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TERMINAL REPORT

AN INVESTIGATION OF THE EFFECTS OF THREE SOUND BACKGROUNDS ON A SIMULATED QUALITY CONTROL INSPECTION TASK

By

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INTRODUCTION

Major reviews of the relevant literature indicate that background sounds have diverse effects on human behavior (Berrien, 1946; Broadbent, 1957; Broadbent and Burns, 1965; Kryter, 1950; Mirabella and Goldstein, 1967; Plutchik, 1959). These effects have been attributed to the nature of the sound, such as whether it is music or noise, the susceptibility of the subject to the sound, and lastly, the characteristics of the performance task. Because of the interdependency between sound conditions, subjects, and tasks, a change in one component will alter the effect due to background sound.

Research has consistently shown that the effects of background sounds on visual search performance are task specific. In one study (Warner and Heimstra, 1971), it was observed that visual target-detection speed under intermittent noise differed as a function of the noise and the difficulty level of the task. And in a study on the effects of noise intensity and target detection performance (Warner and Heimstra, 1972), it was found that target-detection speed was a function of both noise intensity level and task difficulty level. Thus, these findings suggest that noise-induced changes in performance obtained in the laboratory setting may not be the same in the "real-world" if the work situations are not the same.

It is evident from the available literature that there are two fundamental differences between the laboratory setting,

where the majority of studies on the effects of background sound have been conducted, and the actual work situation. These differences involve the length, or duration, of the work sessions and the simplicity of the laboratory task.

With respect to task duration, laboratory studies on the effects of background sound have typically used test sessions that are less than an hour in length. This contrasts with the weeks and months workers are employed in the actual work situation.

Shortening the work period can change the nature of the work situation in three important ways. First, subjects in a simulated laboratory task do not have the opportunity to develop the automatic movements and quick decisions that characterize workers who have been employed for a long period of time. Generally, the laboratory test is terminated just as the subject's performance begins to stabilize. Second, certain biological/psychological changes associated with long work schedules are not manifest in the shortened laboratory task. These include such changes as hunger, moodiness, and wakefulness. Third, laboratory test subjects do not have the chance to adapt to situational stimuli to the degree that long-term workers do. Subjects in the laboratory setting are usually more inclined to turn their attention from the primary stimulus display because the work environment is still so novel to them.

Concerning task simplicity, in most of the laboratory studies on the effects of background sound visual vigilance tasks have been used where subjects monitor a display for the presence or absence of a simple stimulus. These task requirements are quite different from the actual work situation. Workers in industry must make far more complex decisions and judgments. In industrial inspection tasks, for example, inspectors judge the acceptability of products based on quality. Judgments of product quality are not simple, "yes-no" decisions, rather, they involve a determination of acceptability based on a point on a continuum of quality, where products above the criterion level are acceptable and products below unacceptable. To make the inspection problem even more complex, the level of acceptability constantly changes, as a function of the inspector, product supply and demand characteristics, the product receiving agent, and so forth. Thus, it appears likely that the extent to which laboratory studies on the effects of background sound on performance are applicable to the industrial work situation depends on the similarity of the tasks used in the situations.

Purpose and Choice of Test Conditions

In an effort to reduce the discrepancies between laboratory and "real-world" work situations two necessary criteria should be established and applied during the methodological design phase of laboratory experimentation. These criteria are: (1) that the work requirements closely resemble those of the

task to which the results are to be generalized; and (2) that the time at work should be long enough to preclude an interaction of potential experimental treatment effects with the length of the performance task.

In the literature on the effects of background sound on human performance there is an absence of studies utilizing these criteria. For this reason this investigation was designed. The purpose of the study was to implement these criteria in a laboratory work situation with characteristic background sound conditions presented during the test sessions.

To conform to the pre-established test criteria, the task selected for use in the experiment was an assembly-line inspection task similar to that in the electronics industry where operators inspect printed circuits for defectives. The measures of task performance included the number of defectives missed and the number of nondefectives reported as defective ("false-positives").

In the development of the test schedule, it was decided that the minimum suitable test duration should be one full work day, not to include task familiarization, warm-up trials and workers' expectation of test completion. Consequently, the following test schedule was devised: two hours on the first day of testing to provide the warm-up period, eight hours on the second day to provide the full work day, and four hours on the third day for the purpose of determining anticipation of test

completion on inspection performance.

The background conditions were selected on the basis of the feasibility of implementation in the actual work setting, and/or their actuality of occurrence. Restricted to these criteria three background sound conditions were chosen. One group of subjects was tested under music similar to the commercial Muzak. Subjects in the second group were permitted to select their own condition of exposure by making a radio available to them and allowing them to select at any time whatever program they wished during the test session. The third group of subjects was exposed to successive short noise presentations approximately one second in duration occurring in sequential five second cycles. A fourth group was utilized as a control condition in which subjects were tested in silence.

METHOD

Subjects

The subject sample consisted of 40 male college-student volunteers recruited from the University of Missouri at Rolla. The subjects were screened for visual and hearing deficiencies prior to testing, and each subject was paid $28.00 for participating.

Experimental Room

The soundproof chamber used for testing purposes was made from standard cement blocks and had a two inch by three foot by seven foot wooden door. The interior walls and ceiling were surfaced with three-inch thick styrofoam panels and half-inch acoustic tile, and the floor was covered with pile carpeting. Cloth and rubber weather stripping was used to seal the door. The chamber effectively isolated the subjects from extraneous noise generated during normal operation of the test equipment. Inside, the chamber was approximately five feet square and eight feet high.

On the door of the chamber was a twenty inch square double strength translucent "window", which comprised the rear projection screen on which the stimulus materials were displayed. The screen was positioned so that its center corresponded to the line of sight of the subject under normal viewing conditions. The maximum viewing distance from the subject's seated position was two feet.

A response panel was provided in the test chamber immediately below the screen, consisting of four micro switches. The switches were arranged in a 2 x 2 matrix to correspond to the four quadrants of the display.

Performance Task

The task required subjects to inspect the visual display for the presence of a defective printed circuit. A defect was defined in terms of a broken solder line between two terminals. The circuits were prepared on 35 mm. slides and projected from outside the test chamber onto the rear projection screen by means of a Kodak Model 760H Carousel slide projector and a Radiant Carivision rear projection system. Four circuits were displayed simultaneously in each slide presentation in the form of a 2 x 2 matrix. All circuits used in the experiment were of the same basic design. A typical display with a defective circuit is shown in Figure 1.

The slides were constructed in the following manner. From a draftman's drawing of a printed circuit, photocopies were made on white bond paper. Four copies were then arranged to correspond to the screen matrix, and 35 mm. slides were taken of the four copy arrangement. Defective circuits were produced by whitening segments of the circuit on the bond paper.

In some of the slides, two of the four circuits were made defective. These slides were included for two reasons. First, for purposes of task realism, since it is not unlikely that two

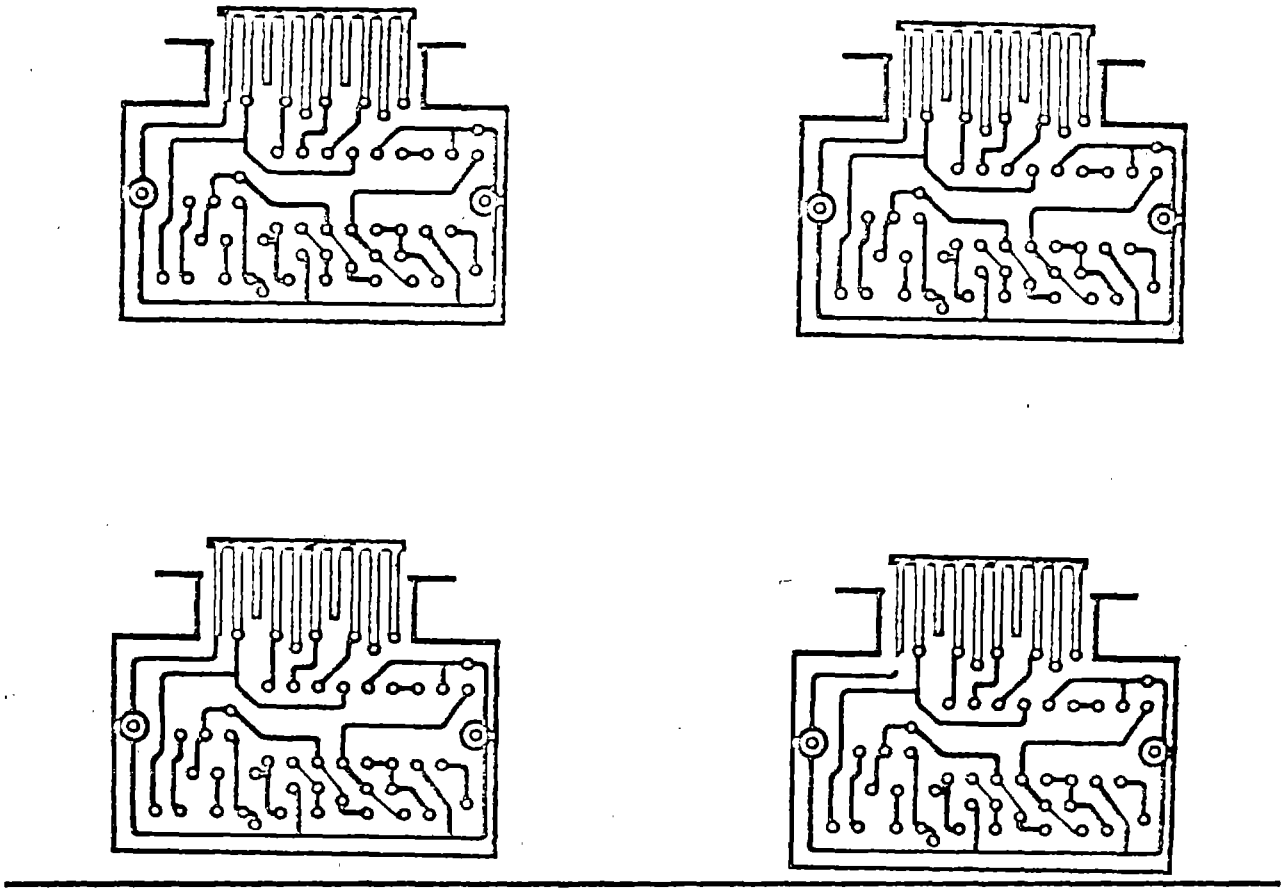

Figure 1. Reproduction of a Slide Containing a Defective Circuit.

defective circuits would appear together. And, second, to sustain the subject's vigilance after a defective circuit is detected because if slides containing only one defective circuit were used the subject would learn that after the defect was detected no further inspection would be required for that particular slide.

Test Schedule

Each subject in the experiment was tested over a three day period: from 3 p.m. to 5 p.m. on the first day, from 8 a.m. to 5 p.m. on the second day, and from 8 a.m. to 12 noon on the third day. On the second day of testing two 15-minute coffee breaks were introduced at 10 a.m. and 3 p.m., and a one-hour lunch break at 12 noon. On the third day, there was a 15-minute coffee break at 10 a.m. The tests were conducted on consecutive days, between Monday and Friday. Half of the subjects in each of the four groups were tested on a Monday/Tuesday/Wednesday schedule; the other half on a Wednesday/Thursday/Friday schedule.

A total of 1,590 slides were shown over each three-day test session. Of the total, 237 contained a single defective circuit, and 14 contained two defective circuits. The ratio of defective circuits (265) to the total number of circuits (6,360) was 4.17 percent. The number of slides, the number of circuits, and the number and the percentage of defective circuits are shown in Table 1. The total number of slides, circuits, and defectives and the overall percentage are also included in the table.

Table 1

Distribution of Slides, Circuits, and Defect Ratio.

Day	Time	No. of Slides	No. of Circuits	No. of Defects	% Defective
1	3:00 - 5:00 p.m.	240	960	40	4.17
2	8:00 - 10:00 a.m.	240	960	40	4.17
	10:15 - 12:00 noon	210	840	35	4.17
	1:00 - 3:00 p.m.	240	960	40	4.17
	3:15 - 5:00 p.m.	210	840	35	4.17
3	8:00 - 10:00 a.m.	240	960	40	4.17
	10:15 - 12:00 noon	210	840	35	4.17
TOTAL		1,590	6,360	265	4.17

Individual slides were automatically changed every 30 seconds. There was no blank interval between consecutive slide presentations, except after each 140 slide block when the slide trays were changed. On these occasions, the screen was blank for 30 seconds.

For purposes of the data analysis, the defective circuits were programmed so that five defectives appeared in each consecutive 15-minute test period. In 14 of the 53 15-minute trial blocks, one slide with two defective circuits and three slides with a single defect were used. In the remaining 39 trial blocks, five slides with individual defects were used.

The position of the defective circuit(s) in the four circuit arrangement was randomized, as was the position of the broken solder line. The interval between defective circuit presentations was randomized, but with the restriction that five defective circuits appear within successive 15-minute test periods. The 14 slides containing the two defective circuits were randomly distributed over the 3-day test session.

Sound Environments

The subjects were tested under one of three background sound conditions, or a silent, control, condition. The background sound conditions used were music, radio, and intermittent white noise.

1. Music. Twenty-one record albums were recorded on Scotch "90" magnetic cassette tapes for the music background.

Each tape provided 90 minutes of continuous instrumental and vocal music, 45 minutes on a side. The tapes were recorded and played on a Telex cassette recorder/player, and a Motorola stereo record player was used for the albums. The albums recorded and the order in which the selections were played are listed in the Appendix.

The music was presented through two loudspeakers located on either side of the subject. The loudness level of the music at the subjects' ears did not exceed 80 dB re 0.0002 microbar, as measured by a General Radio Model 1565-B sound level meter.

2. Radio. In this condition, a Panasonic AM/FM table model radio was provided in the test chamber. The subjects were permitted to select and change radio programs at any time during the test session, but it was stipulated that the radio could not be turned off. The radio was placed on a table to the right of the subject within easy reach from his seated position. A Talk-A-Phone intercom station was also in the test chamber so that the experimenter could monitor the radio programs.

3. Noise. The noise background consisted of intermittent white noise at an intensity level of 85 dB re 0.0002 microbar at the subjects' ears. Intermittency was defined in terms of noise on-time in successive 5-second cycles. In this study, the noise was on for one second and off for four seconds. The noise was produced from a Grason-Stadler Model 901-B white noise generator, and was presented through the two loudspeakers described previously.

4. Silence. A silent condition was included in the test bed to provide an experimental control condition. Subjects in this condition performed the test without any of the background sounds present.

Procedures

The 40 subjects were obtained by a research assistant. In the recruiting process they were told the general nature of the task and the details of the work schedule. Before the test sessions and without knowing which subject the research assistant would supply for it, the experimenter selected the work environment that would be used. The three background sound conditions and control condition were used in rotation. Overall, 10 subjects were assigned to each of the four conditions. The subjects were tested individually.

The subjects were delivered to the experimental laboratory by the research assistant and were given the visual and audiometric screen tests by the experimenter. After the screening tests were completed (none of the 40 subjects had to be rejected), the subjects were asked to be seated and then they were read the following instructions.

"In this experiment a number of printed circuits will be shown on the screen in front of you. Your task is to determine whether or not the circuits are defective.

This is how the circuits will appear during the experiment. (A demonstration slide is shown without a defective circuit.) As you can see, there are four circuits on the screen.

Now, carefully examine the four circuits. Each is made of black lines, which represent solder connections. Notice that all four circuits are the same design. (Pause.)

In the next set of circuits that I am going to show you there is a broken solder connection in one of the circuits. (A demonstration slide is shown with a defective circuit. (Pause.) It is the lower right-hand circuit. (Pause.) Here. (The broken solder is pointed out to the subject.) This is a defective circuit; because of the broken connection it will not work properly.

Below the screen are four switches, which are arranged to correspond to the four positions of the circuit on the screen. If you see a defective circuit you should press the corresponding switch. So that I know you understand, press the switch which is associated with the defective circuit now on the screen. (Pause.)

When the experiment begins, a new set of four circuits will be displayed on the screen. Then, after a given period of time, the set will be replaced by a new set of four circuits, and so on, throughout the entire test session. Examine each circuit carefully for a broken solder line, and be sure to press the appropriate switch if you find a defective circuit."

At this point the instructions were modified according to the particular background sound condition being tested.

For subjects in the music condition these instructions followed.

"So that you won't be distracted by hearing people talking and from the noises of the test equipment, the testing room has been soundproofed to keep these sounds under control. In an earlier experiment, however, several subjects complained the room bothered them because it was unnaturally quiet, so we now counteract that by playing background music."

For the radio background, subjects were read these instructions.

"So that you won't be distracted by hearing people talking and from the noises of the test equipment, the testing room has been soundproofed to keep these sounds under control. In an earlier experiment, however, several subjects complained the room bothered them because it was unnaturally quiet, so we now counteract that by using a radio in the testing room. When the experiment begins, I want you to turn the radio on. You may listen to any AM or FM station you wish, and as loudly or as softly as you want it. You may change the station at any time during the experiment, but you must keep the radio on and tuned to some audible program."

For the noise background these instructions were read.

"In order to make the work environment as realistic as possible, intermittent noise will be presented through the two loudspeakers in the testing room. The noise will be similar

to that generated by the machines used in the manufacture of printed circuits."

Following the specialized instructions, all of the subjects were read these instructions.

"Before we begin the experiment, I want to verify that you fully understand the instructions. Therefore, I am going to give you two more practice trials. Remember to press the appropriate switch if you see a defective circuit. (A demonstration slide is shown with two defective circuits. 30 second pause. A demonstration slide is shown with no defects.)

If you have any questions, please ask them now. If not, we will begin."

A short time was allowed to give the subjects an opportunity to ask questions. During this time the assistant replaced the demonstration slide tray with the first 140 slide tray, and the test was started.

The music and noise backgrounds began simultaneously with the first slide presentation.

After the first and second day test sessions, the subjects were told what time they were expected on the following day. And, on the second and third day, just prior to the start of the sessions, the subjects were reminded when they would be given breaks for coffee and lunch. During the 15-minute breaks, gratis coffee was provided. The subjects were permitted to go

anywhere for lunch, so long as they could return in an hours time.

On completion of the 3-day test, the subjects were asked to sign pay vouchers. Approximately two weeks later pay checks were ready for them.

Stimulus-Control and Data-Recording Equipment

The stimulus-control equipment consisted of the slide projector, the rear projection system, the white noise generator, the cassette tape recorder/player, and a Lafayette Model 55000 programmer-timer. The purpose of the programmer-timer was to automatically change slides at the prescribed intervals and to interrupt the noise. The control equipment was arranged on a movable table to provide easy access to the tester.

The data-recording equipment consisted of a panel which contained four indicator lights, a reset button, and a digital counter. The indicator lights were arranged in a 2 x 2 matrix to correspond to the positions of the switches on the subject's response panel. Whenever the subject pressed a switch, the corresponding light went on and stayed on until the tester pressed the reset button. In this way the tester was able to record which switch had been pressed by the subject. The counter was used to indicate the slide number.

A separate test booklet was used for each subject in the experiment. The booklet was numbered from 1 to 1,590, which was the total number of slides shown. The slides that contained

the defective circuit(s) were identified in the booklet with a mark representing the quadrant the defect was located in. Identifying marks were also provided after the appropriate number of slides to show where the coffee and lunch breaks were to be taken and where the daily sessions were to end.

During testing the tester monitored the panel. Whenever a light was turned on the tester recorded the number of the light (1, 2, 3, or 4) in the booklet for the slide corresponding to the number on the counter.

Response Measures

From the test booklet, two response measures were computed; "missed-signals", which was when the subject failed to report a defective circuit; and, "false-positives", which was when the subject reported a defective circuit when none was present.

RESULTS AND DISCUSSION

Initially, it was decided that both missed-signal errors and false-positive errors would be separately evaluated in the data analysis phase of the experiment. It was found, however, that only 14 response errors of the latter category were committed. Since this small number precluded a meaningful analysis of commissive errors under the background sound conditions tested, false-positive errors were not considered in the data analysis. Consequently, this paper reports only on missed-signal detection errors, except where noted.

The detection error data were analyzed by means of a two-factor analysis of variance (groups x time periods) with repeated measures on the latter factor. In the analysis, there were 53 time periods, which represents the number of 15-minute inspection periods in the 3-day test session. The results of the analysis of variance are summarized in Table 2.

A preliminary check on the homogeneity of variances had indicated that the analysis of variance was a suitable test for these data. The F_{max} statistic computed from the between subjects error ($F_{max} = 5.509$, df = 4, 9) and the within subjects error ($F_{max} = 0.891$, df = 4, 468) sums of squares was shown not to exceed the corresponding critical values, 6.31 and 1.00, at the 0.05 level of significance. Thus, the null hypotheses of equal variances was not rejected.

Table 2

Summary of the Analysis of Variance for Detection Errors

Source of Variation	Degrees of Freedom	Mean Square	F
Between Subjects	39		
Groups (G)	3	7.262	5.795**
Error (between)	36	1.253	
Within Subjects	2080		
Time Periods (T)	52	0.688	2.992**
G x T	156	0.290	1.259*
Error (within)	1872	0.230	

** $p<0.01$
* $p<0.05$

Table 3

Total Missed Signals, Percentage of Incorrect Detections, and Total False-Positives for the Background Sounds

	Music	Radio	Noise	Silence
Missed Signals	55	72	115	194
% Incorrect	2.075	2.717	4.340	7.321
False-Positives	4	2	2	6

In Table 3 the total number of missed-signal errors is shown for the four groups, along with the percentage of incorrect detections, based on the ratio of missed-signal errors to the total number of defective circuits, and the total number of false-positive errors. From Table 2 it can be seen that the differences between missed-signal errors are statistically significant ($p<0.01$). It is evident from the data that detection performance improved under the three background sound conditions relative to the silent, control, condition when considered over the entire 3-day test session. Among the three sound backgrounds, detection performance was most improved under music, followed in decreasing order by radio and intermittent noise.

The total number of missed-signal errors associated with each of the 53 15-minute time periods is shown in Table 4, along with the percentage of incorrect detections and the total number of false-positive errors. It can be seen from Table 2 that the differences between missed-signal errors are statistically significant ($p<0.05$). This indicates that detection accuracy was not constant over the 3-day test session, but varied as a function of time at the task.

Table 2 shows that the interaction between groups and time periods was statistically significant ($p<0.05$). This means that the background sound conditions tested had significantly different effects on detection performance at different periods

Table 4

Total Missed Signals, Percentage of Incorrect Detections, and Total False-Positives for the Three-Day Session

Day	Period	Missed Signals	% Incorrect	False-Positives
Day 1	3:00			
	3:15	26	13.0	1
	3:30	23	11.5	1
	3:45	17	8.5	1
	4:00	6	3.0	1
	4:15	2	1.0	
	4:30	5	2.5	
	4:45	8	4.0	1
	5:00	17	8.5	
Day 2	8:00			
	8:15	9	4.5	
	8:30	4	2.0	
	8:45	8	4.0	
	9:00	10	5.0	1
	9:15	4	2.0	1
	9:30	8	4.0	
	9:45	10	5.0	
	10:00	8	4.0	
	10:15	BREAK		
	10:30	13	6.5	
	10:45	7	3.5	1
	11:00	3	1.5	
	11:15	11	5.5	
	11:30	18	9.0	1
	11:45	6	3.0	1
	12:00	2	1.0	
	LUNCH			
	1:00			
	1:15	3	1.5	
	1:30	4	2.0	
	1:45	5	2.5	1
	2:00	13	6.5	1
	2:15	7	3.5	
	2:30	10	5.0	
	2:45	6	3.0	
	3:00	6	3.0	1
	3:15	BREAK		
	3:30	5	2.5	

Table 4 (Cont.)

Day	Period	Missed Signals	% Incorrect	False-Positives
	3:45	3	1.5	
	4:00	10	5.0	
	4:15	8	4.0	
	4:30	8	4.0	
	4:45	3	1.5	
	5:00	2	1.0	
Day 3	8:00			
	8:15	9	4.5	
	8:30	6	3.0	
	8:45	3	1.5	
	9:00	2	1.0	
	9:15	10	5.0	
	9:30	11	5.5	
	9:45	18	9.0	
	10:00	5	2.5	
	10:15	BREAK		
	10:30	4	2.0	
	10:45	9	4.5	
	11:00	12	6.0	
	11:15	4	2.0	
	11:30	9	4.5	
	11:45	6	3.0	
	12:00	10	5.0	1

in the 3-day test session. The profiles for the detection performance data are illustrated in Figures 2-5. In all figures, detection performance is in terms of the percentage of correct detections for the sake of inspection convenience.

Since the interaction effect was significant, tests on the simple main effects of groups and time periods were called for. These tests were used to identify the time periods at which the differences between groups were significant, and to specify under which background sound condition detection performance differed significantly over the 3-day test session.

Following the tests on the simple main effects, individual mean comparisons were conducted. These comparisons were utilized to test the differences between all possible pairs of group means at each time period where a significant simple main effect of groups was observed, and between all possible pairs of means within each group that was associated with a significant simple main effect of time periods. The Newman-Keuls method was used for these tests.

The significant simple main effects and individual mean comparisons are shown in Tables 5-10. In Tables 5-8, the simple main effects of groups is represented, and in Tables 9 and 10 the simple effects of time periods for the intermittent noise and silence conditions. Tables are not provided for the simple main effects of time periods for the music and radio conditions because their F values exceed the 0.05 level of significance

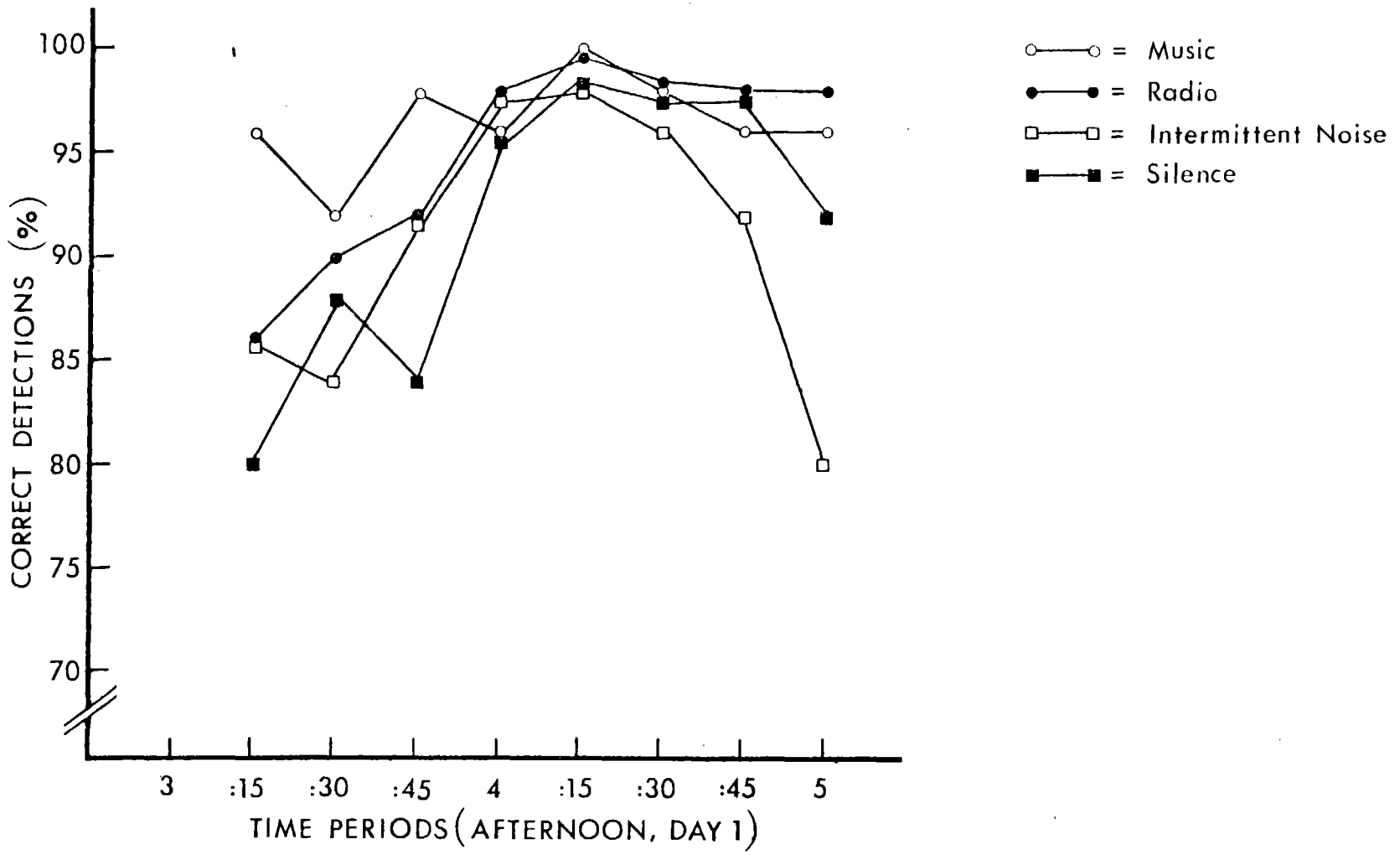

Figure 2. Percent Correct Detections as a Function of Time at the Task (Afternoon, Day 1).

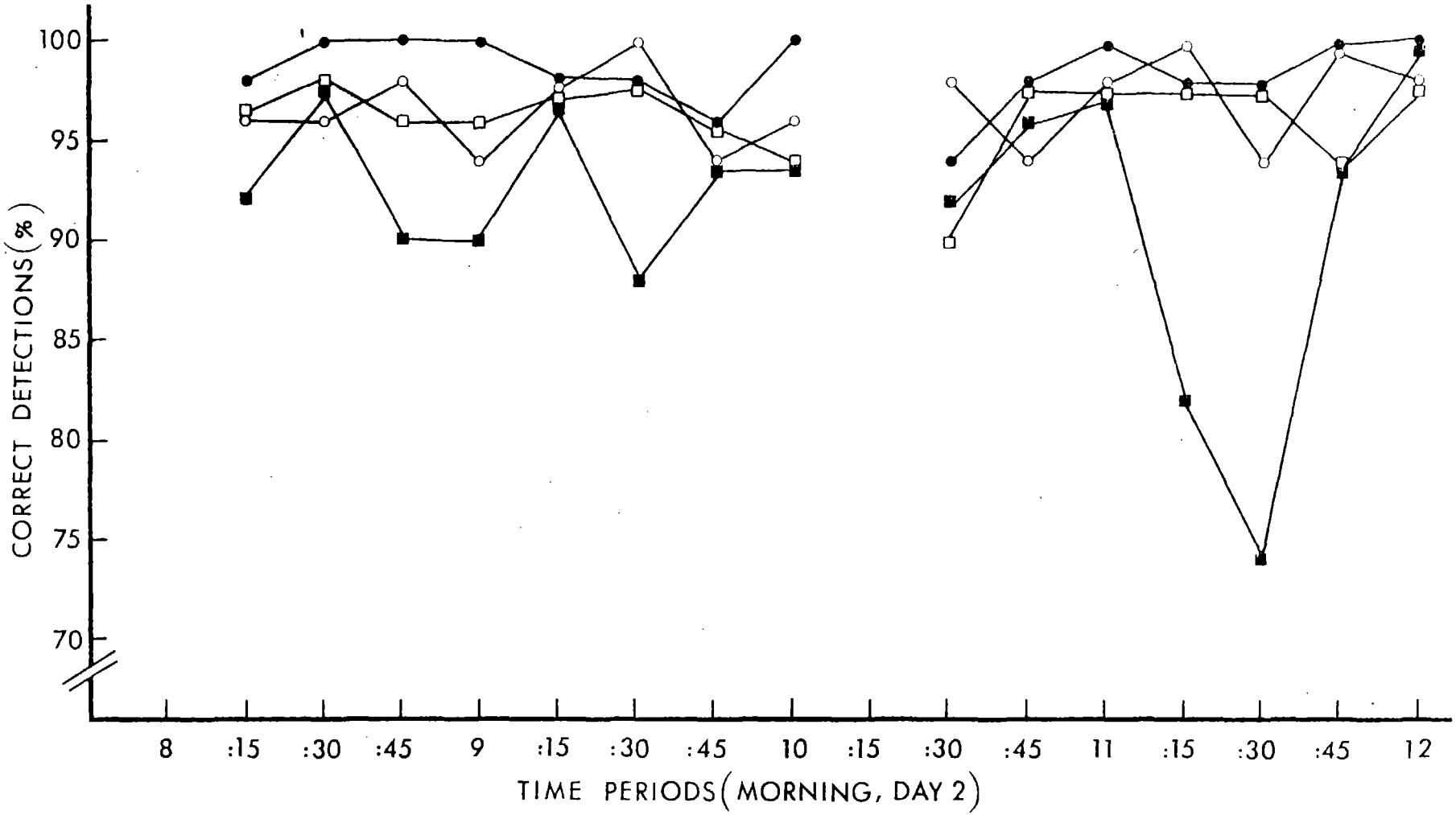

Figure 3. Percent Correct Detections as a Function of Time at the Task (Morning, Day 2).

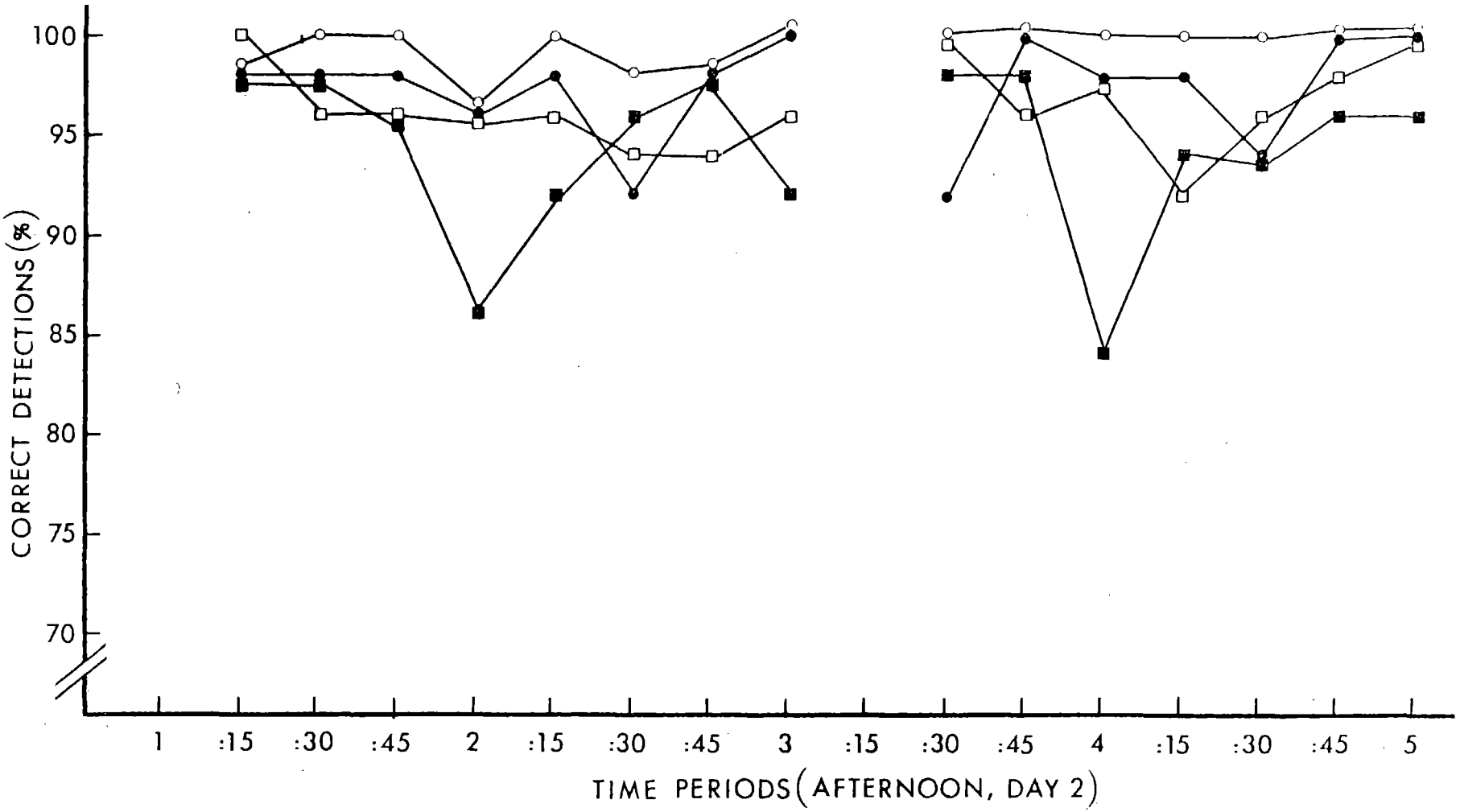

Figure 4. Percent Correct Detections as a Function of Time at the Task (Afternoon, Day 2).

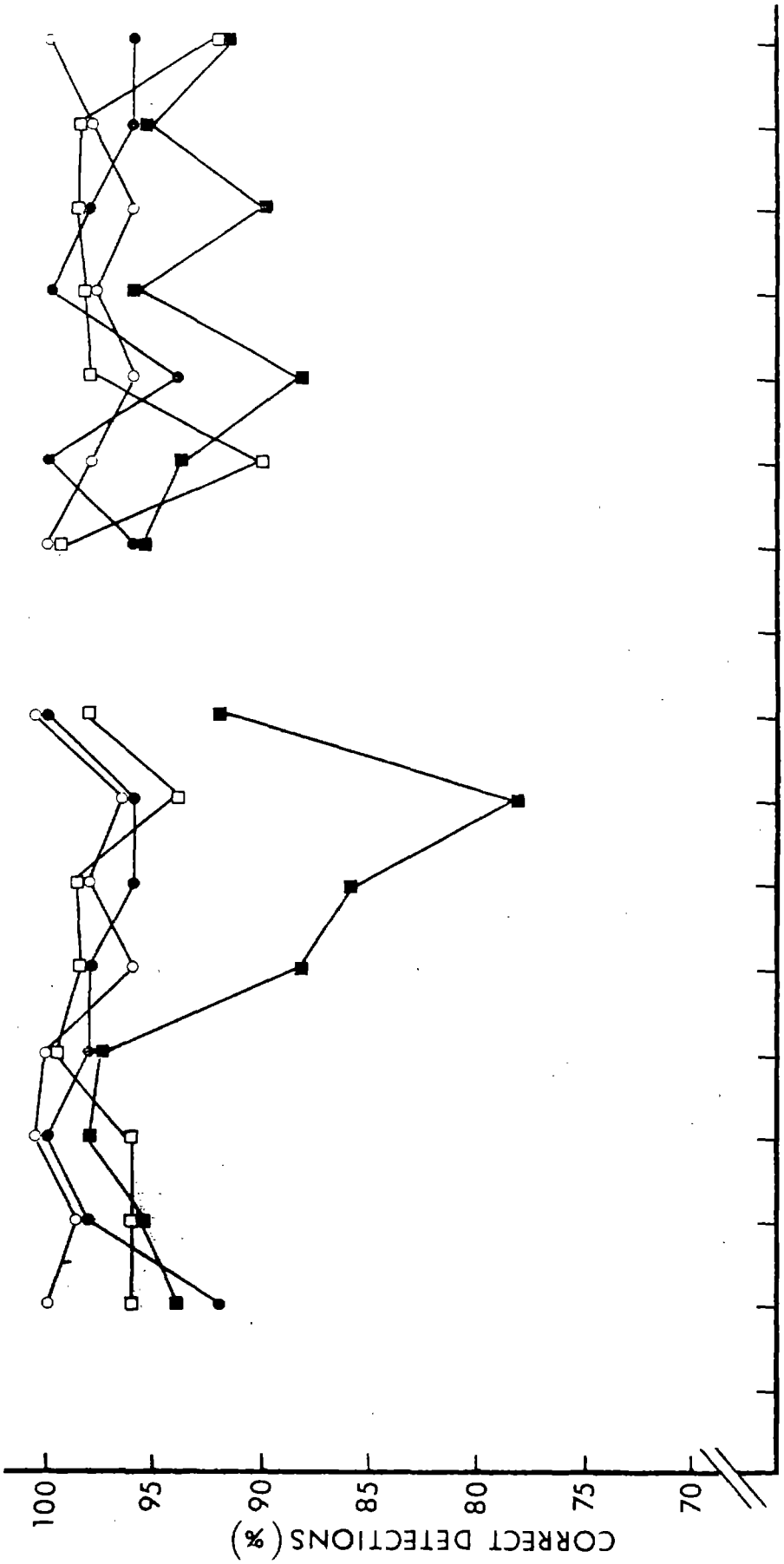

Figure 5. Percent Correct Detections as a Function of Time at the Task (Morning, Day 3).

Table 5

Simple Main Effects of Groups and Significant Mean Comparisons: 3:00 - 5:00 p.m., Day 1

Period	F	Significant Mean Comparisons**
3:00		
3:15	4.413*	mus.-rad., mus.-noise, mus.-sil., rad.-sil., noise-sil.
3:30	1.170	
3:45	3.310*	mus.-rad., mus.-noise, mus.-sil., rad.-sil., noise-sil.
4:00	0.134	
4:15	0.134	
4:30	0.100	
4:45	0.802	
5:00	6.519*	mus.-rad., mus.-noise, mus.-sil., rad.-sil., noise-sil.

** $p<0.05$; mus. = music condition, rad. = radio condition, sil. = silence, control condition

* $p<0.05$; df = 3, 1455

Table 6

Simple Main Effects of Groups and Significant Mean Comparisons: 8:00 a.m. - 12:00 p.m., Day 2

Period	F	Significant Mean Comparisons**
8:00		
8:15	0.635	
8:30	0.267	
8:45	1.872	
9:00	1.738	
9:15	0.000	
9:30	2.942*	mus.-rad., mus.-noise, mus.-sil., rad.-sil., noise-sil.
9:45	0.134	
10:00	0.802	
10:15	BREAK	
10:30	1.170	
10:45	0.368	
11:00	0.100	
11:15	7.054*	mus.-rad., mus.-noise, mus.-sil., rad.-sil., noise-sil.
11:30	13.239*	mus.-rad., mus.-noise, mus.-sil., rad.-sil., noise-sil.
11:45	1.204	
12:00	0.134	

** $p<0.05$
* $p<0.05$; df = 3, 1455

Table 7

Simple Main Effects of Groups and Significant Mean Comparisons: 1:00 - 5:00 p.m., Day 2

Period	F	Significant Mean Comparisons**
1:00		
1:15	0.100	
1:30	0.267	
1:45	0.368	
2:00	2.607*	mus.-sil., rad.-sil., noise-sil.
2:15	1.170	
2:30	0.669	
2:45	0.401	
3:00	1.471	
3:15	BREAK	
3:30	1.438	
3:45	0.368	
4:00	5.483*	mus.-rad., mus.-noise, mus.-sil., rad.-sil., noise-sil.
4:15	1.337	
4:30	0.802	
4:45	0.368	
5:00	0.401	

** $p<0.05$
* $p<0.05$; df = 3, 1455

Table 8

Simple Main Effects of Groups and Significant Mean Comparisons: 8:00 a.m. - 12:00 p.m., Day 3

Period	F	Significant Mean Comparisons**
8:00		
8:15	1.170	
8:30	0.134	
8:45	0.368	
9:00	0.134	
9:15	2.273	
9:30	3.310*	mus.-rad., mus.-sil., rad.-noise, rad.-sil., noise-sil.
9:45	7.622*	mus.-noise, mus.-sil., rad.-noise, rad.-sil., noise-sil.
10:00	1.438	
10:15	BREAK	
10:30	0.535	
10:45	1.972	
11:00	1.872	
11:15	0.267	
11:30	1.438	
11:45	0.134	
12:00	1.471	

** $p<0.05$
* $p<0.05$; df = 3, 1455

Table 9

Simple Main Effects of Time Periods and Significant Mean Comparisons: Intermittent Noise

F	Significant Mean Comparisons**		Day 1, 5:00
1.685*			
	Day 1,	4:00	x
		4:15	x
	Day 2,	8:30	x
		9:15	x
		9:30	x
		10:45	x
		11:00	x
		11:15	x
		11:30	x
		12:00	x
		1:15	x
		3:30	x
		4:00	x
		4:45	x
		5:00	x
	Day 3,	9:00	x
		9:15	x
		9:30	x
		10:00	x
		10:30	x
		11:00	x
		11:15	x
		11:30	x
		11:45	x

** $p<0.05$
* $p<0.05$; df = 52, 1872

Table 10

Simple Main Effects of Time Periods and Significant Mean Comparisons: Silence

F			Significant Mean Comparisons**			
3.628*			Day 1 3:15	Day 2 11:15	Day 2 11:30	Day 3 9:45
	Day 1,	4:00	x		x	x
		4:15	x	x	x	x
		4:30	x	x	x	x
		4:45	x	x	x	x
		5:00			x	
	Day 2,	8:15		x	x	
		8:30	x		x	x
		8:45			x	
		9:00			x	
		9:15	x	x	x	x
		9:45			x	
		10:00			x	
		10:30			x	
		10:45	x		x	x
		11:00	x	x	x	x
		11:45			x	
		12:00	x	x	x	x
		1:15	x	x	x	x
		1:30	x	x	x	x
		1:45	x		x	x
		2:15			x	
		2:30	x		x	x
		2:45	x	x	x	x
		3:00			x	
		3:30	x	x	x	x
		3:45	x	x	x	x
		4:15			x	
		4:30			x	
		4:45	x		x	x
		5:00	x		x	x
	Day 3,	8:15			x	
		8:30	x		x	x
		8:45	x	x	x	x
		9:00	x	x	x	x
		10:00			x	
		10:30	x		x	x
		10:45			x	
		11:15	x		x	x
		11:30			x	
		11:45	x		x	x
		12:00			x	

** $p<0.05$

* $p<0.05$; df = 1872

(F = 0.484 and 0.971, respectively, with df = 52, 1872).

From the profiles of the detection error data and from the simple main effects tests and associated mean comparisons, several observations are possible.

First, it can be seen that the differences between groups were not statistically significant for all 53 of the 15-minute time periods. Tables 5-8 show that ten time periods were associated with significant differences in detection performance.

Second, it is evident that the time periods at which the group differences were significant were not "bunched" together for a particular block of time, but were distributed throughout the 3-day test session. From Tables 5-8 it can be seen that the significant effects of the background sound conditions corresponded to time intervals of 30 minutes or less.

From these findings it might be proposed that the most efficient way to compensate for the debilitating effects of silence would be to introduce background sound only during the interval where a significant improvement in detection performance was observed from exposure to the background sound conditions tested. While this may, in fact, provide an efficient method of error suppression, it should be cautioned that selective exposure could have different effects on inspection performance than continuous exposure which was used in the present study. Selective exposure, such as turning a radio on and off at

irregular intervals, could be distracting. Thus, the effect achieved might be the opposite of the effect desired, which is improved detection performance. Therefore, it is recommended that selective exposure techniques not be implemented until sufficient data is available to warrant its use.

Third, in terms of the nature of the effects for those time periods at which the group differences were statistically significant, it can be seen that detection performance under the silent background condition was, with one exception, consistently inferior to performance measured under the music, radio, and intermittent noise conditions. Among the sound conditions, music was most often associated with the most efficient detection performance, followed by the radio and noise conditions, neither of which seems to have held a clear advantage over the other.

One important fact emerging from the ordering of test conditions for the time periods at which the group differences were significant is that the order does not, in every instance, correspond to the overall order when group totals are considered. Consequently, predictions on the relative effects of varying conditions of background sound will depend somewhat on whether the overall differences between conditions or the differences between conditions at given time intervals are being used as the predictive criteria.

Fourth, it is evident that the effects of the different background sound conditions for comparable time periods were generally dissimilar. At 5:00 p.m. on Day 1, for example, intermittent noise had a marked debilitating effect relative to the music, radio and silent conditions. At the same time period on Day 2, however, the differences between groups were negligible. Similarly, at 11:30 a.m. on Day 2, music had a facilitory effect that was not produced on Day 3.

It should be recalled that the 3-day test schedule was designed so that there would be one, full, eight-hour work day uncontaminated by initial task familiarization and expectancy of task completion. It is likely that the differences between comparable periods are due mainly to "warm-up" effects on Day 1 and anticipation of the end of the test session on Day 3. For this reason, it is recommended that generalization of the present data to actual work situations should be based primarily on the Day 2 work shift, unless, of course, the 3-day schedule used in the study is one that might be considered for actual implementation.

Fifth, the present data show that the effects of the intermittent noise and silent condition on detection performance changed as a function of time-at-the-task, and that the effects of the music and radio backgrounds were consistent over the 3-day test session.

These findings suggest that music and radio backgrounds could be used to stabilize inspection performance. This would appear to be a useful application in situations where work performance is erratic and cyclical over time.

Sixth, from Tables 9 and 10, it can be seen that not all possible time comparisons for the intermittent and silent conditions were significant. For the noise background 24 time comparisons were significant, whereas for the silent condition 103 were significant.

Finally, it appears that the fluctuations in detection performance over time were mainly due to some few marked depressions in performance which occurred in the work schedule that differed significantly from the performance "peaks". From Table 9 it can be seen that a performance depression occurred for the intermittent noise background at 5:00 p.m. on Day 1, and from Table 10 it is evident that four depressions occurred for the silent condition at 3:15 p.m. on Day 1, at 11:15 a.m. and 11:30 a.m. on Day 2, and at 9:45 a.m. on Day 3.

Although the near absence of commissive errors precluded a meaningful analysis of false-positive response errors, the fact that there were so few errors is significant from an applied, practical point of view. It suggests that the subjects had ample time to scan the display and double check on the presence of an apparent defective printed circuit before the slide was changed. It is possible that, had the scan time been

decreased by increasing the slide presentation rate, the number of commissives would have increased. Thus, based on this assumption, a display rate of about 30 seconds would seem to be an optimum period.

SUMMARY

The present investigation was designed to test the relative effects of three sound backgrounds on performance in a simulated assembly-line inspection task. The background sounds utilized in the study included taped music, subject selected radio programs, and intermittent white noise. A silent, no-noise condition was included in the design to provide a control comparison.

Ten subjects were tested under each of the three treatment conditions and control condition. The task required subjects to visually inspect a series of slides, each containing four electronic printed circuits, for the presence of a defective circuit. Over the period of a 14-hour, 3-day work schedule, 1,590 slides were shown. Of a total of 6,360 circuits, 265 were defective.

The data were analyzed in terms of "missed" defective circuits. Although commissive errors were recorded, there were too few to provide a meaningful statistical analysis. The results indicated that the fewest detection errors occurred under the music background (55), followed in increasing order of error magnitude by the radio (72) and intermittent noise (115) backgrounds, and the silent (194) condition. These differences were statistically significant.

Tests on the differences between groups at each 15-minute time period revealed that group differences were significant for 10 of the 53 15-minute time periods in the 14-hour work

schedule. For the 10 periods, detection performance under the silent condition was, with one exception, consistently inferior to performance measured under the music, radio, and intermittent noise conditions. Among the sound conditions, music was most often associated with the most efficient detection performance, followed by the radio and noise conditions, neither of which seemed to have held no clear advantage over the other.

A comparison of each of the four conditions over the 53 15-minute time periods showed that the effects of the music and radio backgrounds were consistent over the 3-day test session, and that the effects of the intermittent noise background and control condition significantly varied as a function of a time-at-the-task. The differences between conditions were mainly due to the performance decrements, or depressions, that occurred under the latter two conditions.

Based on the significantly different effects of similar background sound conditions at comparable time periods in the 14-hour schedule, it was recommended that the application of the data to actual work situations should be based primarily on the eight-hour, Day 2 work shift, unless, of course, the 3-day schedule used in the present study is one that might be considered for actual implementation.

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APPENDIX

Time and Order of Music Selections.

Day	Time	Selections Title/Time	Album Title/Artist/Co./Side
Day 1	3:00	Embraceable You, 2:45 Street of Dreams, 2:48 They Didn't Believe Me, 2:53 It Could Happen To You, 3:58 Again, 2:43	Previn with Voices, Andre Previn, LPM-3551, RCA, Side 1.
		Life Savers Girls (More), 2:43 The Damned Island, 2:45 Girls and Sailors, 1:17 Hong Kong Cha Cha Cha, 3:24 The Last Flight, 2:09 Dog Heat, 1:03 China Tarantella, 1:16 The Fisherman of Ragjput, 4:14	Mondo Cane, Riz Ortolani and Nino Oliviero, UAL-4105, United Artists, Side 1.
		Mexican Pearls, 2:50 Blue Orchids, 2:21 Heart and Soul, 2:27 Melody from the Sky, 2:25 Just One More Chance, 2:24 Love in Bloom, 2:35	Mexican Pearls, Billy Vaughn, DLP-3628, Dot, Side 1.
		Get Out of Town, 2:30 Easy to Love, 2:47 Everything I Love, 1:57 I've Got My Eyes On You, 1:50 It's De-Lovely, 2:30	Pleasant Percussion, Cole Porter, AK-151, International Award Series, Side 1.

Day	Time	Selections Title/Time	Album Title/Artist/Co./Side
		Exodus, 3:00 Karen, 3:10 A Summer Place, 2:20 The Green Leaves of Summer, 3:15 Song Without End, 2:26 Seventy-six Trombones, 2:35	Exodus, Montovani, LL-3231, London, Side 1.
		Theme from Cornish Rhapsody, 2:35 Claire De Lune, 3:55 Chopin's Study in E Major, 3:57 Chopin's Nocturne, 4:35	Concerto Under the Stars, 101 Strings, P-6700, Somerset, Side 1.
		I Can't Get Started, 2:42 Java, 1:55 Man with a Horn, 2:54 Tansy, 2:22 Night Theme, 2:02 Talkin' 'Bout That River, 2:12	Honey in the Horn, Al Hirt, LPM-2733, RCA, Side 1.
		The Way You Look Tonight, 3:10 I Hear a Rhapsody, 2:14	'S Marvelous, Ray Conniff, CL-1074, Columbia, Side 1.
	5:00	They Can't Take That Away From Me, 2:57	
Day 2	8:00	Moonlight Serenade, 2:37 I Love You, 3:18 I've Told Ev'ry Little Star, 2:46	
		Ebb Tide, 2:25 Smoke Gets in Your Eyes, 4:30 Boulevard of Broken Dreams, 2:45 Love by Starlight, 2:40 Among My Souveniers, 2:55 Friendly Persuasion, 2:55	Ebb Tide, Frank Chacksfield, LL-3322, London, Side 1.

Day	Time	Selections Title/Time	Album Title/Artist/Co./Side
		From Me to You, 2:15 I Saw Her Standing There, 2:40 Please Please Me, 2:45 P.S. I Love You, 2:11 Love Me Do, 2:26 I Want to Hold Your Hand, 2:24	The Beatles Song Book, Hollyridge Strings, T-2116, Capitol, Side 1.
		I Won't Dance, 2:35 Long Ago, 3:27 All Through the Day, 2:20 Dearly Beloved, 3:22 I've Told Every Little Star, 2:25	Dancing Percussion, Jerome Kern, AK-190, International Award Series, Side 1.
		Three Coins in the Fountain, 3:55 Dream of Love, 2:13 Love is a Many Splendored Thing, 3:15 Miserlou, 3:03 Gigi, 3:44 Dream Rhapsody, 2:00	The Many Moods of Ferrante and Teicher, Ferrante and Teicher, UAL-3211, United Artists, Side 1.
		You Do Something To Me, 2:28 As Time Goes By, 2:50 In the Still of the Night, 2:55 Someone to Watch Over Me, 2:50 Be My Love, 3:03 Where or When, 3:12	'S Marvelous, Side 2.
		Theme from Limelight, 2:30 Laura, 3:00 Red Sails in the Sunset, 4:15 I Only Have Eyes for You, 4:15 Autumn Leaves, 2:35 Deep Purple, 3:10	Ebb Tide, Side 2.

Day	Time	Selections Title/Time	Album Title/Artist/Co./Side
		Can't Buy Me Love, 2:16 All My Loving, 2:21 A Taste of Honey, 1:56 Do You Want to Know a Secret, 1:58 She Loves You, 2:28	The Beatles Song Book, Side 2.
		The Song is You, 2:22	Dancing Percussion, Side 2.
	10:00	MORNING BREAK	
	10:15	Bill, 2:35 Yesterdays, 2:25 Can't Help Lovin' That Man, 3:13 All the Things You Are, 3:23	
		Possessed, 2:39 Till, 3:29 The Way You Look Tonight, 3:24 Bewitched, 2:51 Camelot, 3:28 Love Affair, 2:15	The Many Moods of Ferrante and Teicher, Side 2.
		Besame Mucho, 2:33 Stranger in Paradise, 2:55 Summertime, 2:33 I've Got You Under My Skin, 2:52 Too Young, 2:32 Softly, As in a Morning Sunrise, 3:13	Say It With Music, Ray Conniff, CL-1490, Columbia, Side 1.
		Just One of Those Things, 3:18 Deep Purple, 2:25 Brazil, 2:57 Night and Day, 3:12 Temptation, 3:30 Say It With Music, 2:20	Say It With Music, Side 2.

Day	Time	Selections Title/Time	Album Title/Artist/Co./Side
		Blue Rondo A La Turk, 6:35 Strange Meadow Lark, 7:08 Take Five, 5:12	Time Out, Dave Brubeck Quartet, CS-8192, Columbia, Side 1.
		The Sundowners, 2:35 Irma La Douce, 2:21 I Love Paris, 3:20 Mr. Wonderful, 3:10 The Carousel Waltz, 3:30 The Sound of Music, 3:00	Exodus, Side 2.
		Yvone, 1:56	Bossa Nova Pelos Passaros, Charlie Byrd, RS-9436, Riverside, Side 1.
	12:00	NOON	
	1:00	A Salute to Bonfa, 2:20 Meditation, 3:09 You and I, 2:55 A Most Beautiful Thing, 2:38 Little Boat, 1:55	
		Chapel by the Sea, 2:07 Petite Fleur, 2:31 Exodus, 3:01 Can't Help Falling in Love, 2:29 Moon River, 2:40 Don't Break the Heart That Loves You, 2:37	Chapel by the Sea, Billy Vaughn, DLP-3424, Dot, Side 1.
		Fly Me to the Moon, 2:35 To Be in Love, 2:52 Al Di La, 2:17 Malibu, 2:34 Theme from a Dream, 2:18 I'm Movin' On, 2:21	Honey in the Horn, Side 2.

Day	Time	Selections Title/Time	Album Title/Artist/Co./Side
		Michelle, 2:26 Who Can I Turn To, 3:17 Polka Dots and Moonbeams, 2:44 It's Good to Have You Near Again, 2:48 The Bad and the Beautiful, 2:55 Where or When, 2:53	Previn With Voices, Side 2.
		Dear Heart, 2:30 It's Easy to Remember, 2:17 Love Letters, 2:20 The Nearness of You, 2:31 Willow Weep for Me, 2:39 Stella by Starlight, 2:55	Mexican Pearls, Side 2.
		Moonlight and Roses, 3:07 It Happened in Monterey, 3:35 Look for the Silver Lining, 3:00 Paradise, 3:17 Marchetta, 3:02 When Day Is Done, 2:40	The Cascading Voices, Hugo and Luigi, LPM-2641, RCA, Side 1.
		I Love Paris, 2:15 I've Got You Under My Skin, 2:40 Do I Love You?, 3:20 Rosalie, 2:27 You'd Be So Nice to Come Home To, 2:07	Pleasant Percussion, Side 2.
		Models in Blue, 3:41 Free Way, 1:49 House of Death, 1:39 Pergatory, 1:26 Repabhan Street, 2:11	Mondo Cane, Side 2.
	3:00	AFTERNOON BREAK	

Day	Time	Selections Title/Time	Album Title/Artist/Co./Side
	3:15	The Festival of the Bull, 3:27 Cargo Cult, 4:25	
		Meditation from Thais, 4:22 Theme from Swedish Rhapsody, 3:40 Liebestraum, 5:35	Concerto Under The Stars, Side 2.
		Desafinado, 2:29 Samba Triste, 2:59 Bim Bom, 1:48 Ho-Ba-La-La, 2:11 She Has Gone, 2:32 The Bird, 3:09	Bossa Nova Pelos, Side 2.
		Desafinado, 5:47 Samba Dees Day, 3:30 O Pato, 2:35 Samba Triste, 4:45	Jazz Samba, Stan Getz and Charlie Byrd, V-8432, Verve, Side 1.
		My Yiddishe Momme, 3:05 Clair De Lune, 3:10 A Walk in the Black Forest, 2:50 When the Girls Go Marching In, 2:30 Donkey Serenade, 3:19 Sing-Song, 3:00	The Genius of Jankowski, Horst Jankowski, SR-60993, Mercury, Side 1.
	-	Midnight in Moscow, 2:57 The Twist, 2:25 Tuff, 2:13 Route 66 Theme, 2:16 Bonanza, 1:50 Wonderland by Night, 3:00	Chapel by the Sea, Side 2.
		Blue Moon, 3:50 Out of This World, 3:49 Duet, 2:31 Easy to Love, 3:28	Bouquet of Love, Percy Faith, CL-1681, Columbia, Side 1.
	5:00	I Only Have Eyes for You, 4:27	

Day	Time	Selections Title/Time	Album Title/Artist/Co./Side
Day 3	8:00	Soft Lights and Sweet Music, 3:45	
		Samba De Orpheus, 3:35 The Morning of the Carnival, 4:41 The Children, 2:37 The Night of My Love, 4:17 The Duck, 2:37	Bossa Nova, Ramsey Lewis, LP-705, Argo,
		A Summer Place, 2:26 Tammy, 2:15 Tracy's Theme, 2:53 Climb Every Mountain, 2:23 Que Sera, Sera, 2:18 The Terry Theme from Limelight, 2:31	A Summer Place, Billy Vaughn, DLP-3276, Dot, Side 1.
		Happiness, 5:00 Whirlpool, 3:19 The Face of the Clown, 2:22 A Song for Geraldine, 6:17	Bossa Nova, Side 2.
		Toselli Serenade, 2:50 Simpel-Gimpel, 2:50 Speak to Me of Love, 2:25 Caroline-Denise, 2:30 Soon Luck Will Also Knock on Your Door, 2:30 Nola, 3:00	The Genius of Jankowski, Side 2.
		Samba De Uma Nota So, 6:07 E Luxo So, 3:40 Baia, 6:35	Jazz Samba, Side 2.
		How High the Moon, 4:00 Invitation, 3:05 If I Loved You, 3:12 Music Until Midnight, 3:50 Stella by Starlight, 3:55 I Concentrate on You, 3:30	Bouquet of Love, Side 2.

Day	Time	Selections Title/Time	Album Title/Artist/Co./Side
		Rhapsody in Blue, 16:00	Rhapsody in Blue, Leonard Bernstein, ML-5413, Columbia, Side 1.
	10:00	MORNING BREAK	
	10:15	True Love, 2:14 Sound of Music, 2:36 Three Penny Opera, 3:12 Some Enchanted Evening, 2:29 All the Way, 3:01 Sayonara, 2:06	A Summer Place, Side 2.
		Three to Get Ready, 5:14 Kathy's Waltz, 4:33 Everybody's Jumpin', 4:12 Pick Up Sticks, 4:07	Time Out, Side 2.
		Invisible Tears, 1:53 People, 2:40 Love Me With All Your Heart, 1:57 The Girl from Ipanema, 2:36 Everybody Loves Somebody, 2:53 Hello, Dolly!, 2:17	Invisible Tears, Johnny Mann, LRP-3387, Liberty, Side 1.
		Honey, 3:26 I Say a Little Prayer, 3:15 The Look of Love, 2:55 Love is Blue, 2:40 Kiss Me Goodbye, 3:41	Honey, Ray Conniff, CS-9661, Columbia, Side 1.
		Shangri-La, 2:04 The World I Used to Know, 3:06 Al-Di-La, 2:57 Today, 2:57 A World Without Love, 2:51 Blue Velvet, 2:00	Invisible Tears, Side 2.

Day	Time	Selections Title/Time	Album Title/Artist/Co./Side
		Gentle on My Mind, 3:05 By the Time I Get to Phoenix, 2:23 Spanish Eyes, 2:30 Theme from "Valley of the Dolls", 3:13 Sounds of Silence, 3:00 Goin' Out of My Head, 2:35	Honey, Side 2.
	NOON	For You, 3:20 I Love You, 3:25 Three O'Clock in the Morning, 3:00	The Cascading Voices, Side 2.