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EFFECTS OF NOISE ON HUMAN PERFORMANCE [1]

HARRY J. JERISON
Antioch College

Until about 1948, the only proper answer to a question on possible effects of noise on nonauditory performance would have been that none had been demonstrated. Kryter (1950), who reviewed the experimental evidence available then, concluded that nearly all, if not all, studies showing deleterious effects of noise could be criticized severely on the basis of faulty procedures. Since that time, Broadbent (1953, 1954) has demonstrated changes in working efficiency on tasks involving vigilance (alertness) and on a self-paced or externally paced serial reaction task provided the tasks were performed without interruption for relatively long time periods. The experiments to be described confirm Broadbent's results on vigilance and indicate additional measurable performance changes in relatively high energy noise fields.

General Procedure

In the three experiments to be reported here the general procedure was to run *S*s individually through three work sessions with one-week intervals between sessions. Subjects were paid volunteer male undergraduates. After all of the *S*s for a particular experiment were chosen they were assigned randomly to two subgroups. The subgroups were constituted to counterbalance order effects, and the order of undergoing various procedures is indicated in Table 1. The training session, Session I, was one hour long for Experiment I on vigilance and two hours long for Experiments II and III.

The designation "quiet" in Table 1 refers to a noise that was used to mask the sounds of equipment. In Experiment I this was about 83 db re .0002 dyne/cm^2, and in Experiments II and III it was about 77.5 db. The designation "noise" refers to the high level noise which was our major concern. In Experiment I it was about 114 db, and in Experiments II and III it was about 111.5 db. A spectral analysis of the noise is presented in Fig. 1. The noise was generated electronically and broadcast by a loudspeaker mounted in the *S*'s room.

Method and Results

Experiment I: Noise and Vigilance

The purpose of this experiment was to check Broadbent's previously reported results that performance on a prolonged vigilance task was poorer in noise than in quiet. The *S*'s task was to monitor a panel of three Mackworth-type clocks (cf. Mackworth, 1950) and to press a response switch under a clock when its hand stepped through twice its usual excursion. The apparatus is illustrated in Fig. 2. Double steps occurred haphazardly at intervals that averaged about once a minute for each clock.

The results of this experiment are summarized in Fig. 3 which gives the average percentage correct for the nine *S*s of this experiment during their experimental and control sessions. It should be noted that average performance during these two sessions when noise levels were the same, that is, during the first half hour, was about 10 per cent better during the control session. The difference between the sessions during the second and third half hours when the 114 db noise was present for the experimental session should, therefore, not be attributed to an effect of noise. The parallel orientation of the two curves during the first one and one-half hours indicates that noise had essentially no effect on

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Table 1

General Experimental Design

	Session I	Session II	Session III
Subgroup QN	Training (Quiet throughout)	Control (Two hours quiet)	Experimental (½ hour quiet followed by 1½ hours noise)
Subgroup NQ	Training (Quiet throughout)	Experimental (½ hour quiet followed by 1½ hours noise)	Control (Two hours quiet)

Note —Sessions were held at one-week intervals.

performance at that time. During the fourth half hour the two curves diverge considerably suggesting that noise may depress performance only after a fairly considerable period of time.

An analysis of variance of the data of this experiment is presented in Table 2. The difference between average performance during the experimental and control sessions was not statistically significant ($.20 > P > .10$). The difference between rate of change of performance for the two sessions (the sessions by time at work interaction) was significant at the .05 level. This supports the impression one gets from viewing Fig. 3 that the differentiation of performance in the fourth half hour is a "true" effect. A more detailed report of this experiment has been prepared for limited circulation (Jerison & Wing, 1957).

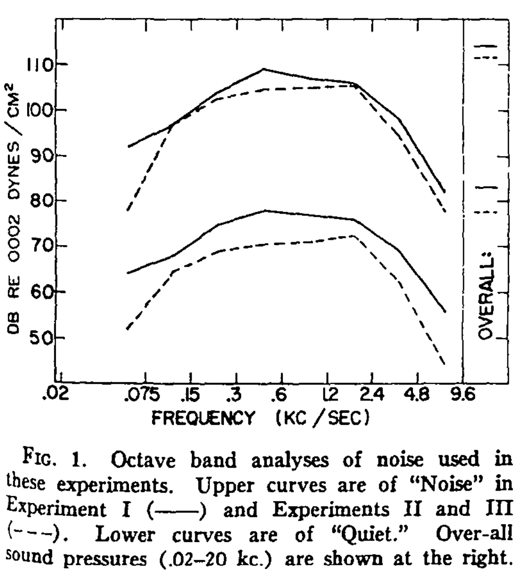

Fig. 1. Octave band analyses of noise used in these experiments. Upper curves are of "Noise" in Experiment I (——) and Experiments II and III (- - -). Lower curves are of "Quiet." Over-all sound pressures (.02–20 kc.) are shown at the right.

Before going on to the next experiments it is of some interest to note that vigilance as measured here did not become less adequate as a result of fatigue alone. This result, the absence of a performance decrement during the two-hour control session in quiet, is contrary to that reported by Mackworth (1950)

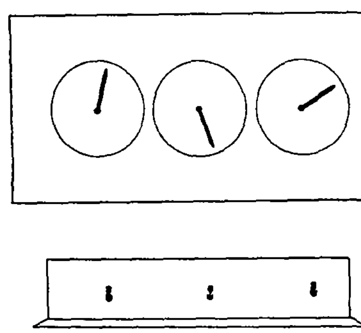

Fig. 2. The display and response panels of Experiment I. Dial pointers normally stepped through 3.5 degree arcs.

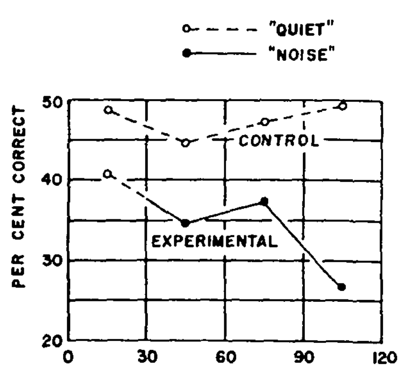

Fig. 3. Average performance of the nine *Ss* in Experiment I during successive half hours of the experimental and control sessions.

Table 2

Analysis of Variance for Experiment I

Source	*df*	Mean Square	*F*
Subjects (*S*)	8	6544 90	
Experimental conditions (E)	1	8490 08	2 93
E × *S*	8	2900 09	
Clocks (C)	2	489.31	1.24
C × *S*	16	396.08	
Time at work (T)	3	479.67	6 32**
T × *S*	24	75.89	
E × C	2	280.52	1.18
E × C × *S*	16	238.36	
E × T	3	600 47	3.48*
E × T × *S*	24	172.60	
C × T	6	138.63	1.32
C × T × *S*	48	105 09	
E × C × T	6	253 10	2 07
E × C × T × *S*	48	122.13	
Total	215		

* Significant at the .05 level
** Significant at the 01 level.

for a simpler vigilance task. No explanation for this discrepancy will be attempted here; it is discussed in greater detail elsewhere (Jerison & Wing, 1957) and has been found again in a subsequent experiment with the same task (Jerison & Wallis, 1957).

Experiment II: Noise and Complex Mental Counting

The procedure in this experiment was developed as a result of a suggestion by Miles (1953) that *S*s working in high energy noise fields could not keep an accurate count of how far they had gone in a repetitive task. The complex mental counting test is described in detail elsewhere (Jerison, 1955) Briefly, it consists of a display of three periodically flashing lights; the *S*'s task was to count the number of times each light flashed and to maintain separate counts for each light. He responded by pressing a button under a light when that light had flashed *N* times and began the count for that light again. (For this experiment *N* was always 10.) The display and response panels used in this experiment are illustrated in Fig 4. Behind the display is the loudspeaker which broadcast the noise Fourteen *S*s were used.

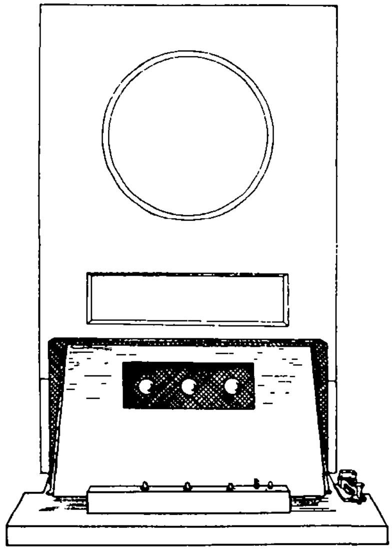

FIG. 4. The display and response panels of Experiment II Behind the display is the loudspeaker cabinet.

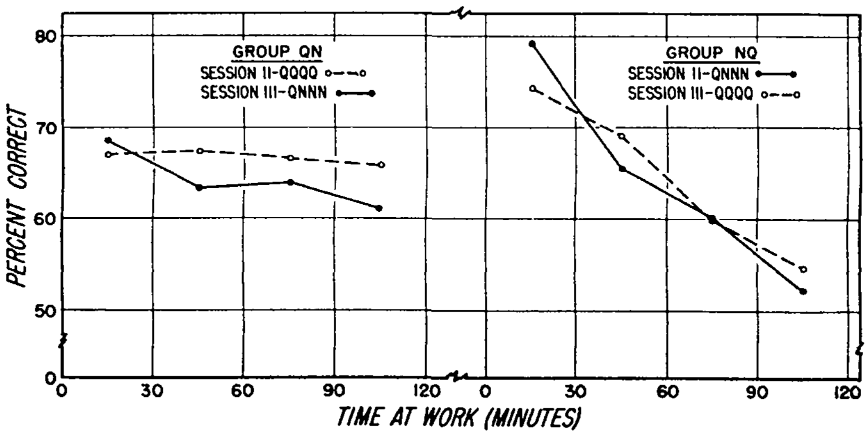

FIG 5. Performance of the 14 *S*s of Experiment II given separately for the seven-subject subgroups "QN" and "NQ" during successive half hours of the experimental and control sessions.

The most relevant results of this experiment are presented in Fig. 5 which shows the average percentage of correct responses for the two subgroups separately for the second and third sessions. Subjects in subgroup QN showed no change in performance during successive half hours of the second (quiet throughout) session. In the third session, when the noise level was raised to 111.5 db after the first half hour, a small decrement appeared, though the performance curve is relatively flat. Subjects in subgroup NQ showed a steady decrement from their high performance level of the quiet first half hour of their second (experimental) session after the noise level was raised, with a total fall in performance of over 25%. In the third (control) session in quiet this group repeated the pattern showing a drop in performance of about 20%. This general effect (the sessions by experimental conditions by time interaction) was significant at the .001 level. A summary of the rather lengthy analysis of variance for this experiment is presented in a more detailed report for limited circulation (Jerison, 1956).

This result suggests that working on this tedious and difficult task for two hours under the QNNN regime conditioned *S*s to a progressive breakdown of performance, and this conditioning was maintained in the subsequent quiet session. Working in quiet first, on the other hand, appeared to dispose the *S*s toward maintaining their original performance level, and this tendency, too, was maintained in the subsequent session despite the presence of noise in that session. Recent experiments by Broadbent (1957, 1958) appear to support this finding.

Experiment III: Noise and Time Judgment

While performing the counting task the *S*s of Experiment II were also required to press a telegraph key (illustrated in Fig. 4, lower right) at what they judged to be 10-minute intervals

The main results of Experiment III are summarized in Fig. 6 which shows the average time between *S*'s responses during successive half hours of the experimental and control sessions. (The subgroups were combined, because no order effect appeared here.) The results were analyzed with *t* tests. The differences between half hours within the control session were not statistically significant, nor was the difference between time judgments in the first half hour of the control and experimental session significant. The difference between the first half hour and succeeding half hours of the experimental session were all significant at the .05 level or better, and the difference between the averaged judgments of the last one and one-half hours of the control and experimental sessions was significant at the .02 level. In other words, a significant difference was found between time judgments as measured in this experiment when the comparison was between judgments in noise and judgments in quiet. A more detailed report of this experiment for limited circulation has appeared elsewhere (Jerison & Smith, 1955).

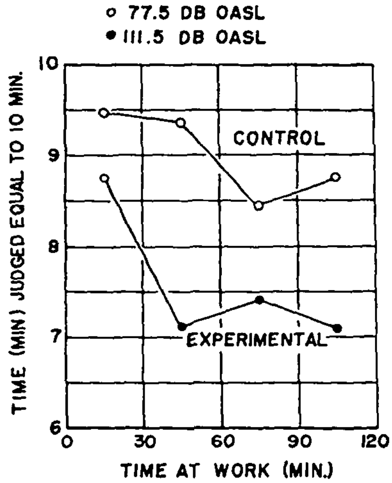

FIG. 6. Time judgments for the experimental and control sessions of Experiment III during successive half hours.

Discussion

It is clear that noise produces readily measureable changes in human performance. The specific changes involved in the three experiments described here are discussed in detail in each of the technical reports devoted to them (Jerison, 1956; Jerison & Smith, 1955; Jerison & Wing, 1957). The purpose of the present discussion is to consider these results in a more general way and to seek some constant features that appear in all of them.

One of the first problems to face is why it has been possible to demonstrate differences between performance in noise and in quiet at all, for, as indicated earlier (cf. Kryter, 1950), most previous work on this problem has given negative results. The main new feature that appears in these experiments is one suggested by Mackworth (1950) and by Broadbent (1953, 1954): Performance was measured over long time periods and conditions were arranged to allow effects of boredom and fatigue to interact with possible effects of noise. These conditions were present in all the experiments reported here. The implication is that for short, spurt-like efforts no performance decrements in noise need be expected. When sustained performance is required, however, and the task is not intrinsically challenging, effects of the sort reported here are likely.

These considerations point to an interpretation of the results which deemphasizes the importance of noise. There is, after all, little reason for regarding noise as a peculiar kind of devil which produces such unusual interactions with fatigue and boredom. It seems reasonable, instead, to regard the more gross effects found as resulting from effects of noise on motivational level or emotional balance, in short, from noise as a source of psychological stress. If this interpretation is correct we should expect similar behavioral effects from other experiments in which other kinds of stress or motivating conditions were investigated. This is, in fact, the case. Mackworth (1950) demonstrated that heat stress resulted in deterioration of performance on a simple vigilance task, and several experiments showing changes in the judgment of time intervals of the order of minutes as a result of different motivating conditions have been reported (Filer & Meals, 1949; Gulliksen, 1927; Rosenzweig & Koht, 1933).

Because stress has been introduced as an explanatory concept a few remarks on its scientific status are in order. The review by Lazarus, Deese, and Osler (1952) emphasizes the lack of systematic research on effects of stress on performance, and, although it attempts an analysis of theoretical approaches, this review does not go significantly beyond a statement relating psychological stress to changes in motivation and emotion. There is danger, when using the concept of stress, of believing that an explanation has been achieved. Actually, here, and in most other contemporary usages of the term, we have achieved little more than communication of intuitive judgment about the kind of situation with which we are dealing.

A final point that should be made is related to the kind of noise used. The noise was actually much softer than that found today in many operational situations. Yet even at these levels it was clear that "higher mental processes" were affected. It is obviously necessary to explore effects of noises of higher intensity on such processes.

Summary

The results of three experiments relating performance changes to noise levels are reported. Noise levels used were about 80 db representing "quiet" and 110 db representing "noise." Changes in alertness as determined on a clock-watching task were found after one and one-half hours in noise though none were found in quiet. Time judgments—the estimation of the passage of 10-minute intervals—were distorted by noise; *S*s responded on the average of every nine minutes in quiet and every seven minutes in noise when instructed to respond at what they judged to be 10-minute intervals. A significant but complex effect of noise on a mental counting task was also found. These effects are discussed in terms of noise as a source of psychological stress.

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