, place the mean and standard deviation for the E score, across American university students, at 28.73 and 8.18, respectively. For the males in this investigation the mean E score was 26.80. For the females it was 30.60. Similarly, the mean for the N score is given as 20.66, with a standard deviation of 10.65. The males in this study had an average N score of 23.00. For the females, it was 24.80. Thus, it can be seen that both groups' average E and N scores fell well within one standard deviation of those given as university student population parameters.

Test Session Two

The mean decibel adjustments, by sex, across the four assigned annoyance levels are shown in Figure 5. Table 5 contains these mean decibel adjustments in tabular form.

Table 6 gives the results of the analysis of variance computed on these data. As in test session one, no significant differences on the dependent variable were observed with the exception that decibel adjustments were differentially affected by the four levels of assigned annoyance, as would be expected. Again, these data confirm hypothesis number one.

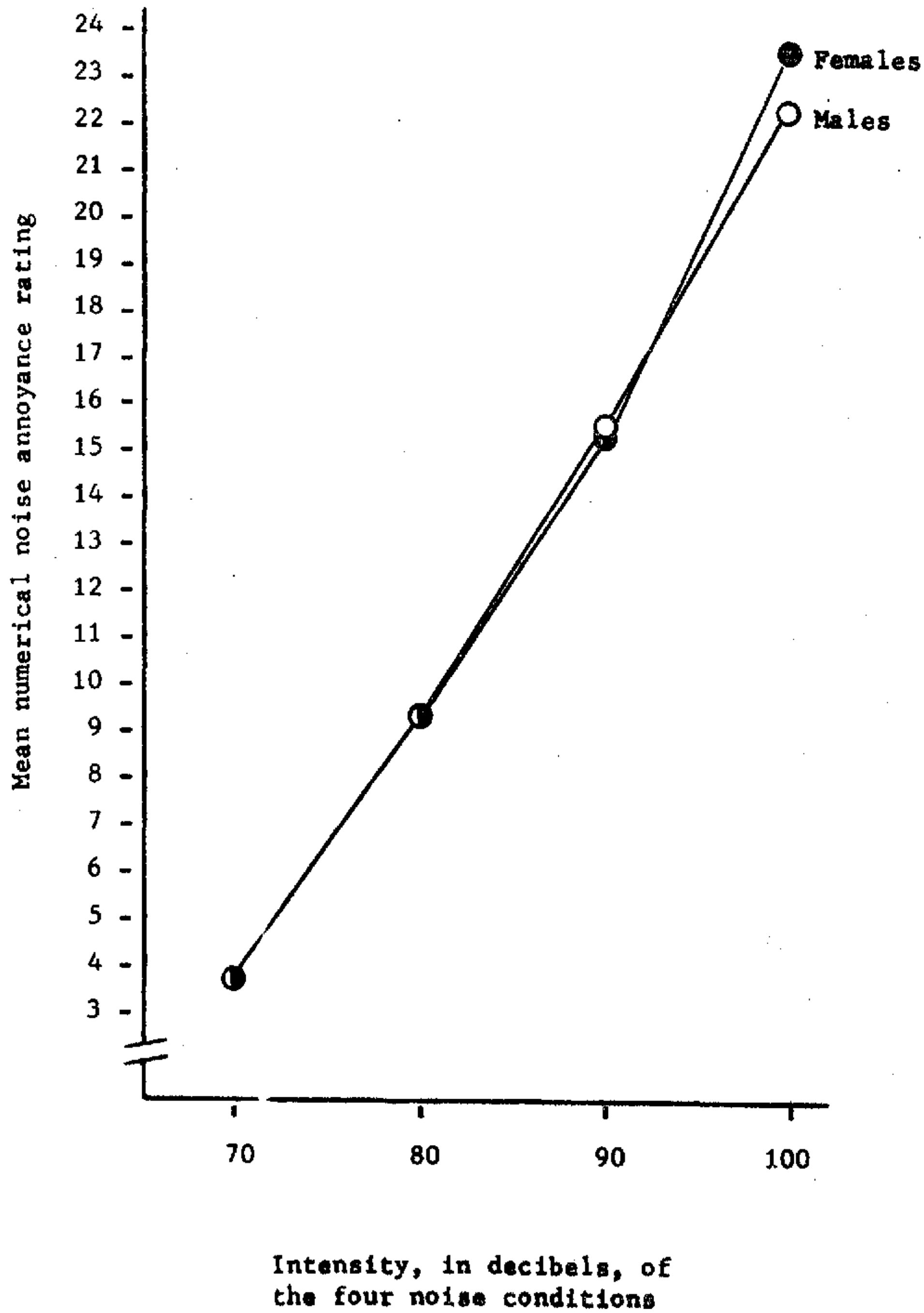


Figure 2.

Mean annoyance ratings, by sex, across four noise intensity levels

Table 1.

	Mean Annoyance Rating		
Noise ntensity	Males	Females	Combined
[illegible]0	3.6	3.6	3.6
80	9.2	9.2	9.2
[illegible]0	15.3	15.2	15.3
100	22.1	23.4	22.8

Tabulation of mean annoyance ratings, by sex, across four noise intensity levels.

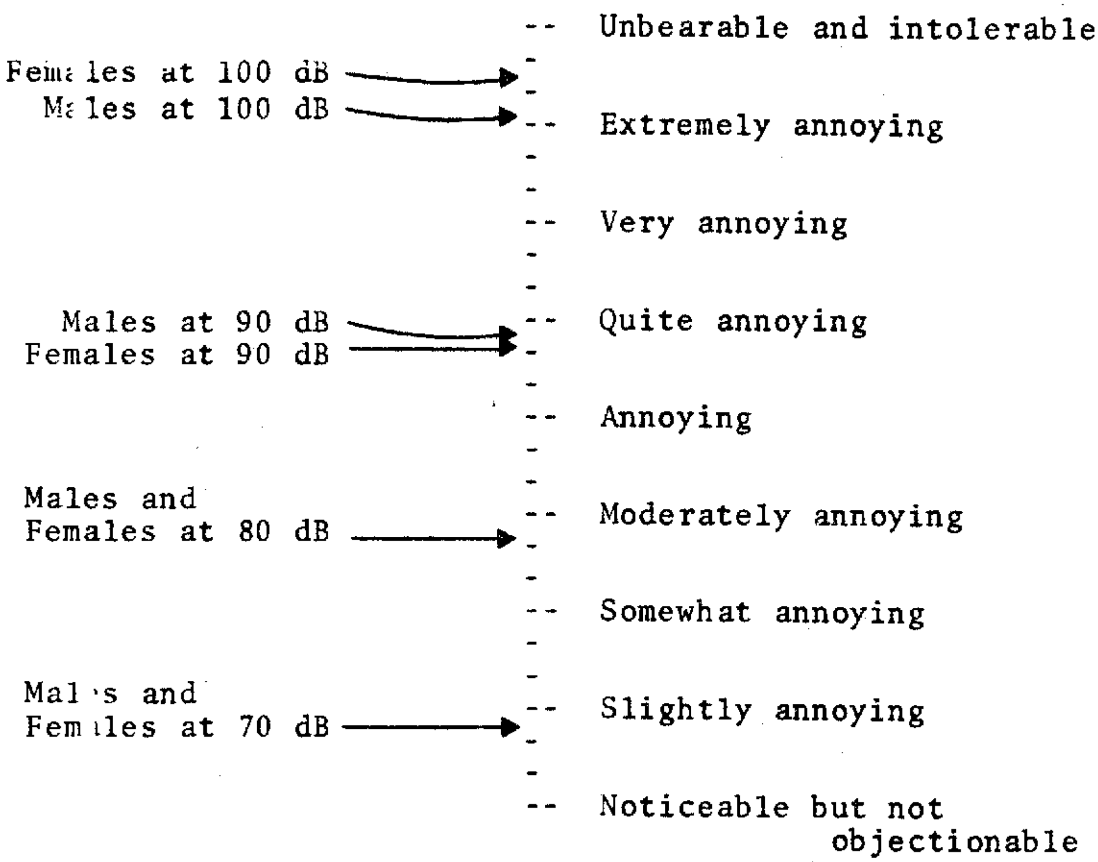


Figure 3.

Mean annoyance ratings, by sex, across four noise intensity levels shown in relation to the Noise Annoyance Sensitivity Scale (NASS).

Table 2.

Source	df	SS	MS	F
Total	159	9203.68		
Between S.	39	756.77		
Sex	1	4.29	4.29	.22
Sub./sex	38	752.48	19.80	
Within S.	120	8446.91		
Noise	3	8108.50	2702.84	945.05*
Noise x sex	3	11.86	3.95	1.38
Sub. x noise/sex	114	326.55	2.86	

* $p < .0001$

Source table showing the results of an analysis of variance computed on mean annoyance ratings of test session one.

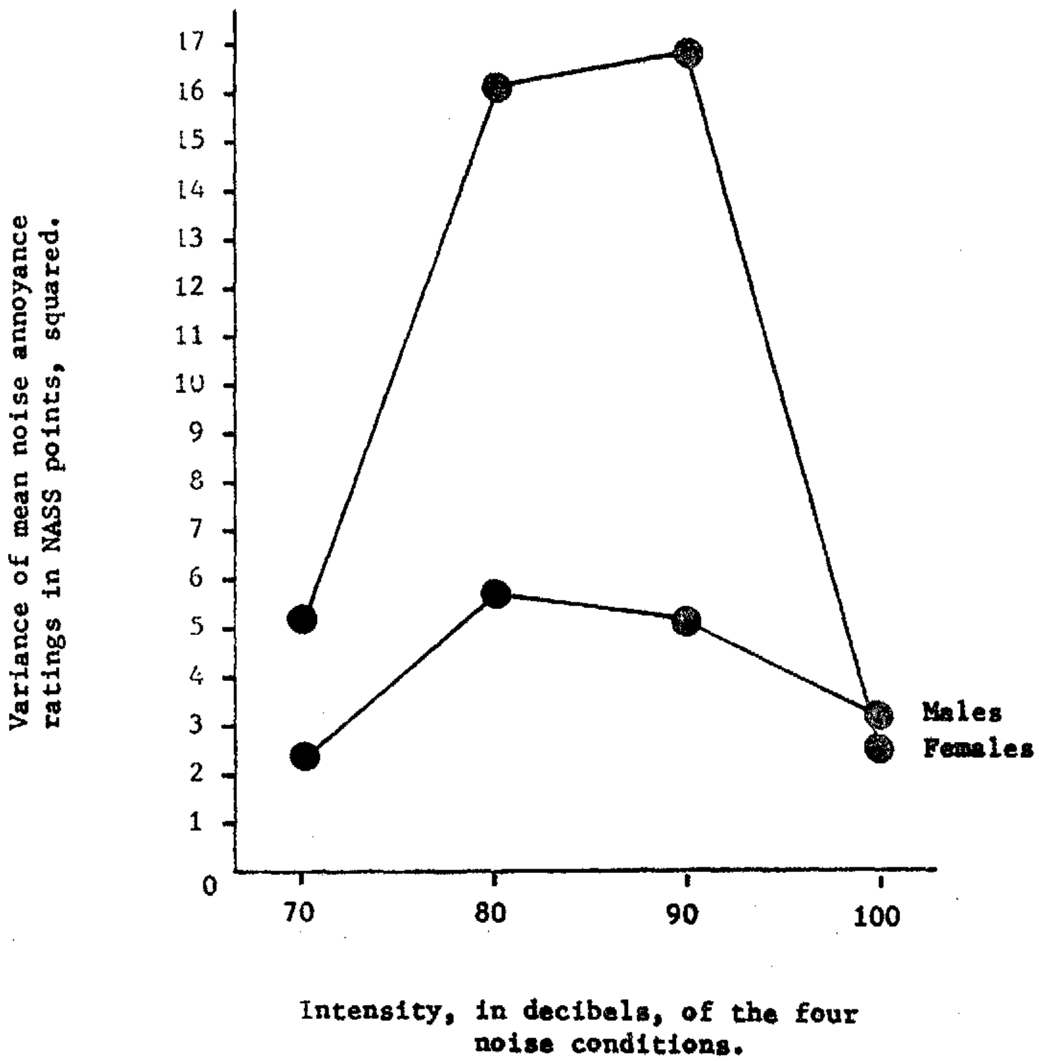


Figure 4.

Variance, by sex, associated with the noise annoyance ratings of test session one.

Table 3.

Noise Intensity	Variance, in NASS units squared, associated with the mean ratings		
	Males	Females	Combined
70	2.3	5.1	3.6
80	5.7	16.1	10.6
90	5.1	16.8	10.6
100	3.2	2.5	3.2

Tabulation of variance, by sex, associated with the noise annoyance ratings of test session one.

Table 4.

Noise Intensity	Variance, by sex, associated with ratings		F-Ratio	p
70	F.	5.1	2.2	< .001
	M.	2.3		
80	F.	16.1	2.8	< .001
	M.	5.7		
90	F.	16.8	3.3	< .001
	M.	5.1		
100	M.	3.2	1.3	< .20
	F.	2.5		

Results of pair-wise F-tests, between sexes, computed on the variance associated with the annoyance ratings at each of four noise intensity levels.

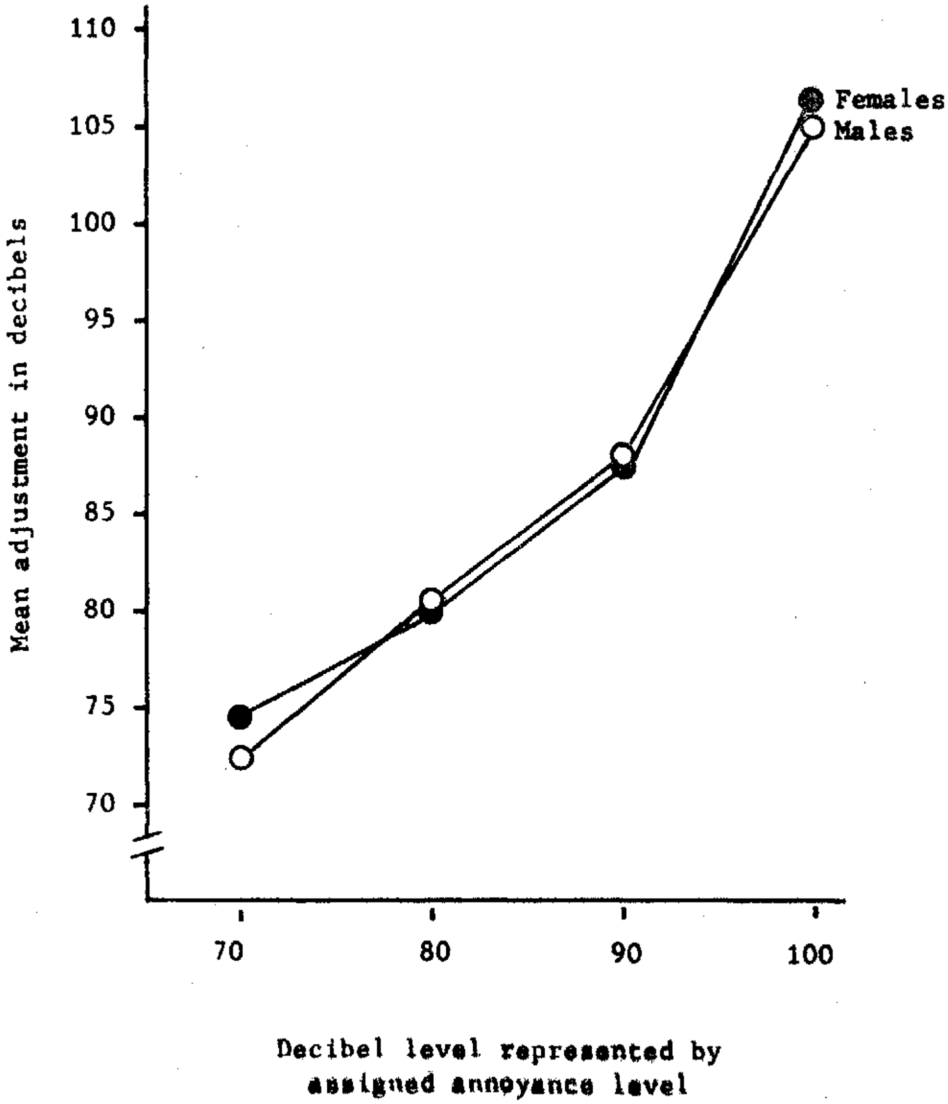


Figure 5.

Mean decibel adjustments, by sex, across four assigned annoyance levels.

Table 5.

Decibel level represented by assigned annoyance level	Mean decibel adjustment		
	Males	Females	Combined
70	72.4	76.4	73.4
80	80.8	79.8	80.3
90	88.9	88.1	88.5
100	105.3	106.6	106.0

Tabulation of mean decibel adjustment, by sex, across four assigned annoyance levels.

Table 6.

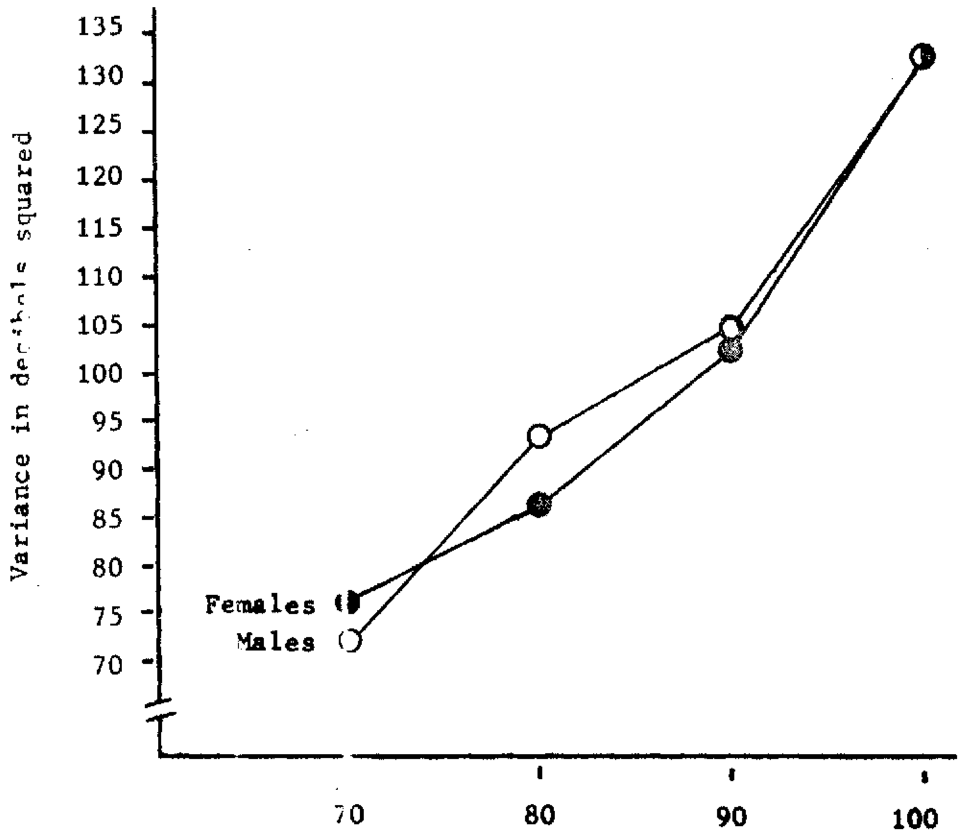
Source	df	SS	MS	F
Total	159	73,876.4		
Between S.	39	11,232.1		
Sex	1	70.6	70.64	.24
Sub./sex	38	11,161.5	293.72	
Within S.	120	62,644.3		
Noise	3	54,009.7	18,003.22	245.7*
Sex x noise	3	280.7	93.56	1.3
Sub. x noise/sex	114	8,354.0	73.30	

* $p < .001$

Source table showing the results of an analysis of variance computed on the mean decibel adjustment of test session two.

Figure 6 and Table 7 show the variance, by sex, associated with the decibel adjustments of test session two. An overall *F*-test calculated on these data did not yield significance ($F = 1.01$, $p < .35$). Consequently, no pair-wise comparisons were completed on these data.

The results of the multiple *t*-tests, comparing mean decibel adjustments of the closed-loop test session with the mean decibel levels rated in the open-loop test session, are given in Table 8. Only two were significantly different, those occurring at 70 and 100 decibels for the females.



Decibel level represented by
assigned annoyance level

Figure 6.

Variance, by sex, associated with the
decibel adjustment of test session two.

Table 7.

Decibel level represented by assigned annoyance level	Variance in decibels squared associated with the mean adjustments		
	Males	Females	Combined
70	72.4	76.4	74.5
80	93.1	85.6	89.9
90	104.4	100.2	102.4
100	131.9	132.1	132.0

Tabulation of variances, by sex, associated with the decibel adjustments of test session two.

Table 8.

Sex	Decibel level that adjustments were based on	Mean adjustment (in decibels)	*t*-score
Males	70	72.4	2.06
	80	80.8	- .04
	90	88.9	.37
	100	105.3	1.26
Females	70	76.4	2.85*
	80	79.8	- .40
	90	88.1	- .09
	100	106.6	2.15*

* $p < .05$

Results of multiple *t*-tests, by sex, comparing mean decibel adjustments of test session two with decibel levels rated in test session one.

EXPERIMENT III

Introduction

An environmental stressor, such as noise, seldom, if ever, occurs under conditions where its effects are not confounded by other environmental variables, by task variables, or by subject variables. This fact has been recognized by researchers in the noise area who have demonstrated, on occasion, that interaction of noise variables and other variables will result in unpredictable performance effects. However, relatively little research has been conducted dealing with these interactive effects.

In Experiment III, a combination of noise and fatigue stressors was employed and the effects of this combination on a complex performance task were assessed. Previous research by Wilkinson (1963) showed that fatigued subjects (fatigue defined in terms of sleep loss) showed a decrement on a performance task. Subjects exposed to 100 dB white noise also showed a decrement on this task. However, when the two stressors were combined, there was an improvement in performance. Other research has also shown that combining stressors will result in performance which would not be predicted based on findings when the stressors were present individually.

Subjects

Subjects were 50 male university students ranging in age from 19 to 24 years. All subjects had either 20/20 vision or vision corrected to 20/20. Subjects were paid to participate.

Procedures

The 50 subjects were randomly assigned to five groups of 10 subjects each. The design of the investigation called for exposing subjects to a two hour pre-test condition which, for four of the groups, was fatigue producing. The pre-test conditions are described below:

Group 1: The subjects in this group, upon reporting to the laboratory, were seated in a lounge area and permitted to read, sleep, listen to music, or do anything else that did not require large physical or mental expenditure. This group was considered as the non-fatigued control group.

Groups 2 and 3: Subjects in these groups performed on a mental multiplication task for two hours prior to being tested on the performance task. The mental multiplication task consisted of a booklet made up of 600 problems, each problem consisting of a four digit number to be multiplied by a two digit number. Subjects performed the multiplication process "in their head."

Groups 4 and 5: Subjects in these groups performed for two hours on a pursuit rotor tracking device prior to actual testing.

Every 15 minutes the rotor was stopped and the subject given a five minute rest pause. A subject switched hands at each rest pause.

It was assumed that two types of fatigue states were generated by the two tasks--mental fatigue and skill fatigue. This type breakdown of fatigue conditions has been employed in this laboratory and others, and studies have shown that performance on various types of tasks will be differentially affected by the two types of fatigue.

Following exposure to the pre-test conditions, subjects were tested on a two-dimensional compensatory tracking task which consisted of a moving target presented on an oscilloscope. The task of the subject was to keep the moving target centered on the display by means of a "joy-stick" arrangement. Subjects were exposed to a short practice session on the task immediately prior to a 30 minute test session. Subjects in Group 1 were tested under a no-noise condition, as were subjects in Groups 2 and 4. Subjects in Groups 3 and 5 received 100 dB(A) of white noise intermittently on a 5 second on, 2 second off periodic cycle during the test session on the compensatory tracking task.

Results

Analysis of variance and a multiple discriminate analysis were utilized in the statistical analysis of the data. No significant differences between groups were found to exist.

REFERENCES

Berrien, F. K. The effects of noise. Psychological Bulletin, 1946, 43, 141-161.

Bregman, H. L., & Pearson, R. G. Development of a noise annoyance sensitivity scale. Report No. NASA CR-1954, National Aeronautical and Space Administration, Langley Research Center, Virginia. 1972.

Broadbent, D. E. Some effects of noise on visual performance. Quarterly Journal of Experimental Psychology, 1954, 6, 1-5.

Broadbent, D. E. Effects of noise on behavior. In C. M. Harris (Ed.), Handbook of noise control. New York: McGraw-Hill, 1957. Pp. 10-1 to 10-34.

Broadbent, D. E. Effect of noise on an "intellectual" task. The Journal of the Acoustical Society of America, 1958a, 30, 824-827.

Broadbent, D. E. Perception and communication. London: Pergamon Press, 1958b.

Buros, O. K. The Sixth Mental Measurements Yearbook. Highland Park, N. J.: The Gryphon Press, 1965.

Burrows, A. A. Acoustic noise, an informational definition. Human Factors, 1960, 2, 163-168.

Cohen, A. Noise effects on health, productivity, and well-being. Transactions of the New York Academy of Sciences, Series II, Volume 30, May, 1968, 910-918.

Eysenck, H. J. The Maudsley Personality Inventory. San Diego, Calif.: Educational and Industrial Testing Service, 1959.

Gilmer, B. von H. Industrial and organizational psychology. New York: McGraw-Hill, 1971.

Grimaldi, J. V. Sensori-motor performance under varying noise conditions. Ergonomics, 1958, 2, 34-43.

Jerison, J. H. Effects of noise on human performance. Journal of Applied Psychology, 1959, 43, 96-101.

Kleinsmith, L. J., & Kaplan, S. Paired-associate learning as a function of arousal and interpolated interval. Journal of Experimental Psychology, 1963, 65, 190-193.

Kleinsmith, L. J., & Kaplan, S. Interaction of arousal and recall interval in nonsense syllable paired-associate learning. Journal of Experimental Psychology, 1964, 67, 124-126.

Kryter, K. D. The effects of noise on man. Journal of Speech and Hearing Disorders, 1950 (Monograph Supplement 1).

Kryter, K. D. The effects of noise on man. New York: Academic Press, 1970.

McBain, W. N. Noise - the arousal hypothesis and monotonous work. Journal of Applied Psychology, 1961, 45, 309-317.

McLean, P. D. Induced arousal and time of recall as determinants of paired-associate recall. British Journal of Psychology, 1969, 60, 57-62.

Park, J. F., & Payne, M. C., Jr. Effects of noise level and difficulty of task in performing division. Journal of Applied Psychology, 1963, 47, 367-368.

Pearson, R. G., & Hart, F. D. Studies relating the individual characteristics of people with their responses to noise. NASA SP-189, Progress report of NASA research relating to noise alleviation of large subsonic jet aircraft. Langley Research Center, Virginia. 1968.

Sanders, A. F. The influence of noise on two discrimination tasks. Ergonomics, 1961, 4, 253-258.

Stevens, S. S. (Ed.). Handbook of experimental psychology. New York: John Wiley and Sons, Inc., 1951.

Super, D. E., Braasch, W. F., & Shay, J. B. The effect of distraction on test results. Journal of Educational Psychology, 1947, 38, 373-377.

Teichner, W. H., Arees, E., & Reilly, R. Noise and human performance. A psychophysiological approach. Ergonomics, 1963, 6, 83-97.

Warner, H. D., & Heimstra, N. W. Effects of intermittent noise on visual search tasks of varying complexity. Perceptual and Motor Skills, 1971, 32, 219-226.

Warner, H. D., & Heimstra, N. W. Effects of noise intensity on visual target-detection performance. Human Factors, 1972, 14, 181-185.

Warner, H. D., & Heimstra, N. W. Target detection performance as a function of noise intensity and task difficulty. Perceptual and Motor Skills, 1973, 36, 439-442.

Welford, A. T., Brown, R. A., & Gabb, J. E. Two experiments on fatigue as affecting skilled performance in civilian air crew. British Journal of Psychology, 1950, 40, 195-211.

Wijting, J. P., & Smith, P. C. Interacting effects of motivation, ability, and noise on activation and performance in a memorizing task. Organizational Behavior and Human Performance, 1969, 4, 353-364.

Wilkinson, R. Some factors influencing the effect of environmental stressors upon performance, Psychological Bulletin, 1969, 72, 260-272.

Winer, B. J. Statistical principles in experimental design. New York: McGraw-Hill, Inc., 1962.