Polish Journal of Occupational Medicine and Environmental Health Vol. 4, No 3, 269-279, 1991

EFFECTS OF NOISE ON COGNITIVE PROCESSES OF INDIVIDUALS IN A LABORATORY EXPERIMENT

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Key words: Noise effects on information processing, Individual noise sensitivity, Noise induced temporary threshold shift, Noise effects on heart rate

Abstract. The effects of noise on information processing in perceptual and memory tasks, as well as time reaction to perceptual stimuli, were investigated in a laboratory experiment. Performance and heart rate in Information Processing Test, Simple and Choice Reaction Time tests and Stroop's test were evaluated at three levels of noise (silence, 75 dBA, 95 dBA). Individual noise sensitivity and noise-induced temporary threshold shift (NITTS) were also assessed.

The results show that neither noise nor individual noise sensitivity, or NITTS, as separate factors have an influence on information processing and time reaction to perceptual stimuli. However, noise effects simple reaction time in interaction with individual noise sensitivity, and information processing – within experimental session duration.

Experimental session duration was the one separate factor affecting information processing.

Noise as a separate factor does not have an influence on task performance, however, it affects heart rate. The higher increase of noise-induced temporary threshold shift, the smaller the number of heart beats/minute was found.

INTRODUCTION

Noise is one of the most common stressors in the human environment. It can disturb man's work, sleep, and communication. Because of its complexity, variability and interaction with other environmental and psychological factors,

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the adverse effects of noise do not lend themselves to straightforward analysis. The results of the effect of noise on the performance of tasks involving cognitive processes are ambiguous. They showed both positive and negative effects (10).

Woodhead (14) for example, shows that noise adversely affects tasks involving a combination of memorizing and problem solving. However, when noise was introduced into the calculation phase only, performance was improved. Data from tasks requiring ordered recall support the view that noise improves ordered recall (2,5,13). Dornic (3) suggests that noise, like other variables which increase task difficulty, induced the use of lower memory processes which force subjects to parrot back lists, thus foregoing deeper levels of analysis. Other studies (6) showed that, sometimes, performance of high-priority aspects of a task could be enhanced while performance of low-priority aspects was diminished by noise.

Noise experiments involving complex mental tasks, analytical processes, learning or information gathering have demonstrated a disruptive effect of noise (4,12). The same effects have been shown in vigilance tasks, and in the accuracy of continuous serial reaction (1). The vigilance activities not being repetitive and demanding accurate, rapid decisions, are more adversely affected by distraction then many other activities.

In general, the negative effect of noise is likely to be more severe as the task becomes more difficult and the experiments involve more complex cognitive processes.

The reception, interpretation, and reaction to noise depends on individual variables. Among them, one of the most important is subjective noise sensitivity. Ohrstrom and her colleagues (7) for example, shown that annoyance after exposure to noise in a laboratory environment is not closely related to neurophysiological sensitivity to noise, but is highly correlated with subjectively reported noise sensitivity and with the attitude to noise. These authors also found a significant noise effect on subjective sleep quality only among the sensitive subjects (8). Stansfield et al. (11) described a relationship between noise sensitivity and the presence of psychiatric symptoms in areas with a high level of aircraft noise exposure.

It is possible that the noise induces a higher stress reaction in noise-sensitive individuals. As a consequence, the sensitive group would have acted worse on the performance tests.

AIM OF THE STUDY

The general aim of this study was to assess the effect of noise on cognitive processes of subjects in experimental conditions. The analysis was limited to information processing in perceptual and memory tasks, and also to reaction time. These psychological functions are important in determining work reliability in some professions demanding accurate decisions based on visual information, such as operators.

The following hypotheses were postulated:

1. Noise adversely affects reaction time and information processing in perceptual and memory tasks;

2. The more the subjective noise sensitivity, the stronger the negative noise effect on reaction time and information processing in perceptual and memory tasks;

3. The longer the time of noise exposure, the stronger the negative noise effect on reaction time and information processing in perceptual and memory tasks;

4. The longer the noise exposure time, the stronger the negative noise effects on functioning (activity) of cardiovascular system.

The last hypothesis was formulated according to the following assumption. The changes in activity of the cardiovascular system (higher heart rate) can be a form of compensation for negative noise effects. In such a situation, negative effects on task performance may not be found.

MATERIALS AND METHODS

Subjects. The subjects were employees of the Institute of Occupational Medicine. They were 18 men aged from 25 to 40 with high-school or university education. They were recruited voluntarily and paid for their participation. Acceptance of the experiment's program and levels of noise exposure was given by the Local Ethical Committee. The final classification of the experiment was made by the internist and laryngologist.

Experimental design. Subjects participated in the experiment four times. To avoid the effect of learning process, a group of six solved the experimental tasks in the same order of laboratory conditions (Table 1).

TABLE 1. Experimental design.

Experimental conditions	Order of experimental conditions		
	n = 6	n = 6	n = 6
silence	1	3	2
75 dBA	2	1	3
95 dBA	3	2	1

During the first session they solved these tasks tentantively. After that, they were asked to fill in the Noise Sensitivity Questionnaire. During the next three sessions the subject was closed in a sound-proof cabin and after five minutes he started to carry out the tests in the following order:

1. Information Processing Test (IPT) – Perceptual tasks – first examination,

2. Simple Reaction Time test (SRT),
3. IPT – Memory tasks – first examination,
4. Stroop's test,
5. IPT – Perceptual tasks – second examination,
6. Choice Reaction Time test (CHRT),
7. IPT – Memory tasks – second examination

These tests were performed by the subjects in silence and at two levels of noise (75 dBA and 95 dBA).

The noise to which the subjects were exposed was natural (taped from a power station). During the experiment heart rate was recorded using an ECG apparatus. Moreover, to assess the noise induced temporary threshold shift, pre- and post-exposure hearing of subjects was measured.

Performance tests. A computer version of IPT, was used, based on Sternberg's additive factors method (9). This version consists of perceptual and memory tasks. Generally, in IPT, the effectiveness of information processing stages was assessed, in particular, the effectiveness of encoding and comparison.

The perceptual test consisted of 60 items. Each of them included two sets of black letters which were exposed on the white screen and separated by vertical line. Each set was the combination of one, two or three letters, on the masked or unmasked background and in a rotated or unrotated position (Table 2). The subject had to compare two sets of letters and answer if they were the same. The number of errors and performance time were measured. According to Sternberg's theory, mask and rotated stimuli recognition is connected with the encoding stage of information processing. Manipulation of "size of set elements" influenced the comparison stage.

TABLE 2. Kinds of stimuli combinations in IPT-Perceptual tasks.

Kind of stimulus	Stimulus position	Number of set elements		
		1 letter	2 letters	3 letters
unmasked	unrotated	a	b	c
	rotated	d	e	f
masked	unrotated	g	h	i
	rotated	j	k	l

Memory test included 16 items. The subject was given a short list of letters to hold in his memory, and had to classify a probe letter as an element or non-element of the memorized set. Each list was the combination of two, three, four or five letters, on a masked or unmasked background, and in a rotated or unrotated position (Table 3). The number of errors and the performance time were measured.

TABLE 3. Kinds of stimuli combinations in IPT-Memory tasks

Kind of stimulus	Stimulus position	Number of set elements 2 letters	3 letters	4 letters	5 letters
unmasked	unrotated	a	b	c	d
	rotated	c	d	e	f
masked	unrotated	g	h	i	j
	rotated	k	l	m	n

IPT (perceptual and memory) was given twice at the beginning and end of the experimental session (after about 30 minutes). It was necessary to assess the effect of time exposure (noise exposure duration) at two levels of noise.

The computer versions of Simple Reaction Time test and Choice Reaction Time test were also used. In the latter, the subject had to react to one of two different perceptual stimuli.

Stroop's test was used to evaluate individual susceptibility to stimuli disturbing mental processes. The computer version of this test included four subtests. In the first one, the subject was asked to press, as quickly as possible, the button of the same colour as the figure shown on the monitor. In the second, he had to press the button of the same colour as expressed by the word exposed on the monitor. In the next, the subject had to react as before, but in this instance the name of the colour was the same as the colour of the type. The fourth subtest included conflict tasks. The subject had to react to the colour of the type, which was inconsistent with the name of the colour expressed by the word. In each of these subtests, the numbers of errors, time of correct and incorrect reactions and difference between number of heart beats/minute in tasks with conflict and non-conflict stimuli were measured.

Statistical analysis. One and two factoral ANOVA for repeated measures were used to analyse the results of Simple Reaction Time, Choice Reaction Time and Stroop's tests.

MANOVA for repeated measures was used to analyse the results of Information Processing Test.

RESULTS

First we will present results of the tests which were performed once (SRT, CHRT, Stroop's test), next – the results of IPT which was performed twice, at the beginning and the end of the experimental session.

As it is shown in Tables 4 and 5, noise does not influence time reaction and number of errors in Simple Reaction Time, and Choice Reaction Time tests and also in Stroop's test. However statistical analysis shows a significant interaction effect of noise and individual noise sensitivity on time reaction and number of errors in the first test (Figs 1 and 2).

TABLE 4. Means and standard deviations of time reaction and number of errors in Simple Reaction Time and Choice Reaction Time tests.

Tests	Laboratory conditions	Silence		75 dBA		95 dBA	
		M	SD	M	SD	M	SD
SRT	time	.276	.105	.293	.083	.284	.077
	errors	3.333	9.701	1.667	7.071	1.778	7.059
CHRT	time	.392	.117	.376	.106	.369	.100
	errors	5.222	13.791	2.722	6.918	2.611	6.946

TABLE 5. Means and standard deviations of time reaction and number of errors in Stroop's test.

Stroop's subtests	Laboratory conditions	Silence		75 dBA		95 dBA	
		M	SD	M	SD	M	SD
subtest I	time	1.010	.211	1.071	.210	1.042	.211
	errors	.278	.826	1.667	3.068	.778	1.555
subtest II	time	1.124	.258	1.106	.214	1.114	.238
	errors	2.056	5.672	1.722	3.357	1.222	1.801
subtest III	time	1.040	.244	1.021	.217	1.010	.197
	errors	2.556	5.294	.778	1.478	.278	.575
subtest IV	time	1.260	.210	1.287	.312	1.265	.294
	errors	1.056	1.434	.778	1.478	.778	1.734

As the results of SRT-test show (Figs 1 and 2), for the highly sensitive group there is no difference in the number of errors and mean time reaction between silence and the two levels of noise. In the same test, for the low sensitivity group, a decrease of the number of errors and also increase of mean time reaction were found at the noise of 75 dBA. It means, that compared to silence, at that level of noise, low sensitivity subjects work longer but better.

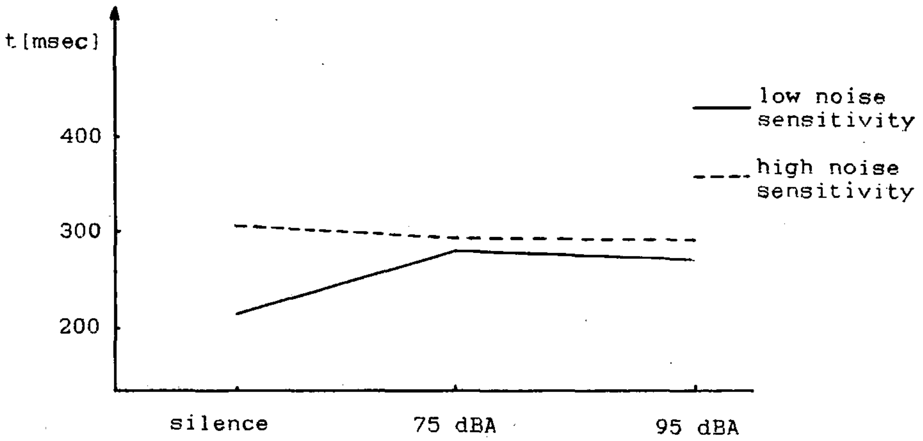

Fig. 1. Interaction effect of noise and individual noise sensitivity on mean time reaction in Simple Reaction Time test.

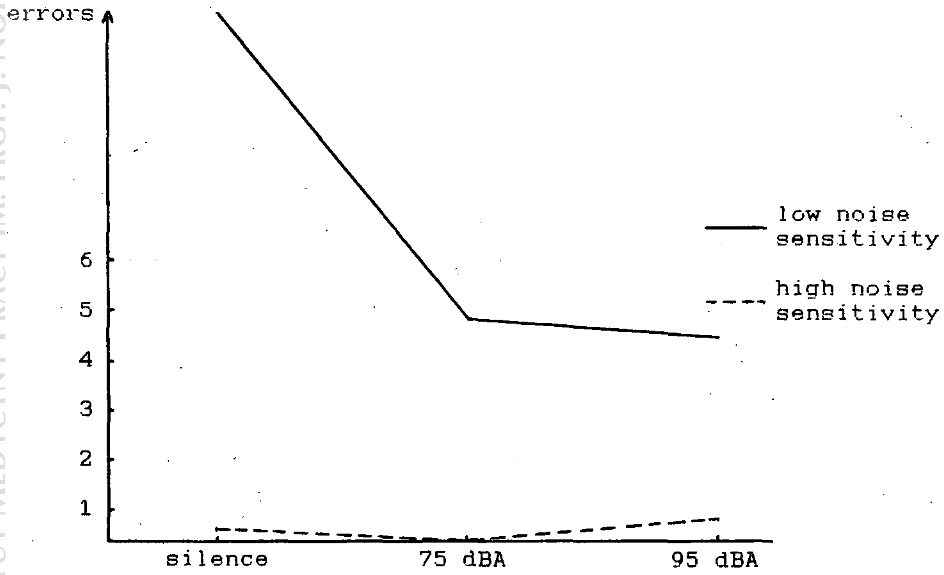

Fig. 2. Interaction effect of noise and individual noise sensitivity on mean number of errors in Simple Reaction Time test.

These results show unexpectedly that noise affects only low sensitivity subjects' performance. May be it is connected with a difference in levels of mobilization between low and high sensitivity subjects. The high sensitivity subjects probably expect a more disturbing noise influence, so they concentrate on the task more than the second group. Furthermore, these results are difficult to explain because low and high sensitive subjects already differ "on input", i.e. in silence.

The results of ANOVA for Stroop's test showed significant noise influence only on heart rate. The value of the difference in heart beats/minute as a reaction to conflict and non-conflict stimuli was decreased by noise ($F(2,16) = 5.04$; $p < 0.02$).

Because of the small number of errors and small differentiation between groups, only performance time was analysed in IPT.

Among all factors, only noise exposure duration influences performance time in IPT – Perceptual tasks (MANOVA Wilks test $F(3.15) = 3.656$; $p < 0.037$). The strongest effect of this factor was found for tasks with 3-element stimuli ($F(1.17) = 12.27$; $p < 0.003$) and unmasked stimuli ($F(1.17) = 10.94$; $p < 0.004$). In the case of more difficult tasks (3-element stimuli), the mean time of performance after 30 minutes was shorter ($M = 1.25$ sec) than at the beginning of noise exposure ($M = 1.30$ sec). Then, in the case of easier tasks (unmasked stimuli) performance time was longer ($M = 1.13$ sec) than at the beginning ($M = 0.96$ sec). Shorter second-time performance in tasks with 3-element stimuli is probably connected with changes of the comparison stage of information processing, while longer second-time performance in the tasks with unmasked stimuli – with changes of the encoding stage.

Furthermore, in case of the tasks with 3-element stimuli, the interaction effect of noise and session duration was found ($F(2.34) = 2.99$, $p < 0.064$; Fig. 3). The higher the noise, the shorter performance time at the end of noise exposure. It means, that noise does not disturb comparison function.

Analysis of heart beats/minute during tasks performance in IPT-Perceptual tasks shows significant results only at the highest level of noise (95 dBA). Two factors determining heart beats/minute in these tasks were found. They are noise exposure duration ($F(1.15) = 4.34$; $p < 0.05$) and noise-induced temporary threshold shifts ($F(1.14) = 4.34$; $p < 0.034$). During the second performance of IPT-Perceptual tasks (after about 30 min of noise exposure) the number of heart beats/minute increased ($M = 84.65$) in comparison with the beginning of noise exposure ($M = 82.65$). However, the higher the increase of NITTS, the smaller the number of heart beats/minute (for the lowest NITTS, $M = 96.17$ beats/minute; for the highest noise-induced temporary threshold shift, $M = 76.43$ beats/minute). It is difficult to explain this effect, but one can suppose that the noise induced temporary threshold shift at the high level of noise is kind of defense mechanism protecting the organism from excessive vegetative stimulation.

The results of MANOVA for IPT – Memory tasks shows that among all factors only experimental session duration influences performance time in these tasks. The strongest effect of this factor was found for tasks with 2-, 3-, 4-element stimuli, unmasked and unrotated, especially in silence and at the

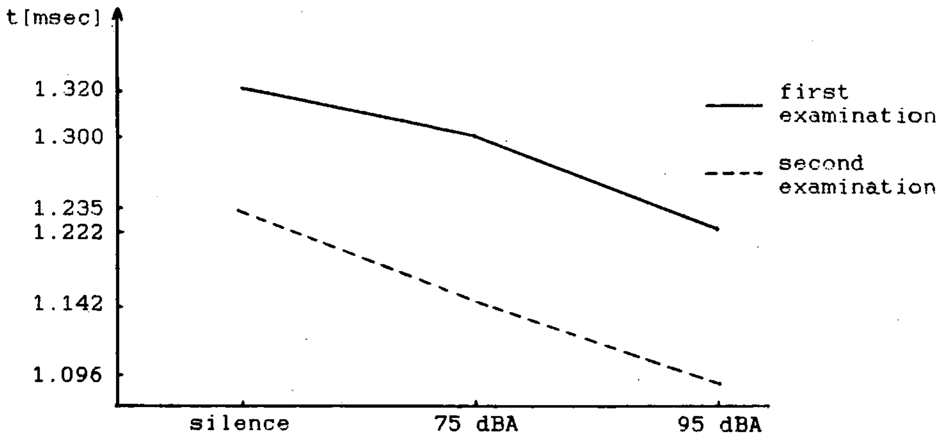

Fig. 3. Interaction effect of noise and experimental session duration on mean time performance for tasks with 3-elements stimuli in IPT — perceptual tasks.

75 dBA level of noise (Table 6). For all these tasks, the longer the time of experimental session, the longer the time of performance was found, except for the tasks with 3-element stimuli. In the case of these tasks the influence of session duration was the same as in the case of IPT — perceptual tasks (ie., time performance was shorter in the second examination). There is no influence of this factor on performance time in tasks with 5-element stimuli, masked and rotated.

TABLE 6. The influence of noise exposure duration on performance time in IPT — Memory tasks in three experimental conditions (results of MANOVA).

Experimental conditions	Kind of stimuli	Significance of influence (p)
silence	2-elements	0.009
	3-elements	0.005
	4-elements	0.001
	unmasked	0.04
75 dBA	2-elements	0.038
	3-elements	0.003
	4-elements	0.003
	unmasked	0.059
	unrotated	0.006
95 dBA	3-elements	0.056

Just as in perceptual tasks, in memory tasks of IPT, the higher the increase of noise induced temporary threshold shift the smaller the number of heart beats/minute at the highest level of noise ($F(2.15 = 4.03; p < 0.041)$.

DISCUSSION

The results show that noise (at levels 75 dBA and 95 dBA) as a separate factor does not influence information processing, and time reaction to perceptual stimuli.

Individual noise sensitivity and noise-induced temporary threshold shift neither influence these variables.

Experimental session duration was the one separate factor affecting information processing. The results in IPT – perceptual task suggest that the encoding stage of information processing is disturbed by session duration. The effect of this factor on the comparison stage of information processing is not clear. On the one hand, it shortens time performance in the tasks with 3-element stimuli in both IPT-perceptual and IPT-memory tasks. On the other hand, it lengthens time performance in the tasks with 2 and 4-element stimuli in IPT-memory tasks.

However, noise influences simple reaction time in interaction with individual noise sensitivity, and information processing – with experimental session duration. The results unexpectedly show that noise affects simple reaction time only in the low noise-sensitivity group. Probably it is connected with differences in the levels of mobilization between low and high sensitivity subjects. This hypothesis should be verified in further studies. As the results of Stroop's test show, noise decreased the difference in vegetative reactions to stimuli of different levels of difficulty.

Another factor affecting heart rate is noise induced temporary threshold shift (NITTS). As the results of IPT show, the higher the increase of NITTS, the smaller the number of heart beats/minute. We formulated the hypothesis that NITTS at high level of noise is a kind of defense mechanism protecting the organism from excessive vegetative stimulation.

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Received for publication: February 20, 1991.
Accepted for publication: September 2, 1991.