ARCHIVES OF ACOUSTICS
3, 2, 85-105 (1978)

EFFECTS OF AIRCRAFT NOISE ON THE MENTAL FUNCTIONS OF SCHOOLCHILDREN

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The levels of mental performance of children from two residential regions: in the neighbourhood of an airport, with a noise level of 95-105 dB (A) during the flight of a single aircraft, and a relatively quiet suburban Warsaw areas were appraised.

A comparative analysis of the results of the investigations has revealed a considerable difference in the psychomotoric performances and attention level.

For the inhabitants from the intensive noise area the lengthening of the time of a simple reaction, reduced visual and motoric coordination, disorder of psychomotoric control, and reduced ability of the concentrated and divided attention were observed.

Experiments on the effects of intense noise have also revealed the detrimental influence of this noise upon all the aforementioned psychological processes for all people regardless of their acoustic environment. However, stronger effect of the experimental noise was found for children from the quiet areas and for children with an increased neuroticity.

1. Introduction

Former investigations of the influence of noise upon man have been devoted to the biological and psychological consequences of noise affecting the human organism engaged in professional work. The results of investigations conducted in laboratories and in manufacturing plants have been reviewed, inter alia, by BINASCHI and PELFINI [6], BROADBENT [7], and JANSEN [17]. In recent years new, more systematic investigations on the influence of industrial noise on workers have been carried out [9-13, 22, 23, 28, 31]. Despite some doubt and controversy in the interpretation of the obtained results, these investigations point to disadvantageous and complex relationships between the performance level of various psychological human functions or the performance and quality of certain types of professional work, and the types and duration of acoustic stimuli. However, it is hard to foresee to what extent the effects found under conditions of intense industrial noise can be related to the influence of noise at the place of residence.

The few papers published so far on this subject reveal a particularly disadvantageous effect of noise at the dwelling-place. This mainly applies to aircraft noise which, owing to its nature and intensity, constitutes a serious health hazard for the people living in the neighbourhood of an airport. The results of these investigations indicate that psychical diseases occur more frequently in the proximity of airports [1]; the weight of newborn children is reduced under the effect of aircraft noise [3]; the reactions of children to noise become modified as a result of their mothers' stay in a noise-affected area during pregnancy [2]; and a reduced mean level of speed of mental work of schoolchildren occurs [4, 19].

The present paper analyses similar problems. The investigations attempted to evaluate some of the psychological processes of pupils born and living in an airport neighbourhood. Attention has been focussed on learning the differences in the way the children exposed to different noise intensities at their dwelling-places react to a standard noise level. Attempts have also been made to establish the relation between the disorder caused by noise and some personal features. Initially the following hypotheses were formulated:

(a) aircraft noise unfavourably affects the psychological processes of children living in an airport neighbourhood;

(b) the performance of mental functions deteriorates during noisy periods;

(c) certain differences in the reaction to the noise intensity can be observed in the children from the acoustically different regions;

(d) a relation exists between the degree of disorder in mental performance and certain personal features.

2. Subjects and methodology

The characterization of the examined persons. The investigations involved 138 children from the 6th and 7th forms of a primary school who were born and living in an area affected by aircraft noise from the Warszawa-Okęcie airport, and 147 children who have lived since their birth within a zone of relative tranquility, in the Zielonka area near Warsaw.

When choosing the groups to be examined, the following variables were taken into consideration: age, sex, socio-economic status, and the professional education group of the main supporter of the family. The analysis showed that both populations were comparable as regards the above-mentioned variables. The average age of the children was about 13 years (12.5 in the 6th form; 13.5 in the 7th form). A factor essentially differentiating between the groups was the acoustic conditions prevailing at their dwelling-places, notably in respect of aircraft noise.

The children from the Warszawa-Okęcie area live in a zone affected by aircraft noise at a level of 95-105 dB (A), as produced by a single flying aircraft. The actual intensity of the noise obviously depends on the volume of the air traffic, which increases with every passing year (in 1975 more than 44 000 flights were recorded). In the area around Zielonka aircraft noise essentially does not occur. There is no railway noise in either region. Apart from the aircraft noise, measurements of noise along traffic routes point to more favourable acoustic conditions in the Zielonka area. The volume of the automobile traffic in this region is insignificant, while equivalent noise levels on the two thoroughfares of the traffic system do not exceed 58 dB (A). In the other streets, which have the character of approach roads to homes, the measured noise level varied between 45 and 50 dB (A).

In the Okęcie residential district the intensity of traffic noise is especially noticeable along the Krakowska Avenue, attaining a value for the equivalent level of 74 dB (A). This noise affected 16 % of the examined persons. In the remainder of the Okęcie area, the traffic noise levels vary from 47 to 55 dB (A). In both regions the buildings are similar, being mainly low, detached houses.

In addition to the above differences in the acoustic conditions at the dwelling-places, it might also be expected that contacts with the noisy centre of Warsaw are more frequent for the children from the Okęcie residential district than for the children from Zielonka. Consequently, the acoustic conditions in Okęcie are less favourable than those in Zielonka. The Okęcie area will, therefore, in the following pages of this paper be referred to as the noisy region, the area around Zielonka as the quiet one.

Description of the methods used. For appraisal of the psychological processes and the verification of the hypotheses we used devices for psychologic examinations and "paper" tests for the determination of psychomotoric performance, attention, perception and neurotic tendencies of children.

The choice of the above-mentioned variables was dictated by both practical and other commanding reasons. Previous investigations on the effect of noise have determined the suitability of many relevant tests and the conditions for their application and their limitations.

The tests have been selected in such a way as to obtain the most comprehensive picture of motoric performance and to estimate various forms of attention. These processes are related to the disposition to mental work [33] and may be of importance in assessing the state of the nervous system [18, 30]. The description of the tests according to the sequence of their application in the investigations is given below.

1. "Attention test by Poppelreuter". The test consists in ordering, during a strictly defined time, the numbers placed at random in various fields of the test tables. The measure of the test is the number of ordered numbers. The test is used for the investigation of the divisibility of attention.

2. "Two-crossing test" in the Zazzo system [32] serves for the comparison of the performance at two levels of difficulty of the task which com-

prises the crossing of one sign followed by the crossing of two signs. The test provides an estimation of the degree of adaptation of the examined child to easy but monotonous work which requires a strong will and concentrated attention. Thanks to precisely defined indicators it is possible to measure precisely the potential of a child as regards the rate and accuracy of the performed work, and to estimate its ability in terms of psychomotority control.

3. The "Piórkowski device" permits assessment of visual and motoric coordination, the division of attention, and perceptivity; it also examines the reaction speed at a prescribed rate. In the investigations three rates of light stimuli, of 93, 107 and 125 pulses per minute, were used. The time of the examination at each rate was 1.5 min. The results were recorded automatically.

4. "Reaction time meter". This is a set of devices comprising an electronic digital time meter, programming equipment to control the exposure to stimuli, and a generator of optical and acoustic stimuli. The time is measured to an accuracy of 0.001s. The reaction time is determined by measuring the time period between the moment of visual stimulus and the moment of pressing by the school-child an appropriate key. The stimuli were generated at random intervals. A series of 28 stimuli was used for each examination. The measurement of the reaction time is used for investigation of the motivation, attention and, especially, the reactivity.

5. "Couvé's test". The test consists in crossing, during a prescribed time, 40 precisely determined numbers out of the 100 three-digit numbers in the table. The Couvé test is used for examining the concentration of attention.

6. "Evident anxiety test". This test serves [25] to examine the neurotic tendencies of children at school age (9-16). The Polish adaptation comprises two scales: the 40-question scale of neurosis and the 9-question scale of falsehood. The neurosis scale measures the mental state of a child as expressed by uneasiness, anxiety, fear or concern, and by psychosomatic symptoms. The falsehood scale is a control scale permitting estimation of the frankness of those answers of the child which might present him in an unfavourable light.

The conditions and methods of performing the investigations tests. The investigations were carried out from November to March in the school year 1975/1976. They took place at a time intended for school teaching in a specially prepared school room. A 4-person group took part in the investigations. Prior to each test, the pupils had been encouraged to put maximum mental effort into solving individual tasks.

According to the assumptions and the purpose of this paper the children from both regions were examined twice.

The first examination was intended to estimate the performance level of some of the mental functions of the children from the different acoustic regions. This investigation was carried out under normal acoustic conditions in the school.

During the second examination an experiment was carried out to discern the reaction of the children to the noise emitted by a loudspeaker system. In the experiment two groups were formed by the method of random choice (including pupils from both acoustic regions). One group was examined during exposure to the noise while the other was examined in the quiet and constituted a control group. In order to check the correct choice of groups for a planned experiment, the results of the first investigation were used.

The interval between the first and the second examination was about two months for each child.

Each series of investigations was carried out using the same set of tests and under similar external conditions. The equivalent level during the performance of the tests in the quiet varied from 38 to 43 dB (A). The upper levels were mostly recorded at Zielonka. The less favourable acoustic conditions found in the test room at Zielonka rather support the hypothesis of this paper, since a possible reduction of the mental performance of the children from the airport neighbourhood can be related with a higher likelihood to the effect of aircraft noise.

In analyzing the noise stress during the second examination, the noise emitted from a loudspeaker system was an imitation of a starting aircraft recorded on magnetic tape with a noise level equivalent to 85 dB (A). The spectrum of this noise is shown in Fig. 1. The distribution of the sound pressure level indicates that the maximum amount of energy generated by the loudspeaker system is at low and medium frequencies.

The moment of transmitting the noise was random, the time of a single exposure was 30 s. During each investigation the noise was emitted about

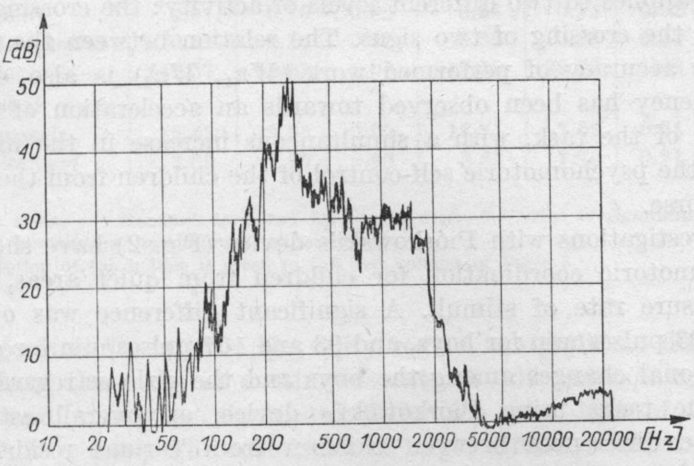

Fig. 1. The spectrum of the noise generated by the loudspeaker system

150 times. Prior to each investigation the noise level was controlled by means of a noise level meter (Brüel-Kjaer). The investigations lasted from 9 to 12 o'clock a. m., thus being the period of time which is most favourable for mental work.

3. The appraisal of the mental performance of children from the different acoustic regions

The investigations carried out have revealed considerable differences in the psychological processes of children living under favourable and unfavourable acoustic conditions. The results of the investigations are shown in Table 1 and Fig. 2.

The analysis of the results shows a lower level of performance of mental functions for the children living in the area affected by aircraft noise. This applies also to motoric performance and attention. A considerable slowing in psychometric reaction, the deterioration of visual and motoric coordination, reduced psychomotoric self-control and the disorder of attention processes were observed.

The most remarkable differences could be observed in the examination of the reaction time. Mean values of the reaction time of pupils from noisy regions are longer for boys by 0.013 s., and for girls by 0.024 s. Also the standard deviations of the reaction times are considerably larger for the children living in an airport neighbourhood. Probably the noise induces not only a reduction in the rate of psychomotoric reaction, but also a variation in its process.

Similar conclusions can be drawn from the analysis of the results of the "two-crossing tests". Both the speed and performance of work, and the accuracy of its execution are much worse in the case of the children from the noisy region. This applies to two different levels of activity: the crossing of one sign and then to the crossing of two signs. The relation between the velocity (V_1, V_2) and the accuracy of performed work (Wn_1, Wn_2) is also disadvantageous. A tendency has been observed towards an acceleration of the speed of performance of the task, with a simultaneous increase in the inaccuracy indices. Thus the psychomotoric self-control of the children from the noisy region was also worse.

The investigations with Piórkowski's device (Fig. 2) have shown a higher visual and motoric coordination for children from quiet areas, independent of the exposure rate of stimuli. A significant difference was obtained only at a rate of 93 pulses/min for boys, and 93 and 107 pulses/min for girls. In view of unidirectional changes among the boys and the girls as regards the performance of the tasks using Piórkowski's device, an overall estimation was made of the differences between children from various residential regions [14]. Apart from the above-mentioned data the analysis has revealed, to the

Table 1. Comparison of the results of the psychological testing of children under various acoustic conditions

Name of test	Noisy region			Quiet region			t	P
	M	σ	E_x	M	σ	E_x		
1	2	3	4	5	6	7	8	9
Boys								
Poppelreuter's test	14,50	3.30	0.41	16.33	3.93	0.43	2.94	0.01
Two-crossing test ([a]):								
speed, V_1	188.26	29.70	3.77	208.30	41.82	4.64	3.20	0.01
performance, W_1	225.68	37.90	4.81	250.36	50.63	5.62	3.21	0.01
inaccuracy, Wn_1	4.59	3.73	0.47	3.95	2.77	0.30	1.18	*n.s.*
speed, V_2	90.48	15.32	1.94	95.73	16.42	1.88	1.96	0.05
performance, W_2	209.22	39.21	4.98	224.89	41.50	4.61	2.29	0.05
inaccuracy, Wn_2	9.52	6.28	0.79	7.33	4.57	0.51	2.39	0.05
speed quotient	0.97	0.16	0.02	0.94	0.15	0.02	1.41	*n.s.*
performance quotient	0.94	0.17	0.02	0.91	0.15	0.02	1.03	*n.s.*
Reaction time	226.84	48.39	1.08	214.17	40.86	1.05	8.41	0.0001
"How are you?"								
scale of neurosis	15.49	6.69	0.85	15.20	6.39	0.82	0.25	*n.s.*
scale of falsehood	3.72	1.69	0.21	3.32	1.58	0.20	2.38	*n.s.*
Girls								
Poppelreuter's test	17.03	4.04	0.46	17.75	3.65	0.44	1.43	*n.s.*
Two-crossing test:								
speed, V_1	205.40	36.25	4.15	222.90	38.53	4.74	2.78	0.01
performance, W_1	221.49	40.46	4.64	268.85	47.66	5.86	6.40	0.01
inaccuracy, Wn_1	5.74	4.48	0.50	3.84	2.89	0.35	2.96	0.01
speed, V_2	98.45	16.23	1.86	103.16	15.42	1.89	1.76	*n.s.*
performance, W_2	224.55	39,54	4.53	241.28	38.95	4.79	2.53	0.05
inaccuracy, Wn_2	11.23	9.30	1.06	7.48	4.99	0.61	2.92	0.01
speed quotient	0.97	0.16	0.02	0.94	0.14	0.02	0.93	*n.s.*
performance quotient	0.93	0.14	0.02	0.90	0.13	0.02	1.08	*n.s.*
Reaction time	241.57	49.61	1.04	217.59	39.78	1.02	16.46	0.0001
"How are you?"								
scale of neurosis	16.43	7.88	0.90	17.71	7.62	0.94	0.94	*n.s.*
scale of falsehood	3.99	1.97	0.23	3.65	1.70	0.21	1.09	*n.s.*

M – arithmetic mean, σ – standard deviation, E_x – mean error, t – value of significance factor, P – probability, *n.s.* – statistically insignificant difference

(a) description of the indices is given in the first column of Table 3.

disadvantage of children from the noisy region, a significant difference in the performance of the tasks at a stimulus rate of 107 pulses/min ($\chi^2 = 10.599$; $P = 0.05$), and almost as significant difference at a rate of 125 pulses/min ($\chi^2 = 9.228$; $P = 0.06$). The occurrence of larger differences in the performance of the tasks at lower rates is to some extent a surprise since it might be expected that, with objectively more difficult and more complicated operations, the differences in the task performance by children from the different acoustic regions would be higher. Perhaps, the difficulty of the intelligence task has encouraged the subjects from both regions and, because of the strengthened motivation, the differences in achieving the visual-motoric coordination have become insignificant.

Fig. 2. The psychomotoric performance of children living in different acoustic conditions (Piórkowski's device)

Clear columns – from the noisy region; dashed columns – from the quiet region.

The results obtained by Poppelreuter's test (Table 1) have confirmed the above trends of differences in psychological processes resulting from acoustic conditions at the dwelling place. Although a marked difference was observed only for the boys, nevertheless the tendency observed for the girls is in agreement with the assumed hypothesis.

The investigations of evident uneasiness as a symptom of neurotic tendencies have shown no difference between the children residing in the different acoustic environments. The level of neurosis among the tested groups was similar, and the distribution of results agreed with the distribution observed for the population of children [25].

4. The reaction of children to acoustic stress

One of the aims of the described investigations was to learn about the disturbances of the mental processes during experimental exposure to noise and to determine the differences in the reactions of children from different acoustic environments. It seemed likely that the children exposed to aircraft noise at their place of residence for many years would react to the acoustic stress differently from the children living in a quiet region. An additional task was to explain the role played by neurosis in the development of disorders of psychological functions under the influence of noise.

Results of investigations of psychological processes in the quiet and in noise. The results of investigations of the effect of noise in the experimental conditions upon the mental processes of children are shown in Table 2. Besides statistical inference arising from differences between the mean values – a more comprehensive comparison was performed using such factors as the differences in reactions in the experimental groups compared to those in the control group, in both investigations [15]. This factor is assumed as a basis for drawing conclusions.

The analysis of the results of tests performed in the initial stage of the investigations indicated a lack of significant differences between the experimental and control groups in all the tests, thus confirming the correct choice of the examined groups.

The investigations of the pupils reactions to the high level of noise (85 dB (A)) revealed a number of significant differences, concerning both psychomotoric performance and attention. The highest disorders in performance occurred during the examination of simple motor-reflex operations and during the examination of higher degrees of difficulty of visual-motoric coordination.

The extension of the reaction times in the presence of noise was averaged to 0.19 s and 0.024 s for boys and girls, respectively. This means that the slowing of the reaction times with respect to those obtained when children were tested in the quiet amounts to 9.2 % and 11.4 % for boys and girls, respectively. The deterioration of the results appears not only with respect to the control group, but also to the rest results obtained prior to testing the effect of exposure to acoustic stress. In the control group a considerable shortening of the reaction time and smaller scatter of the results were observed. Thus acoustic stress not only affects the reaction time, but also increases variations in the speed of execution.

The comparison of the curves depicting the differences between the reaction time in the quiet and in noise during consecutive exposures to stimuli throws additional light on the trends of the analyzed relations (Fig. 3). Taking the sequence of stimuli into consideration permits the differences in the reaction rate as a function of time to be estimated approximately. Although the time intervals between individual stimuli (according to the assumptions of the investigations described in the section about the methods) are not equal, it is obvious that the earlier and the later stimuli are related to the earlier and the later period of the test, respectively. The time required for the exposure to the whole series of 28 stimuli is about 6 min.

The analysis of the presented graphs points to a difference in the reaction rates in the quiet and in noise. For the boys, the reaction times in the quiet undergo an initial extension, but as time passes, the results improve systematically and uniformly. For the girls the curve is somewhat different.

In the initial stage the results oscillate around the average results from the whole series, but beginning with the 20th stimulus an extension of the

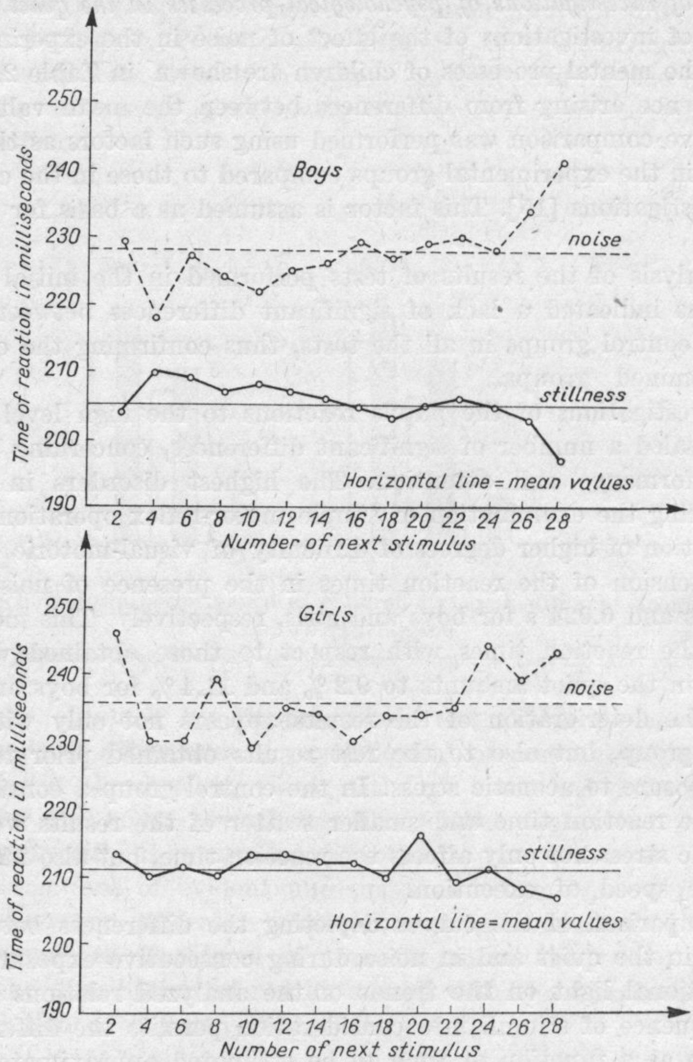

Fig. 3. Changes in the reaction time in the quiet and in noise

reaction rate can be observed, probably due to the fall of interest in performing the task. Nevertheless, in the final stages the reaction times are much shorter – as in the case of the boys. Conversely, under the influence of noise all tested persons showed an initial increase in the rate of motoric reaction, the reaction times extending slowly thereafter until, at the end of the experiment, a considerable deterioration of the reaction rate has taken place. The oscillations of the reaction time are also larger. Initial mental concentration in noisy conditions is reduced after some time, bringing about a considerable deterioration in performance.

The investigations performed by means of Piórkowski's device (Table 2) indicate a considerable improvement in the results of the successive tests both in the experimental group, tested in the noise, and in the control group, tested in the quiet. However, the improvement of the results of the control group in comparison with the experimental group, is considerably higher for both sexes. The largest changes were observed at rates of 107 and 125 pulses/min. The above differences are statistically significant. At a rate of 95 pulses/min a significant change has occurred only for the boys and, although a distinct tendency in favour of the persons tested in the quiet was observed for the girls, it did not attain significant level.

The noise stress also disadvantageously influenced the processes of attention, the degree of disorder being dependent on the kind of the attention engaged. The less severe disorders occurred when the concentration and the resistance to distracting stimuli were examined; while the most severe occurred for the tasks requiring divided attention. Thus a comparison of the results of the investigations by means of Couvé's test indicates only insignificant differences between the children tested in the quiet and in the noise (for boys $t = 1.30$; for girls $t = 1.01$), whereas the results obtained by means of Poppelreuter's test, and also the results of the "two-crossings test" show very significant differences between the investigations in the different acoustic conditions. BINASCHI and PELFINI [5] came to a similar conclusion. They stated that the noise affects more strongly the performance of the tasks which require the divided attention than the tasks requiring greater concentration.

The investigations also indicated that with a lengthening of the acoustic stress the disorders of the attention processes intensify. This can be clearly seen from the graph shown in Fig. 4. Improved skill in solving Poppelreuter's test after 6 min. could only be observed when testing the children in the quiet. On the other hand in the conditions with noise, the deterioration of the execution of this test, in comparison with the results obtained during earlier examinations (after 3 min. of work) could be observed. This regularity occurred both for the boys and for the girls.

In addition to the previous data the analysis of the "two-crossings test" also confirms the disadvantageous effect of noise upon the tasks performed. The comparison of the speed and accuracy of work at two levels of activity indicates reduced speed and performance in both tests, and an increase of errors in the second test. At the same time an excessive accuracy in the test of crossing one sign at execution rates that are too slow, and the sacrifice of accuracy in favour of speed in the test of crossing two signs are observed. For the girls, excessive accuracy in performing the work with a simultaneously decreased speed was present in both types of activities. Also the difference in the quotients of speed and performance, chiefly for the girls, points to the disturbances between the two levels of activity. The above lack of concentration in performing both tests, and the change in the behaviour for each of them,

Table 2. Psychological processes of the children examined in quiet and in noise; during the test II the experimental group was exposed to noise

Name of test or trial	Groups	Test I M	Test I σ	Test II M	Test II σ	t_z	P
1	2	3	4	5	6	7	8
		Boys					
	experim.	16.04	4.43	15,93	4,57		
Poppelreuter's test	t	1.15		3,78***		5.63	0.001
Table I	control	15.14	4.84	18.78	4.40		
	experim.	16.00	4.01	15.61	4.27		
Table II	t	1.05		4.53***		7.78	0.001
	control	15.27	3.54	18.72	3.87		
Two -crossing test:	experim.	200.19	36.02	235.36	36.52		
speed, V_1	t	0.20		1.93		3.43	0.001
	control	198.90	40.84	249.91	46.17		
	experim.	241.26	44.88	285.02	45.09		
performance, W_1	t	0.42		1.88		3.36	0.001
	control	237.94	49.51	301.86	50.61		
	experim.	4.04	2.86	3.07	2.31		
inaccuracy, Wn_1	t	0.42		0.01		0.89	*n.s.*
	control	4.28	3.52	3.07	2.82		
	experim.	93.48	15.42	117.00	18.71		
speed, V_2	t	0.02		2.70**		4.22	0.001
	control	93.42	16.84	126.78	24.17		
	experim.	219.17	40.28	277.90	47.89		
performance, W_2	t	0.31		3.26**		5.57	0.001
	control	217.01	42.18	307.89	51.09		
	experim.	7.85	5.36	7.14	4.57		
inaccuracy, Wn_2	t	0.93		3.26**		5.62	0.001
	control	8.70	5.55	4.98	4.52		
	experim.	0.94	0.16	1.01	0.16		
speed quotient, *I.V.*	t	0.11		0.90		1.06	*n.s.*
	control	0.95	0.14	1.02	0.16		
	experim.	0.92	0.17	0.98	0.17		
performance quotient,	t	0.11		1.62		1.85	*n.s.*
I.W.	control	0.93	0.15	1.03	0.16		
	experim.	220.44	47.49	226.51	48.13		
Reaction time	t	0.39		19.22***		20.11	0.0001
	control	220.86	45.57	207.44	36.42		
Piórkowski's device:	experim.	91.98	24.58	119.01	20.69		
P_1 – 93 p/min	t	0.74		1.67		2.37	005
	control	88.60	29.56	124.23	16.08		
	experim.	91.22	28.31	113.38	25.38		
P_2 – 107 p/min	t	0.74		3.18**		5.14	0.001
	control	86.55	33.73	126.91	25.25		
	experim.	52.35	28.60	73.97	37.00		
P_3 – 125 p/min	t	0.19		3.47***		5.18	0.001
	control	53.34	31.13	95.98	38.41		

c.d. Table 2

1	2	3	4	5	6	7	8
			Girls				
Poppelreuter's test:	experim.	17.56	5.34	18.81	5.81		
Table I	t	0.64		3.14**		3.57	0.001
	control	18.10	4.35	21.48	4.12		
	experim.	16.84	4.06	17.33	5.42		
Table II	t	0.07		3.62***		5.22	0.001
	control	16.90	3.86	20.35	4.38		
Two-crossing test:	experim.	212.08	40.29	254.68	49.76		
speed, V_1	t	0.45		1.16		1.32	*n.s.*
	control	215.04	36.19	263.38	38.30		
	experim.	252.79	50.26	306.86	57.68		
performance, W_1	t	0.16		1.41		1.74	*n.s.*
	control	254.74	46.40	319.28	45.62		
	experim.	5.06	4.53	4.47	3.96		
inaccuracy, Wn_1	t	0.67		2.61**		0.46	*n.s.*
	control	4.61	3.33	2.97	2.73		
	experim.	101.80	14.55	129.33	20.30		
speed, V_2	t	0.87		1.54		2.73	0.01
	control	99.44	17.35	134.54	19.64		
	experim.	233.40	37.57	308.16	52.30		
performance, W_2	t	0.32		1.46		3.46	0.001
	control	231.22	42.61	321.31	54.16		
	experim.	9.77	7.67	6.78	5.60		
inaccuracy, Wn_2	t	0.91		1.28		0.15	*n.s.*
	control	8.82	5.76	5.54	5.89		
	experim.	0.98	0.17	1.01	0.13		
speed quotient, *I.V.*	t	1.76		0.53		2.03	0.05
	control	0.94	0.14	1.03	0.13		
	experim.	0.94	0.15	1.01	0.13		
performance quotient,	t	1.55		0.57		2.21	0.05
I.W.	control	0.90	0.13	1.02	0.14		
	experim.	229.40	46.89	234,34	45.57		
Reaction time	t	0.33		26.01***		26.89	0.001
	control	229.76	46.63	210.54	32.61		
Piórkowski's device:	experim.	92.27	27.94	120.16	17.72		
P_1 – 93 p/min	t	0.09		1.25		1.24	*n.s.*
	control	92.71	26.64	123.68	15.44		
	experim.	86.87	30.58	112.09	28.26		
P_2 – 107 p/min	t	0.19		3.01**		4.33	0.001
	control	85.82	31.80	125.57	24.88		
	experim.	50.12	29.74	70.19	35.27		
P_3 – 125 p/min	t	1.08		3.39***		6.82	0.001
	control	44.88	27.77	91.91	40.54		

t – value of the significance factor between the means,
t_z – value of the parameter of significance between changes,
n.s. – a statistically insignificant difference,
* – differences significant at a level of 0.05,
** – differences significant at a level of 0.01,
*** – differences significant at a level of 0.001

reveal considerable disturbance of the control of the psychomotoric functions under the influence of noise.

Adaptation to noise. In addition to the above discussed effects of noise attempts were made to acquire an understanding of the differences in the reactions of the children from various acoustic conditions to the standard noise stress. The problem was to find a means of detecting the phenomenon of the possible adaptation of the children to the acoustic conditions prevailing at their place of residence.

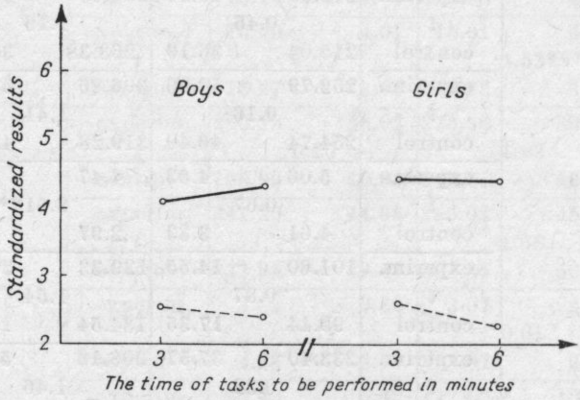

Fig. 4. Improving performance in the solution of Poppelreuter's test under various acoustic conditions: ——— in the quiet, ----- in the noise

A comparative analysis of the results of the investigations is shown in Fig. 5. It presents the level of disturbance of mental functioning under the influence of the experimental noise stress. The dashed columns give the levels of decreased performance of the execution of tasks in particular tests in the group of children living in more favourable acoustic conditions; the blank columns present similar decreased performance in the group of children from the area affected by aircraft noise. It can be clearly seen from the figure that the degree of disturbance of the mental processes, caused by the noise is considerably higher for the group from more favourable acoustic conditions. This applies both to psychomotoric performance and to the processes of attention. However, the largest difference occurred in the speed and accuracy of the execution of various psychomotoric operations. In the processes of attention, differences were only noted in the examining of its divisibility, while a similar level of disturbance occurred in the range of concentration of attention for the children from both regions. Only the index of speed at 93 pulses/min using Piórkowski's device for the boys, and the inaccuracy in crossing one sign in the "two-crossing test" of all the persons examined, point to a somewhat higher disturbance due to the noise effect in the group of children from unfavourable acoustic conditions. These are probably accidental differences.

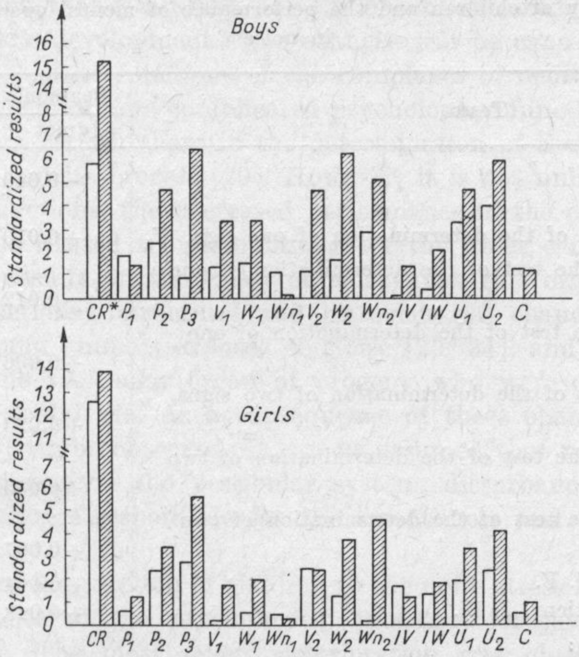

Fig. 5. The level of disturbance of mental processes of the children from different acoustic regions under the effect of an experimental noise stress; clear columns – from the noisy region; dashed columns – from the quiet region; the indices are presented at Tables 1, 2, 3.

Generally, it can be said that noise at the place of residence has reduced the sensitivity of the pupils to the acoustic stress, particularly in terms of psychomotoric operations and the divisibility of attention.

Neuroticity and the performance of mental operations in noise. In the investigations concerning the effect of noise it has been found that some children were more susceptible to its negative influence [5, 8, 16]. The reasons for this are not sufficiently known. In this paper attempts have been made to establish the interrelation between the performance of mental operations in the quiet and in noise, and the neuroticity of the examined children. The results of these investigations are given in Table 3. The obtained results show no relation between the psychological processes in the quiet and the neuroticity. It should be suggested that neuroticity in the normal conditions for the pupil's mental work, without any physical or mental stresses, does not significantly influence the performance of the executed operations. The situation is different during noise stress. The absence of a relationship between the neuroticity and the determined psychological processes occurred only in relation to psychomotoric performance, but the process of attention was disturbed.

The children exhibiting higher levels of neurosis showed a greater decrease in the results of both tests of attention.

Table 3. Neuroticity of children and the performance of mental operations in quiet and in noise

Tests	Pearson's correlation factor[1]	
	quiet	noise
Poppelreuter, U	−0.040	−0.181
Two-crossing test:		
speed in the test of the determination of one sign, V_1	+0.010	−0.022
performance in the test of the determination of one sign, W_1	+0.012	−0.041
inaccuracy in the test of the determination of one sign, Wn_1	+0.006	−0.012
speed in the test of the determination of two signs, V_2	+0.023	−0.064
performance in the test of the determination of two signs, W_2	+0.035	+0.012
inaccuracy in the test of the determination of two signs, Wn_2	+0.007	−0.006
speed quotient, *I. V.*	+0.064	−0.008
performance quotient, *I. W.*	+0.043	−0.011
Piórkowski's device:		
93 p/min, P_1	+0.021	−0.121
107 p/min, P_2	−0.062	−0.143
125 p/min, P_3	−0.040	−0.071
Reaction time, *CR*	+0.133	−0.021
Couvé's test, *C*	+0.031	−0.222

[1] – value of correlation factor ⩾ 0.171 significant at a level of 0.05 and ⩾ 0.228 significant at a level of 0.01.

5. Discussion

The above results indicate a decreased performance of some psychological functions for the children living in the area affected by aircraft noise. The largest differences involve the simplest destination (target) motions. Nevertheless there was some decrease in the performance of other types of mental operations and disorder of the attention processes was also noted.

Similar results were obtained by ANDO et al. [4], who investigated the effect of the aircraft noise on the concentration of attention for the children aged from 7 to 10 years. These authors have found that short periods of a decreased average level of the speed of work occur more frequently for the children from noisy regions than for their counterparts from quiet regions. This decrease can be observed in the investigations performed in the quiet, but was not noticed for the work in noise.

The relation between aircraft noise at the place of residence and the mental processes is poorly recognized. However on the basis of the previous data it can be concluded that if aircraft noise is one of the elements in the environment of a child's development some changes will be caused in the formation of the multi – stage functions of the complexes of neuron groups taking part in both simple and more complicated psychological functions. Consequently, the noise has a certain share in the determination of the structure of the function, its rate and its process [29]. However, it is not unlikely that in the case of motoric functions, the decreased performance of the children from the noisy area may be related to micro-damage of the inner ear. Many authors, in discussing the results on the effect of noise upon this organ, describe the occurrence of functional, structural and histochemical changes in the vestibules of humans and animals exposed to noise [20, 24], and also disorder of the function of the vestibular organ of progeny who were exposed to noise [26] during their foetal life. As a consequence of these changes, disturbance of equilibrium [21] can be observed. It can be assumed that noise at the place of residence produces, via the vestibular system, disturbance in the coordination of the analyzers responsible for the smoothness and precision of movements.

The analysis of the reaction of children to the noise stress has shown a considerable disturbance of the psychological processes for persons from both residential regions. The most severe deterioration was observed when examining reaction times, in accordance with the previously observed disturbance of the reflex functions [6, 11, 12, 31]. Disturbances of other psychomotoric functions and of the attention process also occurred. The disturbances occur primarily in difficult or complex functions that require precise action or great concentration. At simpler functions no marked effect of the noise was observed. At the same time an aggravation of the disturbance of the psychological functions with prolonged noise was found to occur. Mostly, these disturbances did not occur at once; but the negative effect of the noise stress becomes evident only after some time. It is likely that the same interpretation would be valid for the greatest deterioration of the results observed when investigating the reaction times in the initial phase.

The investigations also exhibited to some extent the phenomenon of adaptation to noise as a result of the effect of a noisy environment. ANDO et al. [4], in similar investigations, did not reach the same conclusion. This divergence of the results is caused probably by the investigation of different psychological functions. From the results of the investigations described in this paper it can be concluded that noise at the place of residence reduces the resistance of the organism to the disturbing action of acoustic stress mainly in terms of psychomotoric functions. On the other hand, Ando also investigated the concentration of attention which in our investigations also did not differ for the children from the two residential regions. The noise disturbed the attention of the children from the quiet and noisy regions in similar ways.

Probably the possibility of adaptating to noise is smaller for the more complicated psychological functions.

The analysis of the relation between neuroticity and the performance of mental operations in noise has shown a deteriorated performance for children liable to excessive sensitivity, timidity and psychological breakdown. An additional noise stress causes disorder mainly in neurotic persons performing complicated and difficult operations, while disturbance of the performance of tasks carried out automatically or requiring relatively simple motoric coordination were not observed. Probably the excessive anxiety characterizing the persons with a high level of neuroticity does not cause the disturbances of the psychological processes, under normal conditions but the increased excitation caused by noise stress produces an accumulation of the tension and the deterioration of performance. This phenomenon of the increased susceptibility of neurotic persons to the disturbing action of noise is probably one of the decisive factors in the so-called subjective sensitivity to noise.

6. Conclusions

From the results of the investigations and the discussion the following conclusions can be drawn:

1. Aircraft noise exerts a negative influence on the psychological processes of children living in the neighbourhood of an airport.

2. During an acoustic stress of short duration, a reduced mental performance was observed for all examined children.

3. The direction and range of disturbances are dependent on the type of functions examined, the difficulties of the tasks, and personal traits. The largest changes appear in the execution of the simplest destination motions. A decreased psychomotoric performance of other types of functions, and disorder of the attention processes were also observed. Particular susceptibility to the disturbing influence of noise was observed when examining functions that require a divided attention and, to a lesser extent, when examining the functions related to attention concentration.

4. The children from the noisy region exhibit adaptation to the noise. This adaptation applies mainly to the psychomotoric functions. When examining more complicated psychological processes, the effects of the adaptation to noise are less evident and in some cases are virtually non-existant.

5. The susceptibility to the disturbing influence of noise is related to the level of neuroticity. A high level causes a decrease in the performance of higher forms of the mental functions under conditions of noise. No relationship was found to exist between the level of neuroticity and the psychomotoric performance.

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Received on 6th January 1977