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EFFECT OF NOISE ON THE STROOP TEST

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Noninterference tests and 2 versions of the Stroop color interference test were used to test *S*s in loud noise and quiet. Interference and noninterference tests were performed during the first and last 10 min. of a 30-min. exposure to noise and quiet. Interference in noise and quiet was measured by taking the difference between performance on interference and noninterference tests. The *S*s in Experiment I who were tested at both exposure durations showed increased interference in noise. In Experiment II, exposure duration and practice were assessed independently. The brief exposure to noise was beneficial and decreased interference, and the long exposure increased interference, suggesting a cumulative adverse effect of noise.

Exposure to loud noise undoubtedly produces changes in human performance efficiency (Broadbent, 1953). These performance changes have been attributed to the amount of stimulation being received: excessive stimulation from intense noise is supposed to overarouse *S* and cause impairment (Broadbent, 1963), but a moderate amount of stimulation can cause some improvement (Davies & Hockey, 1966; McGrath, 1963). These performance changes have occurred toward the end of a lengthy (30-min.) test in continuous loud noise (Broadbent & Gregory, 1963). The changes occurring with continued exposure to loud noise include increases in errors and pauses in a serial reaction task (Wilkinson, 1963) and increased attention to high-probability sources of information (Hockey, 1970). Broadbent (1971) suggests that one interpretation of these results is that the increased arousal accompanying exposure to intense noise leads to an impairment of the mechanism that filters information from the environment for further processing. Some of the evidence for this view derives from a series of studies involving the visual identification of common and uncommon words in noise. It was found that the uncommon word was more difficult to see in noise, but only when both classes of words were present. Noise did not alter the ratio of misperceptions of common and uncommon words. Noise clearly affected the selection of the stimulus rather than changing the bias in responding to one or the other class of words.

In the Stroop test (Jensen & Rohwer, 1966; Stroop, 1935) color names written in inks of different hues, excluding ink of the hue the name indicates, are presented to *S*s, who are required to name the hue of the ink and not the color name. The comparison or control task may involve naming monochromatic color names or naming the hue of the ink in which nonverbal symbols are written. Responding to the hue of color names takes longer than either of the comparison tasks because both name and hue are appropriate to the same set of responses. Hence, the irrelevant feature of the stimulus (color name) must be excluded from the analysis. The color name dimension must be filtered from the hue dimension (Dyer, 1971).

It would be expected that if filtering is affected by noise-induced arousal, the Stroop test should show impairment in noise which would increase with length of exposure to noise, as other tests have shown it does. In the following experiments, versions of the test not requiring an overt verbal response were used.

Experiment I

Method

Subjects. Eighteen enlisted men served as *S*s, and each *S* was tested individually. No *S* had

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done the test before. All *S*s had normal hearing; less than 35-db. loss in one ear or 30-db. loss in both ears at any of 7 test frequencies covering the audible range.

Materials. Two packs of 100 cards, one experimental (E) and the other control (C), were used. Cards in the E pack displayed 5 color names—red, blue, green, violet, and black—written in uppercase lettering in inks of the 5 hues. No color name was ever written in the hue the name indicated. There were 5 cards of each hue/name combination in the pack. Each card in the C pack displayed 5 crosses drawn in any one of the 5 hues of the E pack. There were 20 cards of each hue in the pack. The *S*s sorted each of the 2 packs as quickly and accurately as possible into 5 piles corresponding to each of the hues.

Procedure. All 18 *S*s were tested in conditions of noise (N) and quiet (Q). These 2 tests were given on separate days at between 8:00 and 9:00 A.M. Each *S* sorted both the E and C packs in the first and last 10 min. of a 30-min. exposure to N and Q. The *S*s read magazines in the interval between the tests at the beginning and end of the exposure.

Broad-band noise was used in all conditions, having constant energy per cycle between 50 and 4,000 Hz. In N, this was presented at 100 db., and in Q, at 70 db., measured on the C scale, having a substantially flat frequency response.

Half of the *S*s had the N condition on their first test and half had the Q condition. Presentation order of the E and C packs to each group of 9 *S*s was counterbalanced within each *S*. Prior to the first test, *S*s practiced sorting both packs of cards in Q. Each *S* was told his scores after sorting each pack, and the scores were also displayed on a group chart near *S*.

Results

The times taken to sort each pack were analyzed using a repeated measures analysis of variance with logarithmic transformation of the scores to achieve normality of distribution. Interactions of each factor with *S*s were used as error terms.

Sorting on the second test, following the 20 min. of prior exposure, was faster than sorting on the first test in every condition ($p < .008$). Pooling tests in the N and Q conditions, the type of pack sorted interacted with the position of the test in the ½-hr. exposure, $F(1, 17) = 6.32$, $p < .025$. The difference in time taken to sort names and crosses was less at the end of the exposure than at the beginning. Comparing tests in the N and Q conditions independently, N increased the time taken to sort the E pack by about 3% and decreased the time taken to sort the C pack by about 1% (Table 1).

TABLE 1

MEAN TIME (IN MIN.) TO SORT EACH CARD PACK UNDER EACH CONDITION

Time of sorting task	Card-pack stimuli: Color names	Card-pack stimuli: Crosses
Quiet condition		
First 10 min.	2.6156	2.3167
Last 10 min.	2.2630	2.0722
Noise condition		
First 10 min.	2.6990	2.2593
Last 10 min.	2.3880	2.0620

Note. Time of sorting task refers to its occurrence within the 30-min. exposure to either quiet or noise.

The difference in time taken to sort E and C packs was nearly twice as large in N (22.97 sec.) as in Q (14.69 sec.), $F(1, 17) = 4.55$, $p < .05$. Although noise caused an increase in the difference in sorting time of the 2 packs, there was no evidence that it interacted with the position of the test in the ½-hr. exposure ($p = .25$). The increased difference in sorting time of the 2 packs can therefore be regarded as similar at the beginning and at the end of ½ hr. of noise.

EXPERIMENT II

Experiment I examined whether noise increased the interference of color name with the selection by hue and whether this interference increased with the duration of noise exposure. The fact that there was no increased interference with a long as compared to a short exposure to noise could be due to a number of factors; in particular, the fact that duration of exposure to noise was confounded with practice at test, and the latter reduced the interference. In Experiment II, these 2 variables are assessed independently and a modified version of the test, involving a much smaller motor component, was used.

Method

Subjects. Two groups of 16 *S*s each were tested. All were enlisted men, none of whom had taken part in Experiment I. The *S*s were tested in groups of up to 6 at a time. All *S*s had normal hearing; less than 35-db. loss in one or 30-db. loss in both ears at any of 7 test frequencies covering the audible range.

Materials. In the modified version of the Stroop test, the material was presented in a written form, and *S* ticked the appropriate item, rather than sorting it from a set of cards. The material was presented in a series of sheets, each containing 32 lines of material. On E sheets, each line was made up of the color names, red, green, brown, black, and blue, written in inks of these hues. No color name was written in the hue that the name indicated. Each line on the sheets contained 1 stimulus color name on the left and the 5 possible response color names on the right. Each *S* was instructed to select from the response set the color name appropriate to the hue of the stimulus name. As a control, a noninterference (C) test was also used. The format of these C sheets was identical to that of the E sheets, and they contained the same set and number of color names as the E sheets; however, color names were all printed in black ink. Each *S* was instructed to select from the response set the same color name as the stimulus color name.[2] In both C and E tests, *S* crossed out the response word in as many lines of material as he could in 5 min.

Procedure. All *S*s were tested twice, once in both the N and Q conditions. A practice test was also given. These 3 tests took place on 3 consecutive days between 8:00 and 9:15 A.M.

Broad-band noise having equal energy per octave was used in all conditions. This noise was presented at 95 db. in the N condition and at 70 db. in the Q condition, measured on the C scale. The differences in sound-pressure level and spectrum of the noise between the 2 experiments reported here were necessitated by administrative reasons outside *E*'s control.

One group of 16 *S*s (Group 1) was exposed to only 10 min. of Q or N, performing both C and E tests immediately following entry into the experimental sound room: a second group of 16 *S*s (Group 2) performed both C and E tests in the last 10 min. of a 30-min. exposure to N and Q. The *S*s in the latter group read magazines prior to the tests during the first 20 min. of both the N and Q conditions. In each condition, *S* did both E and C tests for the 5-min. period allowed. Half of the *S*s in each group were tested in N on their first test day and half in Q. On each test day, half of the *S*s had the E test first and half had the C test first. Both tests were scored in terms of number of lines responded to correctly. All *S*s were instructed before each test to work as quickly and accurately as possible, completing as many lines of the test as they could. The *S*'s scores were displayed in a group chart on the wall near him.

Results

The number of lines completed was analyzed using analysis of variance, as in Experiment I, and Wilcoxon's test. The *S*s worked faster on their second test than on their first on E sheets ($p < .001$) and on C sheets ($p < .02$), Wilcoxon's test. Every *S* worked more slowly on the E than the C test in every condition. As Table 2 shows, there was a tendency for *S*s to work slower on the C sheets and faster on E sheets in the 10-min. exposure to N, as compared to Q. On the other hand, the group with 30-min. exposure tended to work slower on E sheets and faster on C sheets in N as compared to Q. None of these differences were reliable however. The changes in speed were about 7% on E sheets and about 1% on C sheets.

The differences in number of items correctly completed on E and C tests in each condition were used to assess the interference caused by N as compared to Q. The *S*s made very few errors on either test. The average number of errors on each C and E test was less than 1. Taking the difference, or interference score, between C and E tests, there was no overall effect of N as compared to Q. There was however, a strong interaction between Interference and Duration of Exposure to N and Q, F (1, 30) = 15.81, $p < .001$. This interaction occurred because the interference, or difference between C and E tests, was less in the N condition (45.13) than in the Q condition (55.50) in the first 10-min. exposure, F (1, 30) = 7.46, $p < .025$. Only 2 out of 16 *S*s did not show less interference in N. However, considering the other group of *S*s, there was more interference with the 30-min. exposure to N (57.82) than in Q (40.00), F (1, 30) = 8.38, $p < .01$. Again, only

[2] This monochromatic control was selected in preference to material containing stimuli of different colors for ease of duplication and preparation, with a view to possible large-scale use of the test in the future. This experiment was part of a program of evaluation of the test for use in field studies of environmental stress.

2 out of 16 *S*s did not show greater interference in the 30-min. exposure to N than to Q. These 2 effects of noise did not relate systematically to either the order in which N and Q conditions were received or the order in which the 2 tests were received. Neither could there be any effect of instructional bias upon the group since not all members of a group had C and E tests presented in the same order.

TABLE 2

MEAN NUMBER OF LINES COMPLETED UNDER EACH CINDITION

Group	Stimulus sheet	
	Control	Experimental
Quiet condition		
1	170.13	114.63
2	172.44	132.44
Noise condition		
1	169.38	124.25
2	176.88	125.06

Note. Group 1 *S*s were exposed to only 10 min. of either quiet or noise; Group 2 *S*s were tested after 20 min. of a 30-min. exposure to quiet or noise.

DISCUSSION

The second version of the Stroop test is clearly more sensitive than the card-sorting version. In both experiments, nearly all the change in interference was contributed by performance on the experimental rather than the control material. The *S*s in Experiment II showed a much more reliable change in interference than those in Experiment I, notwithstanding the higher sound-pressure level in the first experiment. This is probably due in part to the much smaller motor and larger perceptual component in the test in Experiment II.

In addition, in the first experiment, the response of sorting by color was unrelated to the semantic description of the hue. In Experiment II, although *S* did not verbalize, he selected the appropriate semantic response in relation to the hue. Pritchatt (1968) considered 2 conditions similar to these experiments and also obtained considerably more interference when *S* was required to press a key labeled by color name rather than hue. The difference in interference between the 2 versions is generally consistent with the view of Hock and Egeth (1970) that much of the interfering effect is due to disruption of the encoding of the name of the hue by the verbal dimension of the stimulus or its aftereffect.

The effect of noise on this interference depends on duration of exposure; interference was reduced by the short exposure, confirming the results of O'Malley and Poplawsky (1971). The increased impairment during the long exposure is consistent with the change in performance in other tests during a long exposure to noise, where impairment has increased with exposure. Hartley (1973) has found that a 40-min. exposure to noise causes impairment in a serial reaction test performed only in the last 20 min. of the exposure. This impairment was worse than when 20 min. of noise was presented in the last half of 40 min. of performance. These results indicated that continuous noise led to a progressive increase in impairment, independent of task duration. In Experiment II, the difference in performance between the brief and the long exposure may also be construed as further evidence that the effect of noise on performance changes with exposure. Impairment appeared following the long exposure without any prior performance.

There is some evidence to connect the difference in interference between short and long exposure to noise with changes in arousal. Agnew and Agnew (1963) and Tecce and Happ (1964), using threat of electric shock, and Callaway (1959), using an amphetamine, obtained results indicating reduced interference under these conditions. On the other hand, Callaway (1959), using amylobarbital, and Ostfeld and Aruguete (1962), using hyoscine, obtained results indicating increased interference under these conditions. It would be reasonable to assume, although without substantiating evidence, that stimulants and shock raised arousal, while the sedatives depressed arousal. The beneficial and detrimental effects of short and long exposure to noise may likewise be connected with changes in arousal level.

A significant feature of Experiment II is the absence of any auditory cues in performance of the test. Some auditory cues, either generated by *S* or by the apparatus, have been present in nearly all tests that have shown impairment in noise. Although the fact that noise has shown its effect at the end of the test suggests that masking of these auditory cues did not contribute to the noise impairment observed, this factor could not be ruled out (Kryter, 1970). For example an interaction between time spent on the task and loss of auditory information could account for impairment in noise appearing at the end of the test. The results of Experiment II, a task with no auditory component, clearly indicate that the adverse effect of noise need not be due to the loss of these cues, particularly in view of the initial beneficial effect of noise also obtained. Nevertheless, these results do not exclude the possibility that loss of task-independent auditory information is connected with impairment when the loss is prolonged for 20 min.

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