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The Effect of Noise and Display Orientation on Cognitive Performance

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Abstract

Military personnel encounter a variety of noise environments. During exercises, high intensity noise levels are often encountered. Twenty-four subjects were required to respond to symbols presented under two levels of task difficulty, two levels of presentation rate, two levels of display orientation, and three levels of noise intensity. The purpose of the experiment was to determine whether noise intensity and display orientation had any effect on a short-term memory task. Results showed that continuous white noise at intensity levels of 30, 85, and 105 db had no effect on the shortterm memory task. Presentation rate and task difficulty demonstrated a significant relationship with task performance as did their two-way interaction. This two-way interaction between presentation rate and task difficulty exhibited a different pattern for the two levels of display orientation.

I. INTRODUCTION

A. THE EFFECT OF NOISE

Over the past several years, human beings have been confronted with a constantly increasing level of noise in their working environment. This problem suggests that noise may affect human performance physiologically and psychologically.

Naval officers are exposed to a variety of noise conditions in the engine room and weapons platforms of modern ships. On the other hand, there are lower intensity levels of noise at night vigilance tasks, i.e., mid-watch on the bridge. In each of these different noise environments, naval officers are required to perform a variety of spatial and cognitive tasks. Shipboard compliance with provisions of the navy's noise abatement and control program is typically manifested by the presence of protective ear-muffs on the helicopter deck during flight operations, and an occasional sign reading "NOISE

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HAZARDOUS AREA" in the engine room. Virtually all noise-induced hearing damage is preventable with the use of protective devices now available; however, the tasks can be performed without these protective devices during short-term noise exposure.

There have been many studies concerning the effects of noise on human performance. Unfamiliar noise produces some decline in the efficiency of tasks when it is first encountered. Noises found aboard ship are variable and may consist of vibration, impact, and turbulence. Most military missions involve tasks which are well practiced and noises which are familiar.

Past research provides conflicting results, i.e., studies have found that (1) noise produces a decrement in performance, (2) noise has no effect on performance, and (3) noise produces an increment in performance. When noise has been found to have a decremental effect, the effect has usually been attributed to distraction. When it has been found to have an incremental effect, the effect has been attributed to a loosely defined concept termed "motivational compensation." When noise has been found ineffective as a variable, the results have been attributed to a lack of sensitivity of the task, the organ, or sometimes to compensation.

Broadbent [Ref. 4] presented each subject with a series of letters among which digits were interspersed. The task was to add up the series of digits. When a series of such sums had been completed, the noise was initiated and continued while another series of sums was attempted. Noise was then extinguished and the final series of measurements taken. The noise was provided by an automobile horn mounted 0.6 m from the subject. The effect was that time to compute the first few sums after the onset of noise was increased but the time per sum then returned to normal. Teichner [Ref. 12] showed that the size of the effect was related to the size of change in noise level. In his study, subjects were required to search a display of letters looking for particular combinations. They were presented with 150 displays under 81 db (white noise) and then without warning the noise was changed to 57, 69, 93, or 105 db for the remaining 50 displays. Performance under these conditions decreased fairly substantially, this decrement was greater for the 24 db change in level than for the 12 db change in level.

In contrast to the above studies, Plutchik [Ref. 11] found that high intensity intermittent noise had no effect on the ability of subjects to track a moving target on an oscilloscope. Hack, Robinson, and Lathrop [Ref. 8] concluded that an initial decrement in tracking performance due to intermittent auditory stimulation was followed by gradual improvement in performance concomitent to noise adaptation. Bailey, Patchett, and Whissell [Ref. 1] found that noise had no effect on the performance of the task, but patterned noise had a greater effect than the quiet (no noise) condition on task accuracy. The task involved stroking out the letter 'e' in a type-written passage for nine minutes under conditions of no noise, continuous 95 db white noise, 95 db patterned noise, and random intermittent noise.

An analysis of the above conflict, that is, the facilitative effect of noise and the decremental effect of noise was attempted by Hockey [Ref. 9]. He concluded that these discrepancies could be explained in terms of (1) the levels and characteristics of the noise used, and (2) the demands made on the subjects by different tasks. Where distraction has been invoked as the explanation of noise effects, a decrement in efficiency has usually been found. Where arousal has been assumed to underlie the observed effects, performance has usually been shown to improve.

II. METHOD

A. SUBJECTS

The subjects utilized in this experiment were 24 male students from the Naval Postgraduate School. Subjects ranged in age from 26 to 35 years. They were not compensated for their time. They were screened for good physical condition. Subjects were told that the purpose of this experiment was to determine the effects of noise on a short-term memory task. They were cautioned against talking about the experiment among themselves.

B. STIMULI AND APPARATUS

1. Response Analysis Tester (RATER)

The RATER, Model 3, was used as the experimental device to display the visual stimuli and collect the response data. The device, built by General Dynamics (Convair Division), is a psychomotor testing instrument designed to provide sensitive, reliable measurement of response accuracy for patterned or colored stimuli.

The patterned stimuli (symbols) were used in this experiment. The symbols presented by the RATER were a plus sign (+), a circle (○), a triangle (△), and a diamond (◇). The basic task required the subjects to press the correct response button associated with each of four symbols automatically displayed in a continuous, random sequence. Total presentations, total responses, and total correct responses were determined from counters installed in the RATER control unit.

The symbols were colored white and presented against a black background. The stimuli-response unit. which is placed in front of the subject had four response buttons and a small 1.25″ x 1.25″ viewing screen.

2. Noise Generation Equipment

A MACIO dual channel audiometer, Model MA-24B generated the continuous white noise at the desired intensity level. The noise was delivered to subjects via headphones. The MA-24B is equipped with two air conduction headsets–a test headset and a monitoring headset. The test headset uses the standard MX 41/AR cushions. The headset was color-coded-blue for the left headphone and red for the right headphone. Each channel is calibrated to its own headphone. The white noise generator was activated and connected for use in broad-band white noise.

3. Environment

The experiment was conducted in a controlled acoustical environment chamber manufactured by the Industrial Acoustics Company of Bronx, New York. The RATER stimulus-response unit and headphones were placed on a desk directly in front of the subject. The RATER control unit and MAICO audiometer were located outside of the chamber.

C. EXPERIMENTAL DESIGN

The design for this experiment represents a mixed (between and within subjects) completely balanced factorial design (Winer, Ref. 50). The 24 subjects were randomly assigned via a table of random numbers to one of three noise levels (30 db, 85 db, and 105 db), therefore each group consisted of eight subjects. Each subject within a group received all levels of the three within-subject factors: (1) display orientation (20° to the right of subject's center line vs. 20° to the left of subject's center line), (2) task difficulty (response required to the symbol currently displayed—delay "0" vs. response required to symbol displayed two symbols before the one currently displayed—delay "2"), and (3) symbol presentation rate (.75 seconds between symbols vs. 1.0 seconds between symbols). Each subject therefore received eight trials representing the eight possible combinations of the within-subject independent variables. In order to control for any potential effects due to the order in which a subject received the eight conditions, a separately randomized 8 x 8 latin square was constructed for each of the three noise level groups.

The numbers in the main body of these tables correspond to the experimental conditions in the following way:

code #	conditions
1	$O_1 D_1 R_1$
2	$O_1 D_1 R_2$
3	$O_1 D_2 R_1$
4	$O_1 D_2 R_2$
5	$O_2 D_1 R_1$
6	$O_2 D_1 R_2$
7	$O_2 D_2 R_1$
8	$O_2 D_2 R_2$

A four way (noise level (N), task difficulty (D), presentation rate (R), and display orientation (O)) analysis of variance was employed to analyze the data for this experiment.

TABLE 1. Model of the Design

		O_1 (left)				O_2 (right)			
		D_1 (Delay "0")		D_2 (Delay "2")		D_1		D_2	
		R_1^*	R_2^*	R_1	R_2	R_1	R_2	R_1	R_2
N_1	105 dB								
N_2	85 dB								
N_3	30 dB								

R_1^*: .75 sec

R_2^*: 1.0 sec

D. PROCEDURE

Upon arriving at the Man-Machine Systems Design Laboratory at the Naval Postgraduate School, the subject was seated at a desk located in the controlled acoustical environment chamber and read the instructions listed in Appendix A. At this time the subject was given two two-minute practice sessions under the self pace mode (new symbol does not appear until subject elicits a correct response). No noise was introduced via the headphones during the practice sessions. During the first practice session, the "0" delay level of task difficulty was utilized; during the second practice session the "2" delay level of difficulty was utilized. The experimenter determined at the end of each practice session whether subject correctly understood the task; if not additional time was alloted. After the two practice sessions were successfully completed, the experiment proper began, in which the subject was presented the eight trials (possible combinations of experimental condition) according to the predetermined order. The entire sequence is illustrated in Figure 1. Each experimental trial lasted for two minutes and was followed by a one minute rest period.

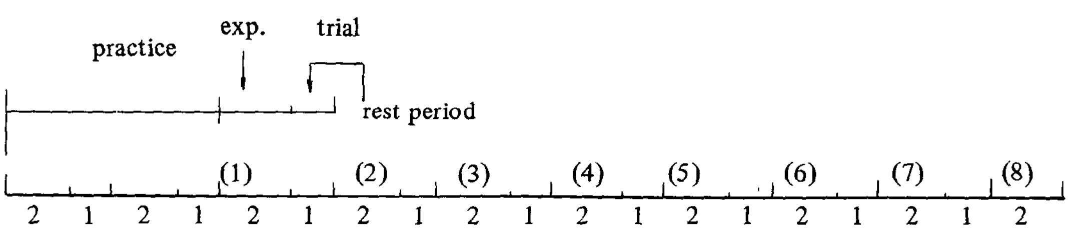

Figure 1. Sequence of Procedure

The response variable used for analysis in this experiment was the number of correct responses in a two minute experimental session divided by the total number of responses for that session. A total of 192 data points were collected, representing all combinations of noise levels (3), by subjects within groups, (8) by task difficulty (2), by presentation rate (2), by display orientation (2). The experimenterpaced mode was utilized during all experimental trials.

III. RESULTS

The results of this experiment are summarized in the ANOVA summary table (see Table 2). The main effects that achieved significance were difficulty of the task and presentation rate. Both noise level and display orientation failed to demonstrate a significant main effect. The significant two way interaction between task difficulty and presentation rate is illustrated graphically in Figure 2. The significant three way interaction between task difficulty, presentation rate and display orientation is graphically illustrated in Figure 3.

TABLE 2. **ANOVA Summary Table**

SOURCE	D.F.	SS	MS	F
Noise	2	12.193	6.097	0.031
Residual/S	21	4127.719	196.558	
Orientation	91	15.413	15.413	0.785
OxN	2	61.020	30.510	1.554
Residual*	21	412.272	19.632	
Difficulty	1	12358.501	12358.501	100.597***
DxN	2	161.755	80.878	0.658
Residual	21	2579.894	122.852	
DxO	1	49.208	49.208	1.620
DxOxN	2	78.793	39.397	1.297
Residual	21	637.704	30.367	
Rate	1	18695.360	18695.360	259.472***
RxN	2	8.584	4.292	0.060
Residual	21	1513.080	72.051	
RxO	1	20.672	20.672	0.492
RxOxN	2	21.180	10.590	0.252
Residual	21	883.228	42.058	
RxD	1	17706.242	17706.242	309.425***
RxDxN	2	258.160	129.080	2.256
Residual	21	1201.683	57.223	
RxDxO	1	194.005	194.005	8.158**
RxDxOxN	2	130.454	65.227	2.743
Residual	21	499.410	23.781	
Total	191	61626.533		

** < 0.01 *** < 0.01

* Each residual sum of squares was independently chosen based on its expected mean square.

IV. DISCUSSION AND CONCLUSIONS

The results of the analysis of variance show that the level of intensity of the noise did not significantly affect performance on the short-term memory task utilized in this experiment. In order to successfully accomplish the required task, the subjects had to store two prior symbols or the present symbol for a period of time prior to making a response. Therefore, the subjects were required to be attentive to their task at all times. These findings suggest that noise at the intensities utilized will be filtered out. Filter Theory – Broadbent [Ref. 5] – is supported by these results. According to this theory focused attention sets the filter to a particular class of stimuli, rejecting all others, i.e., noise. It is possible that at some intensity level (higher than examined in this experiment) the noise could cause a shift in the filter and result in distraction to the principal task. It is also possible that intermittent noise would have created a distraction to the STM task at the intensities examined.

The highly significant effect of presentation rate on performance was in the predicted direction (slower rate (1.0 sec) resulting in better performance) as was the effect of task difficulty (easier task (delay "0") resulting in better performance). Since these experimental variables were included in the study to provide a broader context to investigate the effects of noise on performance, no further discussion is necessary with respect to their individual effects on task performance. The significant interaction between these two variables (see Figure 2) indicates that at the high stimulus presentation rate (.75 sec) there is little difference in performance between the two conditions of task difficulty (53.7% vs. 50.6%), while at the low presentation rate (1.0 sec) there is a large difference between the two conditions of task difficulty (54.3% vs. 89.5%).

The three way interaction between presentation rate, task difficulty and orientation of stimulus display reflected the above interaction of presentation rate and task difficulty at both levels of display orientation with the exception that for a left oriented display, performance associated with high task difficulty decreased from high to low presentation rate, while the opposite occurred for the right oriented display–performance for the high task difficulty condition increased from high to low presentation rate (see Figures 2 and 3).

Although the present study did not find any significant relationship between noise level and performance on the STM task, it cannot be concluded that the type of noise found in the typical ship environment does not degrade operational task performance. Since the typical ship environment involves a variety of noise sources (frequency, intensity, and patterning) and a variety of required cognitive tasks, it is recommended that further experiments be conducted on the effects of noise on performance. Independent variables that should be investigated are frequency of the noise, higher intensity levels than these studied and intermittent vs. continuous noise. Difficulty level of the task should also be increased in order to determine where the shift in the filter would occur. These conditions are of particular importance to the Korean Navy since there are many high speed patrol boats where complex decisions must be made under time pressure in a high noise environment.

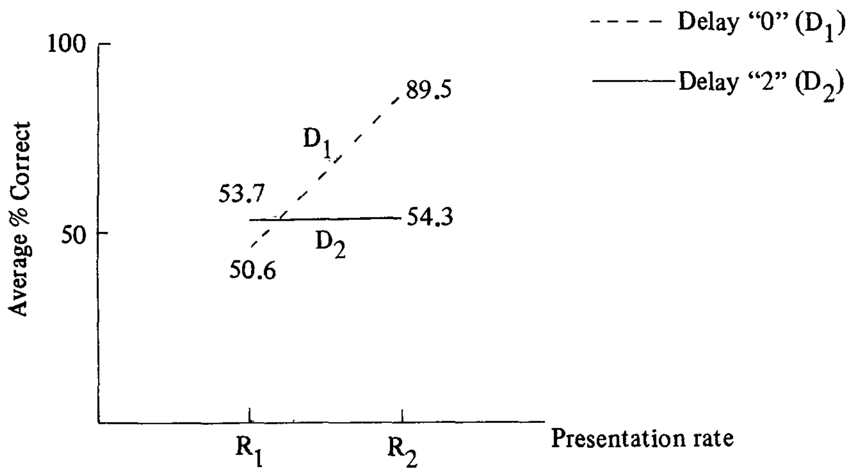

Figure 2. Interaction of RxD

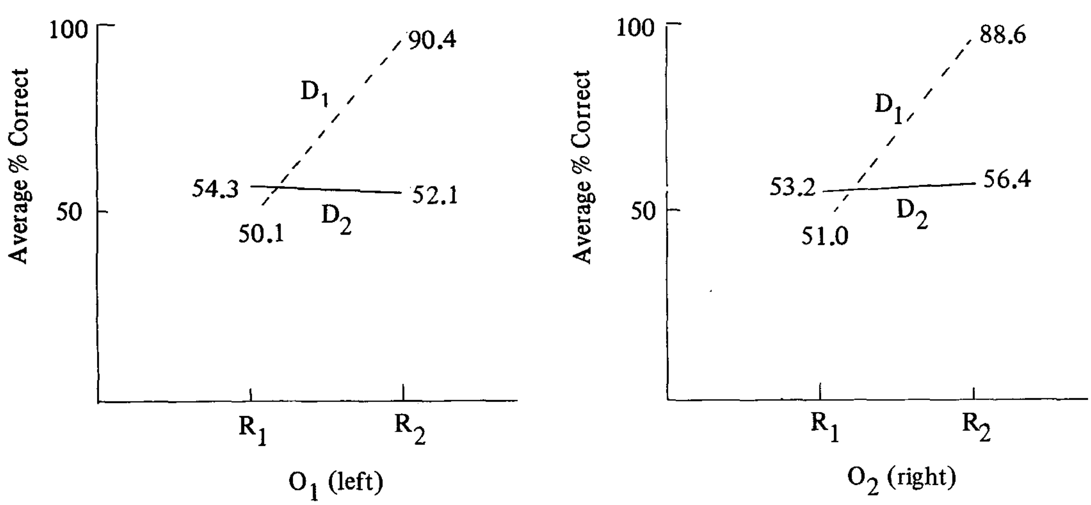

Figure 3. Interaction of R×D×O

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