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Effects of Intermittent Noise on the Performance of a Complex Psychomotor Task

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Manual image-motion compensation, a complex psychomotor task involved in certain photographic activities from orbit, was investigated as a function of the temporal pattern (aperiodic, periodic, or continuous) and intensity level (50, 70, or 90 db.) of white noise. Performance was measured in terms of the total amount of time image motion was held at or below a 40-microradians/second criterion for specific blocks of trials. The results of the investigation showed that white noise had a detrimental effect on image motion compensation performance, and that the magnitude of the decrement varied as a function of both the temporal pattern and intensity level of this noise.

INTRODUCTION

Major literature reviews of the effects of noise on performance (Kryter, 1950; Plutchik, 1959) suggest that performance impairments are more likely under high-intensity intermittent noise than under low-intensity or steady noise. It should be noted, however, that very few studies concerned with the effects of intermittent noise on psychomotor performance were available when these reviews were being completed.

Since Plutchik's review, two studies dealing with the effects of high-intensity intermittent noise on compensatory tracking have been reported. Plutchik (1961) found that high-intensity intermittent sound had no effect on the ability of subjects to track a moving target on an oscilloscope screen. A later study by Hack, Robinson, and Lathrop (1965), a partial replication of the Plutchik experiment, showed an initial decrement in tracking performance due to intermittent auditory stimulation, followed by gradual improvement in performance concomitant to noise adaptation.

Of greater interest than the apparent conflicting results of the two studies is the fact that both efforts used periodic intermittent noise. That is, noise was presented at evenly spaced intervals during tracking. The present study compared, within a single experimental framework, the effects of aperiodic (unevenly spaced) and periodic intermittent noise on complex psychomotor task performance.

METHOD

Subjects

Twenty-four male McDonnell Douglas employees served as subjects. The average age was 28.5 years, with a range from 21 to 45. The group was composed of engineers and engineering students whose education level varied from two to five years of college.

Performance Task

The McDonnell Douglas Image Motion Compensation Simulator, which duplicates an optical system in a 100-nautical-mile earth orbit, was used for the study. The simulator consists of seven major components: a crew station (light-proof cubicle), a high-resolution photograph of an area of the earth's surface, a gimballed mirror system, a Questar telescope, a two-axis hand controller, control electronics, and a performance measurement system. The photograph rotated relative to the line of sight of the optical system outside the crew station to simulate an orbital pass over an area of the earth's surface. A gimballed mirror, positioned between the telescope and photograph, rotated around two axes with step inputs to simulate spacecraft attitude perturbations corresponding to pitch and roll. The subject, while seated in the crew station, viewed the simulated earth movements relative to a reticle in the telescope, and used the hand controller to compensate for the perceived image motion. Performance was measured in terms of the amount of time image motion was held at or below a 40-microradians/second criterion during a simulated orbital pass. A simulated orbital pass (hereafter referred to as a trial) was 40 sec. in duration, and there was a 20-sec. interval between passes.

The independent variable, white noise, produced by a Lafayette noise generator, was fed from a Scott Stereophonic Amplifier into a Hunter noise-operated relay and was presented to subjects binaurally through earphones. The intensity level of the earphone output, measured with a Bruel & Kjaer sound-level meter, was 50, 70, and 90 db., depending upon the experimental condition. The noise began simultaneously with each 40-sec. trial, and a Hunter decade timer was employed to terminate noise presentation at the end of each trial.

In addition to manipulating intensity, the temporal patterning of the noise was also varied. A Hewlett-Packard Audio Oscillator, Massey-Dickenson Programming and Timing Equipment, and an Ampex Stereophonic Tape Recorder were utilized to produce a tape used to pace noise presentation in both intermittent auditory stimulation conditions. For the periodic condition, a tape with alternate 2-sec. intervals of tone and blank was recorded. For the aperiodic condition, another pacing tape was recorded with 2-sec. intervals of tone separated by blank intervals ranging randomly from 0.5 to 3.5 sec., with the average "off" interval being 2 sec. In the experimental sessions, the appropriate pacing tape was played back, and the tape recorder output was used to control the Hunter noise-operated relay in the headset circuit. The pattern of white noise presented to subjects replicated the pattern of tone recorded on the tape. In the continuous noise condition, a switch bypassed the noise-operated relay, and the noise was present throughout each 40-sec. trial. Subjects in a control group wore the headset, but the noise system was inactive.

Experimental Design

Subjects were randomly assigned to one of three experimental groups (aperiodic, periodic, or continuous noise pattern) or to a control group on the basis of order of arrival at the laboratory. Each of the six subjects in the three noise pattern groups was exposed to three noise intensity levels (50, 70, and 90 db.), a different level on each of three successive days (test days one, two, and three). Presentation order for intensity levels was counterbalanced across and within groups of subjects. The six subjects in the control group performed on three successive days in the absence of noise. The image-motion compensation performance measure was the amount of time per 40-second trial that image motion was held at or below 40 microradians per second.

Procedure

Each subject was seated in the crew station and given a set of standardized instructions to read. The subject was then told to focus the telescope and adjust the chin support.

After five introductory trials, the first training session of 25 trials was administered and was followed by a second training session of 25 trials on the following day. Thus, each subject received a total of 50 training trials before the experimental variables were introduced.

On the third day, the noise conditions were introduced. Each of the subjects in the three noise groups (aperiodic, periodic, and continuous) was exposed to one of the three noise intensity levels (50, 70, and 90 db.), and the experimental session was terminated after 20 trials. The fourth and fifth sessions (20 trials each) were similar to the third in that the temporal pattern of the noise remained identical within noise groups, with only the intensity level of the noise varying from session to session. The subjects in the control group received 20 trials during each of the last three sessions while wearing the headset with the noise system deactivated.

RESULTS AND DISCUSSION

Training (Trials 1-50)

An analysis of variance indicated the three noise pattern groups and the control group were equivalent in level of image-motion compensation skill attained prior to the introduction of the experimental variables (F [3,20] < 1). Therefore, the differential noise-performance effects exhibited during testing were attributed to variation introduced by the treatment conditions.

Noise and Image Motion Compensation Performance

To assess the effect of noise on manual image motion compensation, the performances of the three noise pattern groups were compared with that of the control group. Since the noise intensity variable associated with each of the three noise groups had no counterpart in the control group, it was collapsed under the noise pattern variable. The test days variable was a negligible source of variation ($F < 1$) for the three noise groups and the control group, and was also collapsed under the noise pattern variable. The mean and the standard deviation of each group's scores on the performance measure (total time image motion was held at or below the criterion) as a function of temporal pattern and intensity level are presented in Table 1. The effect of noise on image motion compensation performance was evaluated by comparing mean total time below criterion for the continuous-noise group (161.07) and the control group (195.90). This difference was highly significant ($p<.01$). Since this was the smallest of the mean differences, it was concluded without further statistical analysis that all noise patterns employed produced significant decrements in image motion compensation performance.

TABLE 2

Summary of Noise Pattern X Intensity X Test Days Analysis of Variance for Total Time Below Criterion

Source of Variance	*df*	*MS*	*F*
Noise pattern (P)	2	105.50	35.17*
Subjects within groups (S)	15	3.00	
Intensity (I)	2	237.40	13.19*
P X I	4	12.60	
I X S	30	18.00	
Test days (D)	2	1.00	
P X D	4	9.40	
D X S	30	17.50	
I X D	4	.80	
P X I X D	8	5.20	
I X D X S	60	1,380.40	

* $p<.001$

Temporal Pattern and Intensity Level of the Noise

A 3-X-3-X-3 factorial analysis of variance was performed on the data. The results of this analysis are presented in Table 2. The main effect for noise pattern was highly significant, ($p < .001$), indicating that the temporal patterns of noise had differential decremental effects upon image motion compensation performance (cf. Figure 1). The main effect for noise intensity level was also statistically significant ($p < .001$; cf. Figure 2). The effects of blocks of trials and the interactions of the various main effects were not significant. The 20 test trials were divided into five blocks of four trials each, and inspection of the times below criterion revealed that the trends re-

TABLE 1

Mean Total Time (Sec.) Image Motion was Below Criterion for 20 Test Trials

	Aperiodic Noise			*Periodic Noise*			*Continuous Noise*		
	High	*Medium*	*Low*	*High*	*Medium*	*Low*	*High*	*Medium*	*Low*
Mean	112.70	129.60	165.30	133.70	158.90	174.20	147.70	161.40	174.10
σ	8.00	11.60	6.00	6.00	8.50	8.80	5.30	8.50	4.00

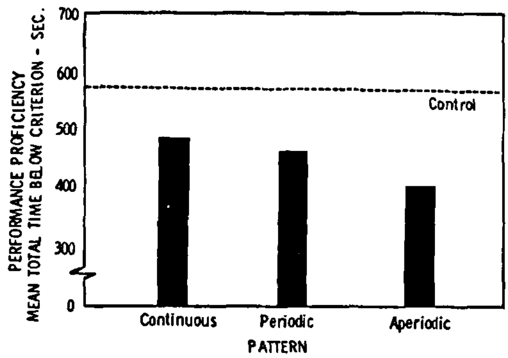

Figure 1. Performance proficiency as a function of noise pattern.

flected in Figures 1 and 2 were relatively stable across test sessions. This suggests that the performance decrement was not localized in any particular segment of the testing sessions, but was present throughout.

Comparisons between specific noise patterns and intensity levels were made using the Duncan New Multiple Range Test (Winer, 1962). The aperiodic-noise group exhibited the largest noise-induced performance decrement, and differed significantly from the other two noise groups (periodic and continuous) in terms of image motion compensation performance ($p < .01$). No significant difference in image motion compensation performance was found between the periodic- and continuous-noise groups. Significant differences, in terms of magnitude of image motion compensation decrement, were found between each of the three noise intensity levels ($p < .01$), with

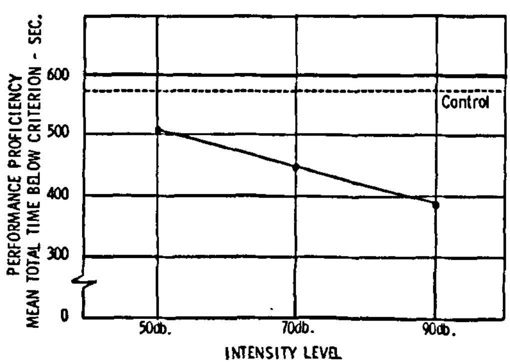

Figure 2. Performance proficiency as a function of noise intensity level.

performance deteriorating as noise intensity increased.

This study shows that noise produces a significant decrement in image motion compensation performance, and that the magnitude of this decrement varies as a function of (a) the temporal pattern of the noise and (b) the intensity level of the noise. However, a thorough examination of the major reviews of the relevant literature (Broadbent, 1957; Kryter, 1950; Plutchik, 1959) suggests little basis for positing a noise-performance relationship generalizable across experimental situations. Some studies have demonstrated that noise has an incremental effect on performance, while others show a decrement. Task difficulty seems to be the variable that accounts for these apparently conflicting results (Broadbent, 1958; Jerison, 1957). Performance on easy tasks is thought to be improved by noise, with the increments typically being attributed to "arousal," a concept akin to the "varied-sensory-environment" hypothesis of vigilance behavior (cf. Scott, 1962). In general, it is argued that extraneous stimulation focuses attention on the task and makes the organism more alert with respect to the environment, thereby effecting improved performance. Performance on difficult tasks is thought to be degraded by noise, with the decrements typically attributed to "distraction," a concept similar to the "expectancy" hypothesis of vigilance behavior (cf. Baker, 1963). Extraneous stimulation is viewed as competing with the task, and inhibiting efficient performance.

The preceding explanation seems to account for the marked decrement in image motion compensation performance noted in this study. Manual image motion compensation is a complex psychomotor task that requires continuous processing of sensory information and is, therefore, extremely susceptible to the distracting effects of noise. The fact that subjects were better able to deal with the continuous and periodic patterns than with the aperiodic pattern suggests that the regularity of noise is a critical determinant of the noise-performance function. A highly predictable noise occurrence (periodic) is much less distracting than a noise unanchored with respect to time (aperiodic). The relationship between noise intensity and magnitude of image motion compensation decrement found in the present study was not unexpected. High-intensity sounds usually are more distracting than low-intensity sounds.

Numerous studies are available (e.g., Carterette, 1955; Hood, 1950) which indicate that the distracting effect of noise diminishes and eventually disappears with continued or repeated exposure (adaptation). In the present study, brief (20 trials) and distributed testing sessions (days one, two, and three) were utilized in an attempt to assess the effects of temporal pattern and intensity level of noise on psychomotor performance independent of adaptation. The aperiodicity-adaptation issue poses an interesting problem for future research.

Because manual image motion compensation is a task found in spacecraft systems and is similar to tracking tasks in aircraft systems, the observation of a noise-produced decrement in performance has an implication for future system design. If an operator must perform complex psychomotor tasks in an environment characterized by irregular noise occurrence, it may be necessary to soundproof his workspace.

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