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NOISE AS AN OCCUPATIONAL HAZARD: EFFECTS ON PERFORMANCE LEVEL AND HEALTH

A Survey of Findings in the European Literature

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by

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16. Abstract (Limit: 200 words)

The effects of noise on performance and health in the workplace are reviewed. The review is based on a survey of the non English literature of the preceding 10 years, with an emphasis on publications that are available in the Communist countries. The influence of noise on performance as a function of the factors, noise characteristics, age, and exposure is discussed. Age and duration of exposure are the most important factors that cause performance impairment. Noise exposures of less than 100 decibels (dB) exert inconclusive effects on work performance; however, adverse effects have been noted at noise levels of 80 to 85dB. The effects of noise on health are considered. Noise induces increased fatigue, manifest both behaviorally and physiologically. A decreased capacity for focusing attention and a slowing of motor reactions have occurred after several hours of noise exposure. Autonomic disturbances, including cardiovascular disturbances, and the occurrence of an asthenovegetative syndrome have been noted in subjects exposed to excessive noise. Digestive, endocrine, and biochemical dysfunction have also been observed. The author concludes that noise is a noxious factor for the health and working capacity of individuals in as much as it disturbs, irritates, annoys, and induces organic and functional disorders.

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FOREWORD

Foreign investigators, notably those in Europe, have shown considerable interest in studying possible adverse effects of noise apart from hearing damage and interference with aural communication. This review of European research is addressed to such "extra-auditory" effects emphasizing those having implications for workplace health and safety. Reference materials cited here are from many non-English technical journals including a number published in East European countries whose accessibility to U. S. researchers might be quite limited. Thus, some studies summarized in this review may be appearing for the first time in an English document though originally published some years before.

Dr. Edith Gulian, a research psychologist at the Institute for Psychology, University of Bucharest, undertook this review project under the auspices of the National Institute for Occupational Safety and Health. Dr. Gulian's fluency in several European languages, her on-going scientific work in psychological and physiological acoustics, and her intimate knowledge of the European research literature in these subject areas uniquely qualified her for this review task. Dr. Gulian's designation as the 1974 foreign scientist representative to the U. S. National Academy of Science Committee on Hearing, Bioacoustics and Biomechanics (CHABA) also proved timely in enabling her to visit the U. S. for discussions on this project as well as other matters. In addition, Dr. John Webster, U. S. Naval Electronics Laboratory Center, San Diego, California, was a vital source of encouragement during this survey and provided important editorial assistance in its completion.

While this review is largely non-evaluative in nature, the author offers some summary comments about select findings and observations. The reader is invited to do the same. A clear need exists for definitive, validating studies in this problem area.

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I. Introduction

The study of noise effects on man has been mainly directed to the analysis of hearing impairment and interference with speech intelligibility. While these two aspects of noise action are undoubtedly of the greatest import, they only partly cover the wide range of noise effects.

Until recently, only isolated studies have been devoted to other consequences of noise exposure, particularly in industrial settings, a fact all the more surprising as persons with occupational hearing loss often report various health disturbances.

Nowadays, occupational hearing loss rates among the most frequent hazards in industry, as shown by statistics available in all countries. Preventive measures and sanitary norms are implemented in many countries of the world; in the socialist countries these norms are compulsory and enforced by law for all enterprises. People with noise-induced hearing loss (NIHL) are granted a special compensation proportional to the disability incurred.

Still, NIHL is only one particular aspect of the more comprehensive health problem posed by excessive noise exposure. This review will, therefore focus on the extra-auditory effects of noise, a field less explored and where results are less clear-cut. The range of issues discussed will be further narrowed, by restricting it to extra-auditory effects in industrial noise settings. Specifically, noise-induced alterations of health and performance as well as other effects (e.g., absenteeism, accidents) which could be caused by occupational noise exposures will be considered.

The survey aims to report the status of research in this field in Europe and particularly in European socialist countries. As the English literature was purposely discarded, this review is necessarily incomplete and limited. The data reported here, however, are found in many reference materials not normally available in English-speaking countries and thus offer added information for broadening one's knowledge in the problem area.

II. Influence of noise on performance level

It is generally assumed that noise impairs work performance, but actual demonstrations of this effect, either by laboratory or field investigation are rather scarce. The laboratory studies which are better controlled than field studies have yielded contradictory results with respect to noise effects (Cohen 1969, Broadbent 1971, Metz & Mery 1971, Gulian 1973a), and as such are at present only of limited value in judging the hindrance noise represents in achieving higher performance level in real life situations. On the other hand, estimation of workers' performance in noisy industrial settings poses difficult methodological problems among which the following should be mentioned:

a) noise is usually not the only environmental noxious agent;

b) there are specific and diverse motivational factors, different from those intervening in laboratory studies;

c) the job requirements prevent a voluntary relaxation of attention which may occur during long-term laboratory study;

d) the work activity can be partially or completely automatized such as to make it difficult to determine the extent to which noise produces performance deterioration.

Two main approaches were found in order to correctly evaluate whether and to what extent work output in industrial settings are adversely affected by noise.

The first approach refers to laboratory researches studying the effect of industrial type noise on humans' (or animals') performance in different psychological tests. In this case, the noises used are tape recordings of the noises produced by machines in factories, set at the same or different intensities as found in the work place.

The second approach consists of investigations performed in factories where the sound pressure level (SPL) exceeds the legally established norms (which means the SPL can be harmful), comparisons being made at the beginning and at the end of the working day or at different moments during the shifts. Some of the shortcomings of such an approach were discussed earlier, but there are also clear-cut advantages, one of which is the reliability of results due to long-term exposure.

The effects of noise are evaluated according to the interaction of three factors: the independent variable-noise characteristics, the intermediate one-man's organic and psychological reactions, and the dependent variable-work output and general performance level.

There are two major performance indices used in Eastern European laboratory studies. (See Andreyeva-Galanina, Alexeyev, & Kadyskin (1967)). The first is reaction time (RT) or latency of motor reaction to sensory stimuli. In Pavlovian literature it is considered that RT is an index of the functional state of the central nervous system (CNS), an increase in RT being proportional to an increase in fatigue in the CNS. The second performance index is called "normal strength relationships" which is the dependence of the strength of the motor reaction on the intensity of the conditioned stimulus. When these "strength relationships" are distorted, phasic states appear, i.e., inadequate relations between the intensity of the stimulation and that of the response. The phasic states include the paradoxical phase, when to a low-intensity stimulus the subject responds strongly; the equallizing phase, when the subjects respond with the same intensity to both weak or strong stimuli; and the ultraparadoxal phase which inverts the "sign" of the conditioned response: the S does not respond to the positive stimulus while he responds to the negative one.

The advent of the phasic states indicates the disturbance of the basic nervous processes and the beginning of process of transmarginal inhibition, which appears as a means of protection against a noxious influence in this case (Andreyeva-Galania et al. 1968).

Discussions of results in investigations of noise effects on performance in industrial settings are the main scope of this section. Several aspects are focused upon including the impact of different characteristics of noise (intensity, frequency or type, i.e., continuous vs. intermittent vs. impulse etc.) on performance. Still others evaluated noise-performance changes as a function of age or noise exposure duration.

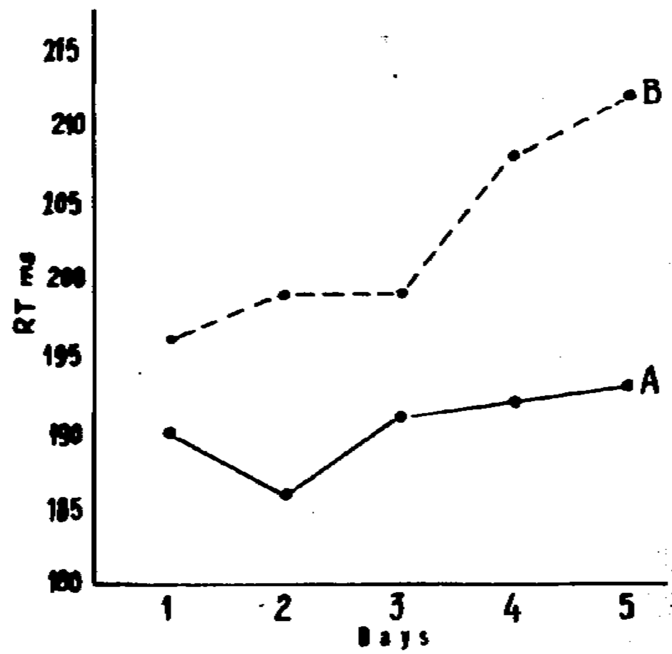
1. Effects depending on noise characteristics

1.1. Action of noise intensity and spectrum

Intensity. Laboratory studies have shown that noise under 90 dB usually does not impair performance level, i.e., number of omissive and commissive errors (Gulian 1966, 1970, 1971). However, speed of information processing is reduced (Stefanov 1972) although in this respect the positive or negative feedback (i.e., knowledge of results) the subjects (Ss) receive is of great importance (Schonpflug 1973). In general there is a steady increase in RT (longer latencies) with increasing noise intensity (Alexeyev & Suvorov 1965, Arkadievsky 1966, Kubik & Seres 1966, Gulian 1967). Some authors point to the fact that this rise is only temporary, as after 5 min, RT returns to the initial values or even below them (Paranko & Vyshpar 1967). It was also found that no changes in RT are apparent when the task is not difficult (Gulian 1970, 1971, Jansen 1973).

Results obtained in field investigations are also contradictory. In a study by Gorshokov et al., 1972, two groups of workers, each of 10 persons, 23-40 years old, working in a weaving factory for 7-20 years were followed up for two weeks, 4 times a day (before work, before the meal rest, after the meal rest, and at the end of the shift). One of the groups (Group A) was exposed to 100-102 dB noise, while Group B was exposed to a 108-113 dB noise. It was found that visual RT was significantly longer in Group B than in Group A ($p < .001$). There is also a cumulative adverse effect of noise which was manifest both by increased number of errors at the end of the working day and in higher RT at the end of the week (see Fig. 1a, 1b).

Another investigation tried to establish the capacity to focus attention in 28 persons working in a chemical plant, exposed continuously to a 85-90 dB, broadband noise with greatest concentration of energy between 125-1000 Hz. Testing was carried out twice a day, at the beginning and during the 5th-6th hour of the shift, 15 min. in quiet and 15 min. in noise. (A tape recording of the workshop noise was transmitted through earphones). The results are shown in Table 1. It can be seen that (1) there is a general deterioration of performance after several hours of noise exposure, even in persons accustomed to the noise, and (2) that noise impairs performance more later in the day than at the beginning of the shift (Toader 1973).



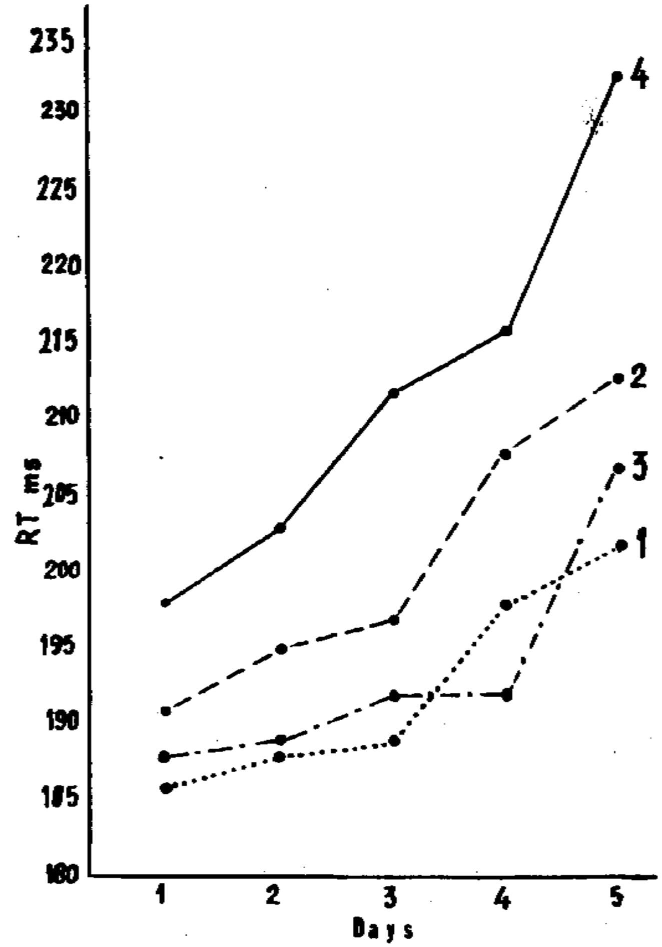


Figure 1a. Evolution of reaction time during a week of testing in group A (100–102 dB) and group B (108–113 dB).
Figure 1b. Dynamic evolution of reaction time during five days of a week in the higher noise exposed group (group B, 108–113 dB). 1. before work; 2. before the meal rest; 3. after the meal rest; 4. at the end of the shift.

Table 1

Performance level in the Kraepelin test (n = 28)
(after Toader, 1973)

Testing conditions	Accuracy				Errors				Speed			
	Quiet	Noise	Difference between means	p	Quiet	Noise	Difference between means	p	Quiet	Noise	Difference[x] between means	p
Morning	90.57	91.97	1.31	NS	10.64	13	-	NS	18.14	20.42	-	NS
After 5 h	86.87	83.90	1.82	<.034	15.57	19.89	1.34	.10	14.48	15.35	-	NS
Difference[xx] between means	0.94	2.57	-		1.67	1.92	-		2.47	3.54	-	
p	NS	.005	-		.047	.027	-		.006	.0002	-	

[x] The difference was calculated by the Mann-Whitney U test for uncorrelated samples.

[xx] The difference was calculated by the Wilcoxon rank matched-pairs test for correlated samples.

On the other hand, a sample of 20 flying specialists of the Italian Air Force was subjected to some psychometric tests (visual and acoustic RT, examination of visual perception speed and of the free two-hand coordination) before and immediately after 4 hours work performed under the noise (100-120 dB) generated by jet engines. Work consisted in controlling (trimming) the engine before take off. No statistical significant differences were found between performance levels (1) before and after work, or (2) when their intervening period was with jet engines running or silent. This lack of significant differences was attributed to motivational factors (Calapaj & Bellia 1969).

Angeleri et al. (1969) measured visual RTs in either quiet or 100-120 dB high frequency (4200-9000 Hz) noise on several tasks for 70 Ss, 30 from a textile factory and 40 from a metallurgy plant. A few of the workers showed higher noise RTs but there was no statistically significant difference between quiet and noise conditions. There were some variations among Ss on different tasks.

Spectrum. Kublik and Seres (1966), in a laboratory study point out that certain frequencies (1000 Hz) even at high SPL (90 dB) do not impair performance. Alexeyev and Suvorov (1967) found that as compared to noise in the 300-600 or 600-1200 Hz bands, a 90 dB 1200-2400 Hz band noise caused the maximum modification in performance. Orlova (1955) found that a 85 dB level of broadband noise was even more detrimental. She found that noise greatly increased the inadequacy between the physical strength of the conditioned stimulus and the conditioned motor reaction, and diminished the discrimination capacity by 30%.

Field investigations tend to corroborate these laboratory findings, that is, high frequency noises seem to impair performance more than low-frequencies of equal SPL. Dumkina (1965) studied 109 workers exposed to turret lathe generated noise at two ranges of levels, 82-87 dB and 92-99 dB, with strong high frequency energy. She tested the Ss in a visual RT task (strong and weak signals) before and after work, for two days and compared them with a control group of 52 Ss. She found a higher RT, irrespective of differences in intensity, at the end of the shift for the noise exposed workers (an increase of 12-37% of the Ss to strong stimuli, and of 19-33% in 64% of the Ss to weak stimuli). There were no phasic shifts. The author suggests that the RT increase probably shows a deterioration of the mobility of cortical processes due to a decrease of excitability, concomitantly with an increase of inhibitory processes.

1.2. Action of noise type

Several laboratory studies have established that intermittent noises have a more adverse effect on performance than continuous ones (Gulian 1966). However, there are researches showing that this is the case only under certain circumstances. For example, Mariniyako and Lipovoi (1972) found that high frequency intermittent noise induce larger decrements in performance than continuous noise while at low frequencies the reverse is true. An extreme case is set by impulse noise which has a clear detrimental effect on performance level in comparison to continuous noise of the same SPL (Orlovskaya 1967). Suvorov (1970) found that time and the difference between background noise and the impulse SPL was especially important. Experiments conducted by Andreyeva-Galanina & Suvorov (1968) have shown, for example, that a rise time of 10 ms. is particularly noxious.

Lipovia (1969) studied the effect of impulsive noise on riveting press operators. The ambient intensity was 103-105 dB, but reached 117 dB peaks due to the impulses. The impulse spectra ranged between 500-8000 Hz with a weighting at 2000 Hz and was often interrupted for 85-90 sec. with interruption durations being 3-3 1/2 times greater than noise durations (25-30 sec.). Twenty-seven Ss with different noise exposure histories were tested three times a day (before work, 3 1/2 hour later and at the end of the shift). Sixteen Ss worked on the morning shift and 11 in the afternoon. No univocal changes in their reaction time could be established, since RT sometimes increased, while other times it decreased. No differences appeared in the direction of RT changes as a function of noise exposure duration, but those who were less exposed to noise had quicker RT in the morning. There were, however, clear-cut differences depending on the specific job requirements: Thus, the supervisor, although not directly involved in the work process, after 3 1/2 hours and at the end of the shift had a clear increase in RT (a poorer performance) as compared to the initial values. In workers the RT decreased as compared to the initial values. In another psychomotor test (a type of tracking task), it was found that the supervisor made many more inaccurate (early) responses at the end of the shift, while for the workers the opposite trend occurred. It is probable (though the author does not draw this conclusion) that the higher emotional stress of the supervisor, due to greater responsibility, induced a quicker fatigue of the CNS and played an important role in his performance decrement.

Mariniyako (1966) studied the dynamics of cortical visual stimuli and performance in a tracking task in workers testing industrial machines. The maximum energy was in the 6400 Hz octave band. The tests were repeated for five days, four times a day (before work, 3 1/2 hours later), 1 hour after the meal rest, and 30 min. after the end of the work day.

It was found that after 3 1/2 hours there was a rise of only 0.03 sec. in simple acoustic RT and of 0.05 sec. in acoustic choice RT. At the end of the work the rise was more pronounced. In visual RT the changes were even smaller. Results in the tracking task showed a slight deterioration after 3 1/2 hours but a return to the morning values after the rest interval.

The conclusions which can be drawn from field studies about the effects of noise characteristics on performance level indicate:

1. High frequency noise (above 1200 Hz) is definitely detrimental to work output.

2. Intense noise over 90 dB can impair performance, but not invariably. The evidence shows that the harmful effects of intense noise can be successfully overcome when motivational and/or other job-related factors are involved.

3. Intermittent, particularly impulse noise, impairs performance, but its after effect is relatively small as shown by the lack of deterioration found in the psychological tasks during pauses or the termination of noise.

2. Effects of noise as a function of age

In the Soviet Union particular interest has been shown in age-related sensitivity to noise. There are special regulations setting the noise levels acceptable for adolescents, working in industrial setting, to different and lower levels than those in force for adults. Even stricter norms are proposed by scientists on the basis of their research.

Thus, Geltyshcheva (1973) in a mechanical engineering plant investigated three groups of adolescents (56 Ss) between 16-19 years. Group A worked in noise levels permissible for adults (but higher than those accepted for adolescents), Group B worked in noise levels higher than those permissible even for adults. A visual and acoustic discrimination task, with simultaneous recording of RT and errors was carried out before work, before the meal pause and at the end of the shift. It was found that: (a) RT is higher in these Ss than in high school students of the same age, which means an absolute increase in RT due to noise exposure; (b) RT increases more in the higher noise group; and (c) the number of errors increased more in the high noise group than in the low noise group. These results show that teenagers are very sensitive to intense noise.

Another investigation was conducted in a car factory (Ponomarenko 1966) where cooperative work-study pupils (15-16 years old) from a professional school worked 6 hours a day (including a 1 hour meal rest). The noise was generated by lathes, at an intensity of 85 dBC with a concentration of energy in the 1000-2000 Hz range. The 30 Ss (625 check-ups) were tested three times a day in a place in the workshop where noise was less intense. In order to differentiate the influence of noise per se from that of the working process, 65 tests were run when Ss were not working but were under the same noise exposure. It was found that the RT (4 min. task) increased in these teenage Ss much more than in adults, under the same conditions: from 14.5 conventional units (c.u.) after 1 hour to 23 c.u. at the end of the shift for the visual RT, and from 16 c.u. to 26 c.u., respectively, for the acoustic RT. An arithmetic task (5 min. long) was performed more poorly after 1 hour (solving time increased by 8 sec. and the number of errors increased an average of 0.8. Further deterioration was noted at the end of the shift (solving time increased by 13 sec. and number of errors by 1.1). An interesting point is that there are no differences between those who work and those who just sit in noise, this finding being at variance with results obtained on adults. Studies on adults in a laboratory by Alexeyev and Suvorov (1967) show that just staying in but not working in noise can have deleterious results if the exposure lasts at least 3 or 4 hours. They relate their results to fatigue of the CNS. They found that fatigue of the CNS is followed by (1) an increase of RT to strong and weak visual stimuli (from 179.8 to 198.9 msec., and from 214.5 to 234.1 msec., respectively), (2) decrease of response intensity (14% on the average), and (3) a distortion of the normal strength relationships, the normal amount being diminished by 45% at the end of exposure to noise as compared to the beginning of exposure. These changes increase as a function of exposure duration, being negligible for exposures of less than two hours.

In a field investigation, Toader (1973) corroborates this laboratory study. She compared 14 workers, compressor operators (CO) who sat in their usual working setting exposed to a 85-90 dB noise, but did no work throughout the entire shift, to 14 other persons, members of an auxiliary team (AT), who worked intermittently, but rather seldom in a noisy environment. She found that performance level in a concentrated attention test (Kraepelin's) was consistently lower in subjects permanently exposed to noise even when relaxing, than in those exposed to noise only from time to time. The mean score for accuracy was 51.7 points for CO and 93.3 points for AT, $U = 23$, $p < .001$, while for errors the mean score was 24.9 and 17.7 respectively, $U = 52$, $p < .025$. On the other hand, speed was higher in CO than in AT (23.2 vs. 13 points, $U = 51$, $p < .025$). (The difference between scores was calculated by means of the Mann-Whitney U test for uncorrelated samples) (Siegel 1956).

Thus it can be said that noise elicits fatigue in the CNS even when people are relaxing. This affirmation is also supported by the numerous complaints of people living in or near industrial districts (Paranko & Trotsenko 1972, Rudenko et al. 1972) or airports (Karagodina et al. 1969, etc.) who state that the environment noise tires them.

In a metallurgic plant where teenagers (16-18 years) were trained 3 hours per day, for 3 years, Timokhina (1965) studied different variants of the working schedule: (a) continuous for 3 hours, and (b) with 10-15 min. pauses after every 50-55 min. of work. Ss were exposed during their work to a 95-105 dB white noise. It was found that RT varied as a function of the working schedule, increasing in Condition (a) and decreasing in Condition (b). In a problem solving task, though, both duration and number of errors increased with time, irrespective of the other conditions, which shows that when higher mental activities are involved, noise acts adversely.

A follow-up of performance modifications depending on noise spectra was undertaken by Kovaleva (1967) on 80 Ss, 16-18 years old with a work history of 2 to 4 years (milling-machine and lathe operators). She divided the sample into

2 groups: Group 1--exposed to high frequency bands of noise centered at 1000, 1600 Hz, 2500 Hz and 4000 Hz, 95-109 dB noise; Group 2-- exposed to a lower intensity noise with a concentration of energy in low and medium frequencies (63-1600 Hz), 80-85 dB. Ss were tested for 3-4 days, 4 times a day (before work, after 4 hours, after the meal rest, and at the end of the shift). Performance in a choice reaction task showed an increase in RT as a function of time. There was an increase in number of errors in discrimination and in consecutive inhibition i.e., the post effect was a deeper inhibition. These shifts in neurodynamics of the cortical processes indicated a chronic fatigue and are a strong warning against letting teenagers work in such a noxious environment.

Other studies were devoted to the protective effect of earplugs in adolescents. It was found that the earplugs reduced the adverse effects of noise on performance. Thus, without ear protectors the acoustic and visual RT increased in a statistically significant manner as a function of time (from 207 to 218 ms. in the visual RT task and from 175 to 192 ms. in the acoustic RT task); with ear protection the increase was very small, from 1964 to 200 ms. in the visual and from 182 to 185 ms. in the acoustic RT task.

No special studies have been devoted to the effect of noise on different age groups, but Gulian (1973b) analyzed the performance level and its relation to noise annoyance as a function of age. One hundred persons working in a chemical plant were tested with the Stroop test and a test of concentration of attention. Sixty of these Ss were exposed to noise (85-106 dB), with a concentration of energy above 1000 Hz while 40 Ss served as a control group. Ss were divided according to their age into 6 groups, between 20 and 50 years. It was found that noise annoyance was greater for the noise exposed persons, with maximum annoyance after the age of 40. There is a high correlation ($r = .41$, $p < .001$) between the personal tempo as determined by the Stroop test and age in the noise exposed group; perceptual interference as interpreted from the Stroop test rises steadily with age in both groups, more so in the noise exposed one where a high correlation was found between these scores and age ($r = .30$, $p < .02$). In all the noise exposed Ss there was a critical age (between 41-45) when performance deterioration was highest, the next age group (46-50) seemed less sensitive to noise, and often performed better than the control group. Age seems thus an important variable which, if studied, could provide a necessary clarification of many still unsolved questions in noise-performance research.

3. Effects of noise as a function of noise-exposure duration

It is well established that there are wide individual differences in auditory susceptibility toward noise and that long-term noise exposure elicits hearing loss. Another question is whether there is any correlation, or at least a parallelism, between hearing loss and performance impairment as a function of noise exposure duration. Only few data are available and many others are required in order to clarify this issue.

In one study, Svistunov (1969) evaluated the performance of 101 Ss exposed to electrical machinery noise of 120 dB, with a concentration of energy in the 1250 Hz-2500 Hz frequency range. He compared them with a control group of 33 Ss. The tests were completed before and after work. The author found that there was an increase in RT of 6% in workers exposed for 1 year, of 7.2% for those exposed between 1-5 years and of 10.3% for those exposed over 10 years, the differences between the noise exposed and the control group were statistically significant ($p < .01$) both to weak and strong visual stimuli. The same Ss were given a test of distributed attention which showed that for exposures up to 1 year there were only slight modifications, but that as noise exposure duration increased beyond 1 year there was a progressive deterioration of attention.

Gulian (1973b) found that noise annoyance increased with longer noise exposure and Ss working in noise were more annoyed by noise than the control group, particularly for those exposed between 2-5 years ($p < .05$) and between 11-15 years ($p < .025$), see Figure 2; 11-15 years of noise exposure seems critical for performance too. Those in the 11-15 years exposure group also made significantly more errors in the Stroop test ($p < .025$) (see Figure 3). The noise-exposed group suffered a higher degree of perceptual interference in the same test, except when exposed for over 15 years (see Figure 4). More in the noise group performed better in the attention test except when exposed for less than 2 years or for those over 45 years of age (see Figure 5). Shifts in performance levels due to workers in noise have also been mentioned by Dumkina (1966) and Lipovoi (1969). Lipovoi noted that as compared to those who had worked in noise between 5 and 10 years, those who had worked in noise for less than 5 years had shorter latencies by 0.02 to 0.04 seconds in a simple RT task, and by 0.02 seconds in a choice reaction task.

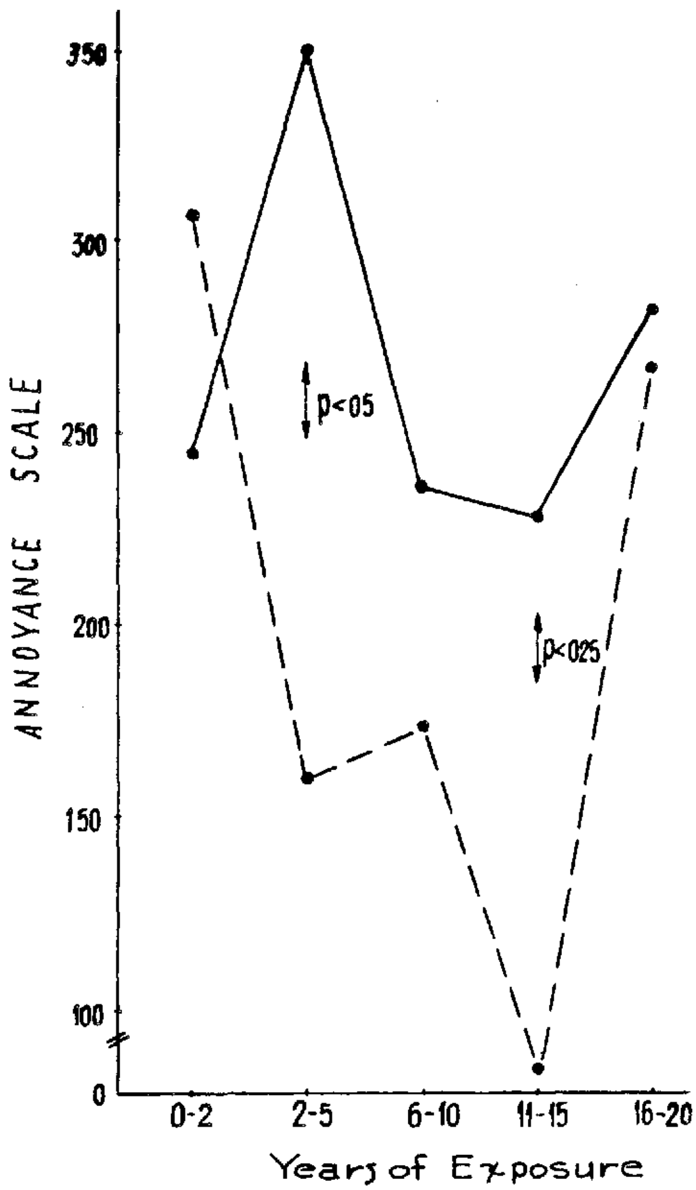


Figure 2. Noise annoyance as a function of noise-exposure duration.

—— noise group — — — control group

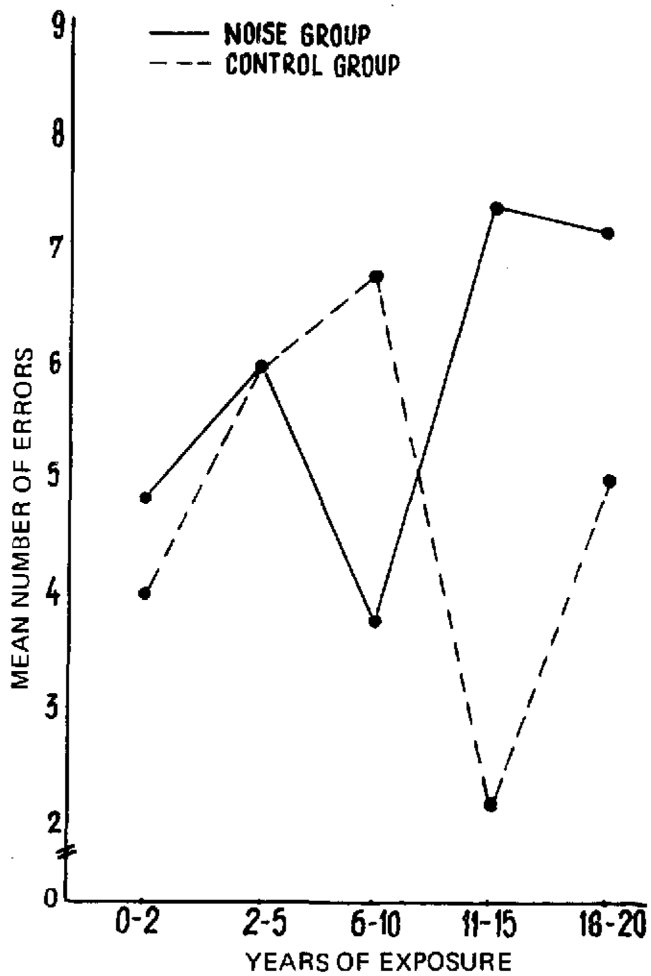


Figure 3. Number of errors in the Stroop test as a function of noise-exposure duration.

—— noise group   – – – control group

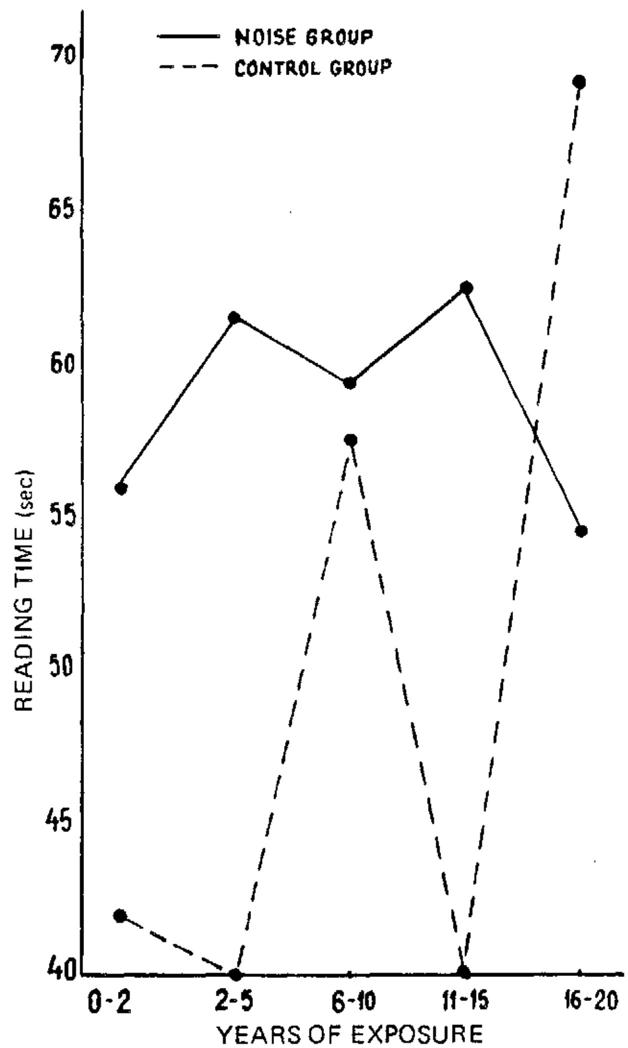


Figure 4. Level of perceptual interference in the Stroop test as a function of noise-exposure duration.

—— noise group — — — control group

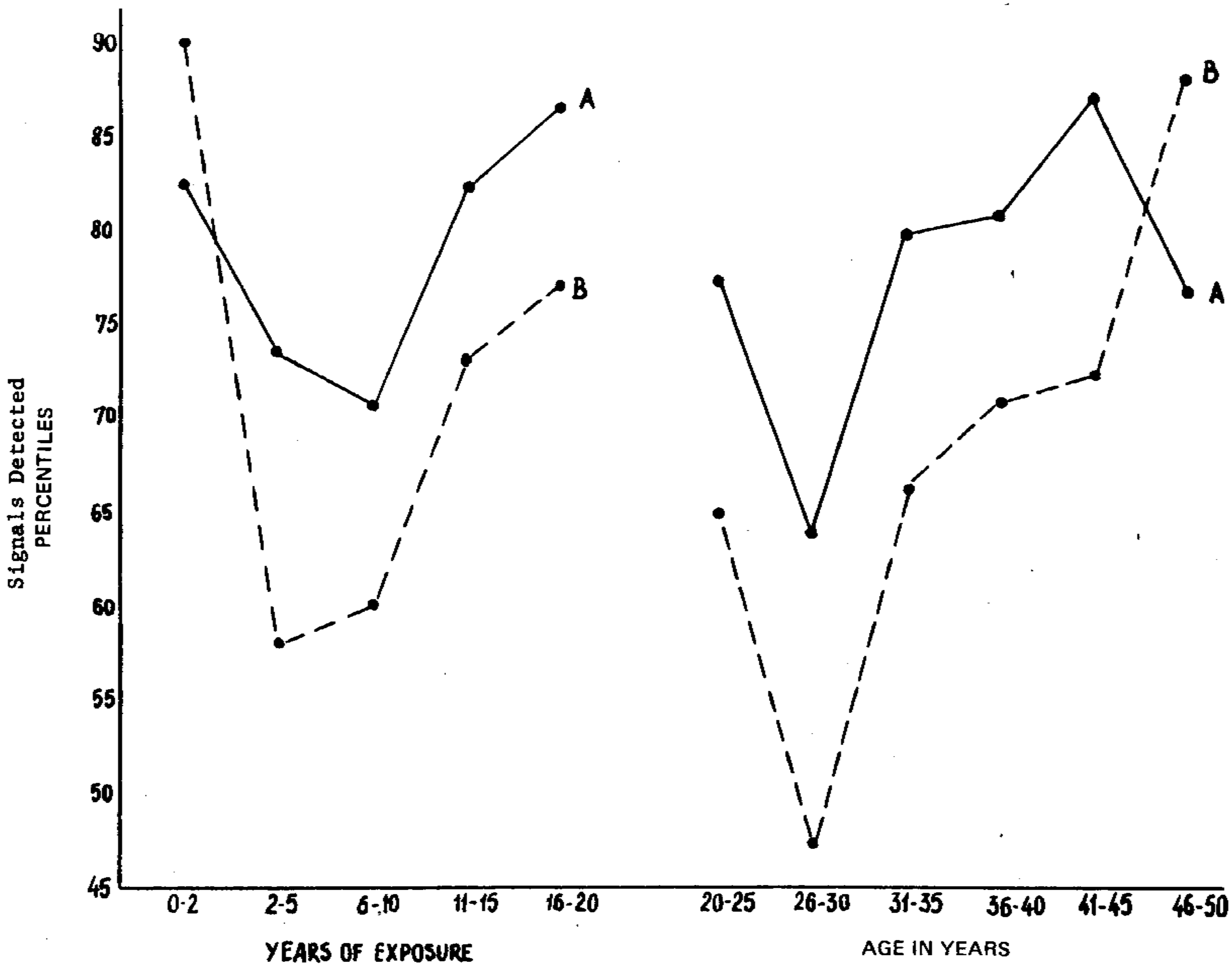


Figure 5. Number (percentiles) of signals detected in an attention test as a function of age and noise-exposure duration. Noise group ——, control group --- (after Gulian, 1973b).

4. Studies on work output and its modification after noise reduction

Studies on work output in noisy office settings are extremely rare. Trbuhovic (1970) states that in big rooms where noise levels reach 50-55 dB due to multiple typewriter use, the number of errors made by typists approaches 50%. Kovrigin & Mikheev (1965) studied the work output in post offices where the noise generated by the mail sorting machines reaches 83-89 dB. They noticed that at the end of the work shift, the muscular output decreased and the number of errors increased by 50-150%. Another study carried by Mikheev et al. (1967) in post offices compared a group of employees exposed to a 75-84 dB noise with energy distributed over 500-4000 Hz frequencies, whose work required attention and precision (telegraphy, etc.), with another group of employees exposed to a higher SPL (85-87 dB) with an energy maximum in the 1000 Hz octave band, whose work involved minimal attention (stamping, etc.). The authors found that after 405 hours of work, typical shifts appear in the dynamics of higher nervous activity--paradoxical and ultraparadoxical (phasic) states, which show a transmarginal inhibition.

Very few attempts have been made to study the economic impact of noise, including the meaning of hearing protection on work output (performance). One such study was performed by Rentzch (1972) in the German Democratic Republic. He evaluated how well experienced universal excavator operators handled the excavator under three noise conditions: (1) while wearing ear protection (SPL at ear = 76 dB), and with no ear protection in levels of; (2) 86 dB; and (3) 96 dB. His results are summarized in Table 2 and show that (1) performance efficiency decreased and operating cost increased in the highest noise level, and (2) performance efficiency decreased less and operating costs increased less for the "ear protection" conditions.

Hartig (1966) refers to data from Poland and GDR which demonstrate that noise reduction has a favorable effect on output. Thus, in a big joinery plant where the main noise source was a circular saw, it was reported that when the saw was not working the output increased by 5%. Similarly in offices when sound-proof measures were introduced, Baumgarten (1957) found typing errors to decrease by 29% and calculating errors by 52%. At the same time there was an overall 9% increase in work output.

TABLE 2

EVALUATION OF THE INFLUENCE OF EQUIVALENT CONTINUOUS NOISE ON PERFORMANCE EFFICIENCY AND OPERATING COST

(adapted from Rentzsch, 1972)

Designation	Dimension	NOISE LEVEL		
		I[x]	II	III
Equivalent continuous noise level(leq)	dB(A)	76.o	86.o	96.o
Normalized performance	-	o.95	1.o	0.89
Performance cost	m^3/hr	35.6	37.4	33.3
Economic cost	DM/m^3	0.79	o.75	o.84
Economic costs/year	DM/year	27413.	26025.	29148.

x With earplugs

5. <u>Summary Comments</u>

Analysis of the performance level of noise exposed industrial workers have been evaluated in the main using reaction time tasks, plus discrimination and attention tests. The results show:

1. A clear-cut detrimental effect of noise on adolescents.

2. A deterioration of performance with increasing noise exposure duration.

3. Critical and dependent relations between age and/or noise exposure duration and performance impairment.

4. A rather inconclusive effect of noise when levels are lower than 100 dB. However, even a 80-85 dB noise can exert adverse effects in certain work settings.

On-job performance decrement is in fact seldom witnessed in industrial plants and thus there is a discrepancy between laboratory derived research data and the real work output. However, the lower efficiency level observed on different psychological tests given to workers at their work place demonstrates "fatigue," or "stress" of the nervous system after several hours of work in noise (in fact after years of work in noise) and is not at variance with results obtained through observations of work output. In factories, most jobs are automatized and as such do not require quick reactions or concentrated attention. It looks like the tests used are only partially suited or sensitive enough to disclose direct effects of noise on industrial workers, but it is hardly probable that performance measures will be able to show without doubt the complicated processes involved in maintenance of work capacity under the noise stress.

III. Effects of noise on health

There is a steadily increasing tendency to take into account the effects of noise not only on the auditory function but on the whole organism as well. There are some who consider that noise produces health disturbances and/or adverse effects on well-being even before auditon is adversely affected.

As early as 1958, Andreyeva-Galanina (1972) referred to "noise sickness" evidenced by nervous and cardiovascular disorders in addition to auditory troubles. Data gathered since, tend to confirm that such a nosological entity indeed exists. Scientists from different countries also support this view (Quevanviller & Levrier-Pottier 1973, Markievicz 1967, Wisner 1966) and emphasize the effects of noise on various organismic functions, other than the auditory ones. Maugeri & Odescalchi (1967) stress that there exists a noise induced pathology which can be direct (sensorial or psychic) or indirect, manifested in vegetative, digestive, etc. symptoms. A fatigue syndrome and a lowering of the general resistance of the organism are often in evidence in noise-exposed people (Stefaniu & Celuschi 1973). Recent data (Ratner et al. 1973) rate noise and vibration sickness as the second foremost occupational disease, topped only by pneumoconiosis.

Different field studies have shown relative independence between the functional changes in the central and autonomic nervous system due to noise and those manifest in the auditory system, the former appearing earlier than the latter. The predominant symptoms and syndromes are determined by the noise characteristics--mainly intensity and spectral composition--as well as by individual sensitivity to noise.

Krivoglaz et al. (1967) distinguish three syndromes of noise sickness, while Drogichina et al. (1965) consider that there are four main syndromes. All agree that noise induces primarily an astheno-vegetative syndrome as well as cardio-vascular and neurological (diencephalic) disorders.

There is, therefore, a growing necessity to establish firm criteria for analyses of different shifts in the human organism as a function of noise characteristics and relate them to subjective symptoms as well as to different work conditions (Maximova et al. 1973).

1. General morbidity

There are few comparative data about the morbidity level in noise exposed vs. non-noise-exposed workers. However, some noncomparative data are presented in Table 3 about the morbidity in Romania in certain selected branches of noisy industries. The data included noise-induced hearing loss as well as other diseases. Andreyeva-Galanina et al. (1972) in their recent book about Noise and Noise Sickness maintain that the general morbidity of noise exposed (over 100 dB) workers is greater by 134% than that of all workers. The absentee rate differential is 111.4%. Similar data were reported by Quaas (1970) about morbidity in a steel mill, where the noise level reached 110 phons.

Kangelari et al. (1966) investigated morbidity for 3 years (1960-1962) in workers of 2 industrial groups, 135 mechanics and 152 foundry workers whose average was 39.4 years and who were exposed to a 116-120 dB, high frequency noise with a concentration of energy around 2500 Hz. They were compared to a control group of locksmiths exposed to a 88-90 dB, 120-800 Hz noise. It was found that in high noise-exposed workers there is an increased morbidity, which in time could lead to disorders of the immunological reactivity and of the defense capacity of the organism (Table 4). In a further comparison of foundry workers in the same age range exposed not only to high noise (over 110 dB) but also to vibrations, it was found the joint effect of the two noxious factors provokes a 2-3 fold increase in morbidity in persons suffering from the vibration sickness.

A recent study of worker medical records in 6 thermal power plants where noise exceeds the sanitation standards by 10-16 dB, but where other noxious agents were also present (high temperature, low humidity, etc.) showed that the general morbidity depends on the type of work and the emotional involvement just as much as on the environmental conditions. For example: (1) the fewest cases of disease were recorded among operators supervising water storage (50% and 564.1 days lost); (2) the highest rate (104.2% and 1081.5 days lost) was recorded in the foundry and steam boiler sections among which were 54% (or 357.3 days lost) with influenza or angina; and (3) persons working at the ash removal and crushing sections showed a 90.9% case rate with 968.5 days lost (Nagornaiya & Tupchii 1973).

Barhad et al. (1969) compared the morbidity between persons working in boilershops and those in engine workshops in a metallurgic plant, where the noise level reached 98-127 dB.

Table 3

Occupational diseases according to trades

(1968-1972, per 100 000 workers)

Type of industry	1968	1969	1970	1971	1972
Metallurgical	919.0	693.5	1116.1	528.4	839.2
Boiler Shops	491.4	261.1	291.8	601.2	785.7
Mines	1294.9	1193.9	1151.8	1007.4	682.2
Chemical plants	599.5	405.9	331.3	251.8	266.0
Textile	82.5	69.1	274.8	254.5	112.2
Metal processing	141.5	131.3	126.0	71.5	96.4

Table 4

Effects of noise on health. The morbidity per 1oo workers (after Kangelari et al., 1966)

Type of disease	Mechanics (116-12o dB)	Locksmiths (88-9o dB)
All kinds of disease	1o3.1	77.o
Among which influenza, cathar of respiratory paths	55.9	39.1
Angina	8.9	7.8
ORL	3.2	1.5
Respiratory organ	3.2	1.5
Peripheral nervous system	2.3	1.5
Gastritis	1.6	o.4
Ulcer	2.9	1.6
Diseases of the locomotor organs	1.1	1.5
among which myositis	o.8	1.1

They showed that boilersmiths had a higher rate of diseases of the respiratory system (1.90 times), of the nervous system and sensory organs (1.34 times), of the locomotor system (1.33 times) and of the circulatory system (1.26 times).

A comparative study in a chemical plant revealed a much higher morbidity in noise-exposed workers than in those working in other sections, even though in the latter case other noxious environmental conditions such as gas vapors were present. Thus, 56.77% of the noise-exposed sample of workers were ill during the years 1972-1973, as compared to only 27.50% of the control group, the difference between them being statistically significant ($t = 2.90$, $p < .01$).

Among the most frequent diseases found by Gulian (1974) are gastrointestinal disorders (22.58% in the noise group vs. 12.50% in the control one), cardiovascular dysfunctions (11.29% vs. 2.50%) and neuroses (12.90% vs. 2.50%). The difference in this latter case being statistically significant ($t = 1.81$, $p < .05$).

Although most authors find pathological shifts in health state and aggravation thereof with increasing noise exposure (a critical threshold seems to 10 years of work in noise), almost no attention has been devoted to isolating the mechanisms which grant adaptation to noise. A rather isolated exceptions are Nesswetha's (1963, 1971) studies in West Germany. In a first set of investigations (1963), he compared the reactions of people accustomed and unaccustomed to broadband industrial noise. In unadapted persons he found almost twice as many cardiovascular, endocrine, etc. disorders than in the adapted ones. Subsequently, for 2 years, he compared the adaptation symptoms of 100 persons, who were exposed to 96 dB white noise for the first time with the reactions of a sample of 100 persons already accustomed to the noise, and with a control group subjected to a 75 dB noise. During the 2 years a small number of diseases occurred in the control group only, in the group accustomed to noise the illness incidence was also very small (6%) while in the group unaccustomed to noise an enormous incidence of disease occurred, particularly during the first 4 months (35% report cardiovascular disorders and 16% gastric ones). At the end of the 2 year period, however, the health disturbances receded to 0.5% for the orginally unexposed group.

Even more relevant was Nesswetha's report (1971) on 3500 immigrant workers in West Germany employed in the chemical industry and exposed for the first time in their lives to noises up to and over 90 dB. In the majority of these people, starting within the first few days of work, strong vegetative (non-pathological) reactions could be noticed. The primary phase of higher vegetative irritability was followed by a phase whose chief characteristic was a relatively constant hypotension, sometimes so acute as to require work interruption (the arterial pressure fell very much as did the minute volume). Finally, after 8-12 months, pathological alterations of the gastrointestinal tract began to occur. The duration of these phases fluctuated between a few weeks and several months, then the symptoms regressed but no complete adaptation was noted during the observation period covered.

Such studies offer an insight into stress and adaptation mechanisms and point to the fact that the organism exposed to noxious influences reaches only a fragile equilibrium.

2. Neuropsychical disturbances

2.1. Subjective symptoms. Characteristic complaints and analyses of questionnaires

People working in noise complain mostly of increased irritability, headaches, growing tiredness, bad sleep and drowsiness (Andreyeva-Galanina et al. 1972, Toader 1973). A direct relationship was found between the number of complaints and the duration of noise, although Tsigel'nik et al. (1969) state that complaints about central nervous system (CNS) disorders are independent of noise exposure duration.

Statistics compiled by Kariukaev (Andreyeva-Galanina et al. 1972) for groups of workers exposed to high and medium frequency, 97-116 dB noise show that as the duration of exposure increases from 0-5, 6-10, 11-15 and over 16 years, the number of complaints correspondingly increase from 10, 28, 65, to 94 percent. Similarly, Svistunov (1969) studied workers in a plant where the noise levels varied between 94 and 120 dB with concentrations of energy in the 1250-2500 Hz range. He noted the following number of complaints: headaches --13.8%, sweating--20%, bad sleep--7.6%; heart--7.6% for those exposed up to one year; for those exposed between 6-10 years there was a clear-cut increase in the number of complaints and also an increase in the symptoms described, to wit headaches--29.4%, sweating--23.5%, dizziness--23.5%, increased excitability --47%, tiredness--23.5%, heart pains--17.6%; for those exposed over 10 years, headaches appear in 30.7%, bad sleep in 33.8% and heart pains in 30.7% of cases.

Gorshokov et al. (1972) found that higher SPL (over 95 dB) elicited more complaints among workers than lower intensities. In this case the workers were also more specific in their complaints; headaches were localized to the frontal area and usually appeared at the end of working day or even later whenever the noise-exposed people were worried or angry. In another study, Kangelave et al. (1966) found emotional lability, heart pain, increased sweating, dizziness, and loss of appetite. They compared workers exposed to 82-87 dB to those exposed to 96-99 dB. They found that ringing in the ears (tinnitus) often accompanied headaches which appeared to be localized to the frontoparietal area. No correlation could be established between hearing loss and the frequency of complaints and/or the autonomic syndrome (Table 5).

Pokrovskii (1968) investigated the effects of noise on 995 workers in a mechanical engineering plant. He found that 171 (or 17.18%) were characterized by the syndrome "weakness

Table 5

Frequency of complaints in automatic and turret lathes operators (after Andreyeva-Galanina et al., 1972)

Complaints	Turret lathes operators		Automatic lathes operators	
	Number	%	Number	%
Headaches	68	60.7	37	61.6
Vertigo	28	25.0	12	20.0
Fatigue	43	38.4	35	58.3
High excitability	51	45.5	30	50.0
Emotional lability	36	32.1	8	13.3
Sleep disorders	27	24.1	11	18.3
Heart pains	46	41.0	15	15.0
Palpitations	23	25.5	5	8.3
Pain in the epigastrium and dyspepsia	30	26.8	10	16.6
Hearing impairment	19	16.9	10	16.6
Weight loss	-	-	6	10
Increased sweating	25	22.3	23	38.3

of excitability" whose symptoms are: asthenia, headache, sleep disorders. Many of these workers complained that noise irritated them, especially when it appeared suddenly or irregularly, and that they were extremely sensitive to noise at home. Investigations in a spinning mill (Pokrovskii 1968) showed that the frequency of complaints rises proportionally to noise intensity (Table 6), but that the "weakness of excitability" syndrome depends both on noise intensity and on the workers age. Younger workers (up to 20 years) were relatively unaffected (Figure 6).

Other parameters of noise also have effects on the workers well-being. Thus Andreyeva-Galanina et al. (1970) show that workers exposed to infrasounds (between 6.3 and 32 Hz, and a SPL between 90-111 dB also complained about fatigue, headache, sleep disorders, and general indisposition.

Another study was carried out in a chemical plant on 236 workers (Elias et al. 1972). The authors investigated reactions to noise in 3 groups: Group A--exposed to 102 dB noise, with energy concentrations in the 250--2000 Hz range; Group B--subjected to 101 dB with energy concentrations in the 500-400 Hz range; and a control group exposed to a 90 dB noise in the 125-1000 Hz range. In addition to the differences in levels and spectra of noise to which they were exposed, Groups A and C were manual workers and Group B were supervisory personnel. Analyses of the medical records of each case showed that symptoms of nervous fatigue appeared during work, and analyses of answers to a questionnaire (checklist) established the presence of neurotic symptoms (sleep disturbances, psycho-affective syndrome, neurovegetative disorders). Figure 7 shows the rate of the different neuroticism symptoms (irritability, anxiety, hyperemotivity, emotional lability, etc.). Comparative analyses of the incidence of the disturbances in the three groups showed a higher frequency in the group where noise was associated with survey and control activity (Group B), while in the other groups, where the manual activity prevailed, the frequency was lower and rather similar in the 2 groups despite differences in noise intensity (Elias et al. 1973). The authors suggest that the lower neuroticism level in Groups A and C is due to a "motor discharge" of the activation induced by noise, but it is also possible that the higher responsibilities involved in a person's job (Group B) elicited a higher rate of neurotic symptoms. An examination of 250 medical files, concomitant with interviews of boilersmiths in a metallurgical plant, exposed to high noise (115-129 phons) showed sleep disorders and headaches mainly located in the frontal and occipital areas. Iancu et al. (1964) showed distinct alterations of the emotional balance and a high degree of irritability.

Table 6

Frequency of complaints as a function of noise intensity
(after Pokrovski, 1968)

Type of complaints	Noise intensity (DB)					
	100		90		80	
	Number of subjects					
	196		212		169	
	Frequency of complaints					
	Abs.	%	Abs.	%	Abs.	%
Increased excitability	32	21.9±3.4	26	12.2±2.2	21	12.4± 2.5
Headaches	62	41.9±4.1	32	15.1±2.5	10	5.9±1.8
Vertigo	27	18.5±3.2	35	16.5±2.5	2	1.1±0.3
Heart pains	12	8.2±2.2	11	5.2±1.5	13	7.6±2.0
Noise, sounds in the ears	4	2.7±1.3	4	1.4±0.7	1	0.6±0.4
Increased fatigue	27	18.5±3.2	7	3.3±1.2	2	1.1±0.8
Bad sleep	18	12.3±2.7	21	9.9±2.0	7	4.1±1.5

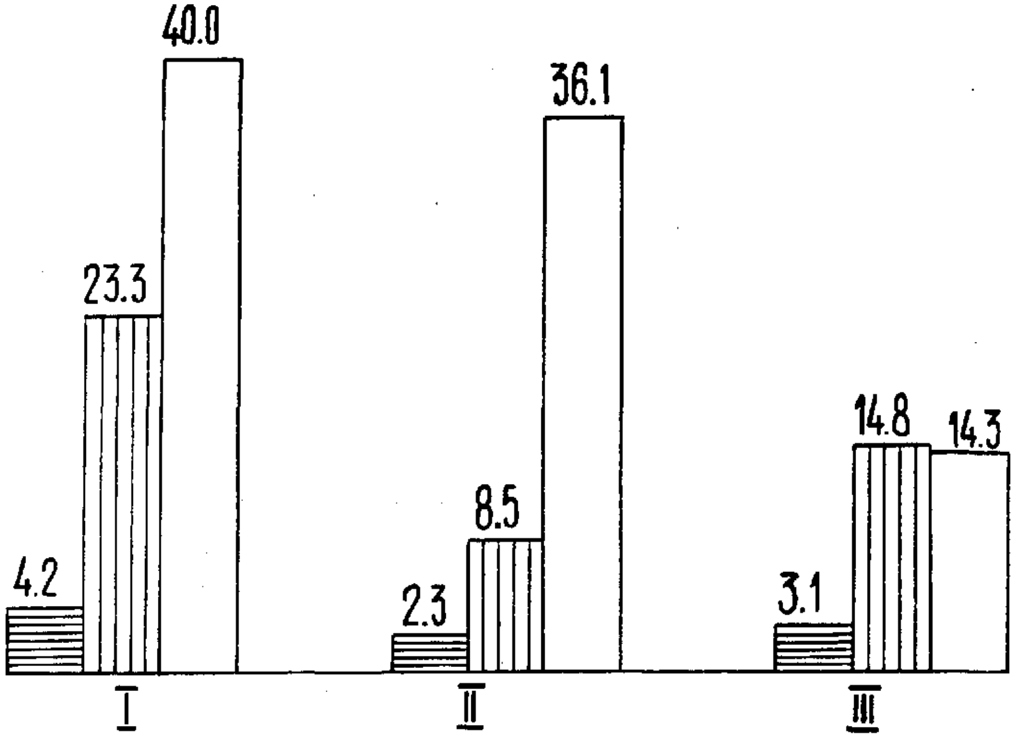


Figure 6. Number of workers suffering from the so-called weakness of excitability syndrome (in percent to examined workers).

I. Middle frequency range, 100 dB;
II. low frequency noise, 90 dB;
III. low frequency noise, 80 dB.

Columns with straight horizontal lines indicate people up to 20 years; those with vertical lines – people between 21–40 years; white columns designate people over 40 years.

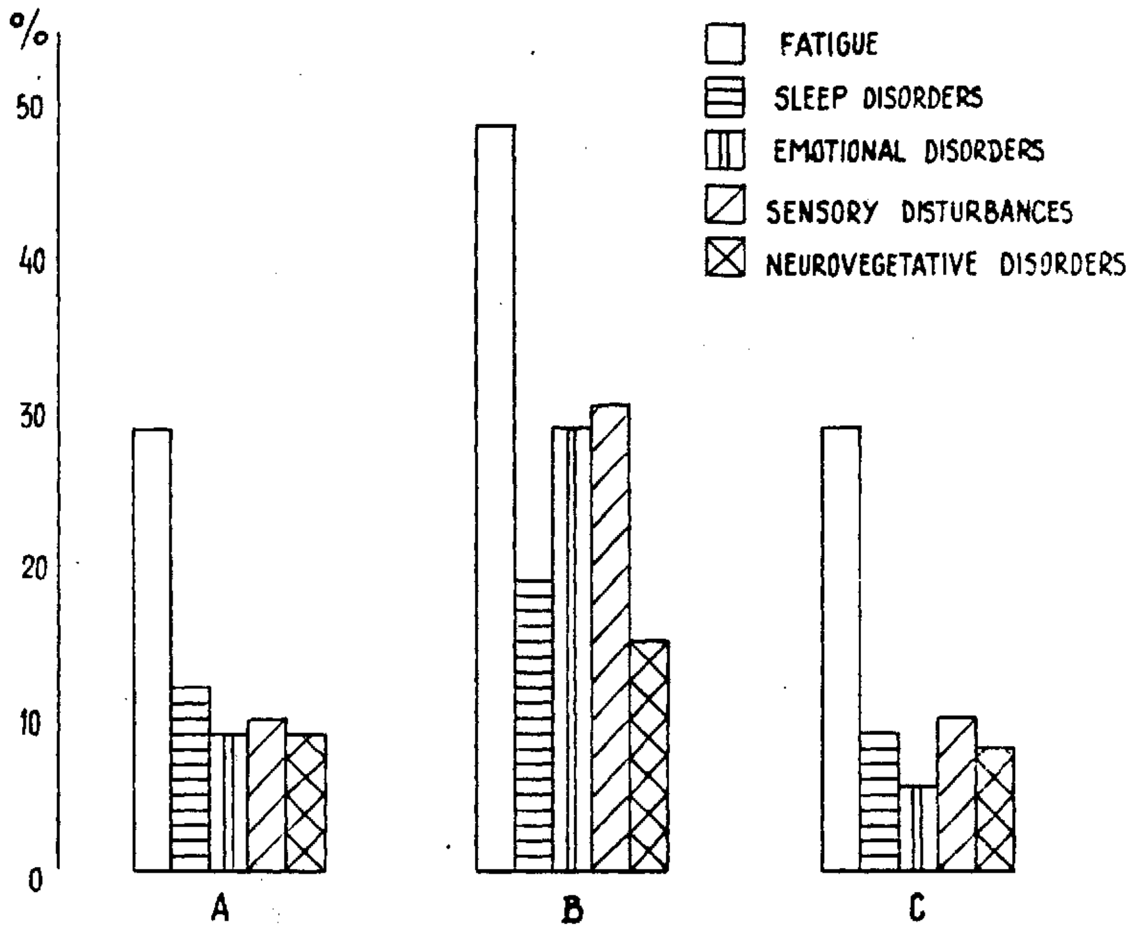


Figure 7. Synthetic presentation of different neuroticism symptoms found in noise exposed workers in a chemical plant.

A. 102 dB, 250–2000 Hz noise;
B. 101 dB, 500–4000 Hz noise;
C. 90 dB, 125–1000 Hz noise.

These studies tend to show a preponderance of complaints which would seem to point to a neurotic syndrome in noise--exposed Ss. Yet very seldom have neuroticism scales been used to check on the potential relationships between neuroticism level, number of complaints and effect on performance.

Gulian (1973b) used the Eysenck Personality Inventory in one such investigation to check on the neuroticism level of a control group and persons exposed to noise in a chemical plant. The control group matched the noise-exposed group in age range- 20 to 50 years, time on the job-0 to 20 years, salary, social status, and job routines consisting of monitoring gauges and dials and making appropriate adjustments. It was found that more persons displayed neurotic symptoms in the noise group (27.86%) than in the control one (22.50%), and that in the noise group neuroticism increased with age and duration of noise exposure. (The correlation coefficients were $r = .47$ and $r = .45$, respectively at $p < .001$) (Figure 8).

Statistically significant differences in neuroticism were found between the noise and the control groups as a function of noise exposure duration in the first 2 years ($U = 19.5$, $p < .073$) and more in the 11-15 year period ($U = 14$, $p < .05$) (Mann-Whitney U Test, Siegel 1956), neuroticism rising sharply after 10 years of work in noise, which seems a critical period.

There was also a direct relationship ($r = .39$, $p < .01$) between neuroticism and performance in the first Stroop table which indicates that with increasing neuroticism the personal tempo slows down.

In order to further analyze the neuroticism influence, high and low neuroticism subgroups were formed by grouping subjects with scores greater than and less than one standard deviation from the mean neuroticism level. In the high neuroticism subgroups, there were statistically significant differences between the performance scores of the noise exposed and control subjects ($U = 39$, $p < .025$). Such differences were insignificant in the low neuroticism subgroups. Also in the high neuroticism category, it was found that the noise exposed Ss performed better (80 points) than the control Ss (63.33 points) in the attention test ($U = 35.5$, $p < .025$), but not even a single statistically significant difference was found between the noise exposed and control Ss in the low neuroticism subgroups. Among the noise exposed Ss, statistical differences were found between high and low neuroticism categories in noise annoyance (HN = 101 points, LN = 91.54 points, $U = 59.9$, $p < .025$) and number of errors in reading the incongruent Stroop table (HN = 8.06, LN = 3.15, $U = 50.5$, $p < .01$). For

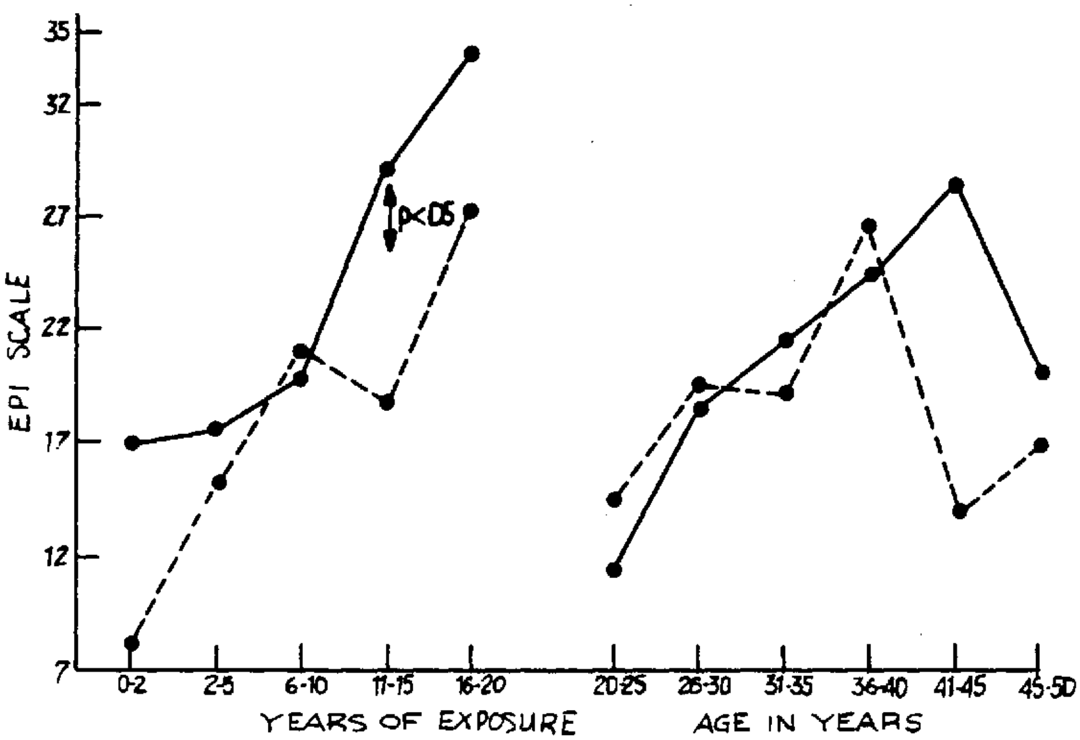


Figure 8. Increase in neuroticism level as a function of noise-exposure duration and age.

—— noise group — — — control group

the control Ss, statistical differences between high and low neuroticism categories were also found in noise annoyance (HN = 99.78 points, LN = 88.37 points, U = 15, $p < .025$) and in the attention test (HN = 63.33 points, LN = 80 points, U = 16.5, $p < .05$).

Thus, it appears that neuroticism is higher in the noise-exposed group. The highly neurotic are more annoyed by noise than the low neurotics, whether or not they are exposed to noise during their work. Also, that highly neurotic noise exposed Ss have a slower personal tempo and commit more errors in the Stroop test than the low neurotic noise exposed group. On the other hand, high neuroticism is not detrimental for concentrated attention, better scores being obtained by them (whether working in noise or not) than by the low neurotic group.

2.2. Neurological dysfunctions

In industrial noise-exposed people symptoms of slight neurological irregularities are often found. However, no organic CNS disorders have yet been demonstrated although clinical signs indicate the possibility of their future development. In health, long-term noise-exposed persons the clinical symptoms most frequently appearing are: a decrease (very seldom an increase) of tendon reflexes, a slight tremor of the outstretched fingers, an inhibition of the pupillary, swallowing and palatal reflexes, diminishing of abdominal reflexes,an instability of the Romberg's sign, a cooling of hands and feet, increased muscular excitability, the Chovstek's sign; similarly a decrease in critical fusion frequency (CFF) is often found (Ursoniu et al. 1973, Milkov, 1963).

A large-scale study recently carried out in Bulgaria (Apostolov & Vibranov 1973) on 2000 workers showed several neurological disorders: headaches, high excitability, sleep disorders, increased sweating, tremor of extended hands, nystagmus, coordination troubles, Romberg's sign, hyper- or hypoesthesia, more frequently hemihyper or hypoeshesis, dermographism. In 132 Ss out of 267 working in the aviation industry, neurotic or neurovegetative syndromes were found. The authors also found a biphasic evolution of the autonomic reactivity with the predominance of sympathetic functions, and when the noise level increased from 100 dB to 122 dB, a decrease and then a lack of reactivity of vegetative functions.

Dumkina (1965) observed in some persons working with automatic and manual turret lathes a reduced tone of the pupillary reflex to light, a slight nystagmus, and insufficient convergence (Table 7). More frequent and general are the symptoms connected to the reflectory area, associated to the general psychomotor reaction. These symptoms vary as a function of

Table 7

Frequency of neurological disorders in automatic and turret lathe operators. (after Dumkina, 1965)

Neurological symptoms	Turret Lathe Operators		Automatic Lathe Operators	
	Number	%	Number	%
Weak pupillary response and accomodation to light	5	4.4	2	3.3
Insufficient convergence	4	3.5	2	3.3
Asymmetry of the facial innervation	6	5.3	1	1.6
Nystagmüs	6	5.3	3	5.o
Increase of tendon reflexes				
in the hands	28	25	11	18.3
in the feet	22	19.6	7	11.6
Decrease of tendon reflexes				
in the hands	4	3.5	1o	16.6
in the feet	8	7.1	1o	16.6
Weak or lack of abdominal reflexes	6	5.3	6	1o
Tremor of outstreched hand	48	42	18	3o
Tremor of eyelids	36	32.1	16	26.6
Romberg's sign	15	13.3	13	21.6
Dystal hypalgezia	5	4.4	4	6.6
General hyperhydrosis	25	22.3	23	38.3
Dermographism,light,persistent	5o	7o.7	3o	5o
Acrocyanosis	4	3.5	4	6.6
Trophic alterations of the skin	12	1o.7	1o	16.6
Increased muscular excitability	5	4.4	4	6.6
Chvostek's symptom	39	34.8	2o	33.3
Symptom of oral automatism	11	9.8	6	1o

occupational characteristics, length of work in noise, etc.

Thus Reznikov (1966) shows in a study on dye makers the instability in Romberg's sign in 45.2% of the workers, dermographism in 53.6%, etc. Again Dumkina (1966) in turret lathe workers, exposed to 82-87 dB and 92-99 dB noise, found either an increase (in 18-25%) or a decrease (in 7-16%) of the deep reflexes, a slight decrease of pain sensitivity, instability of Romberg's sign, a higher rate of Chvosteck's sign (33.3%).

Inhibition of the autonomic nervous system (ANS) is a usual consequence of noise (over 95 dB) exposure, characteristic of the preclinic stage. Frequently, thermoregulatory disorders are found (Haimovich 1960, as cited in Andreyeva-Galanina et al. 1972, Cadariu et al. 1966) which increase as a function of noise exposure duration; sometimes even alterations in cutaneous temperature topography in the form of a "mosaic."

Dumkina (1966) noted hyperhydrosis, general (in 22-38%) and distal (in 32-50%), constant red dermographism (in 50-70%), acrocyanosis, etc. She also found that the reactivity of skin capillaries to mechanical stimulation and to the subcutaneous injections of adrenaline and histamine was characterized by lability and a tendency to rapid reduction and exhaustion. The vegetative vascular reflexes (ortoclinostatic and oculo-cardiac) were adequate but exaggerated, or negative and insufficient. Barhad et al. (1969) found that in the morning the ortostatic reflex was completely lacking in 132 workers exposed to the joint action of a 98-127 dB, 40-15000 Hz noise and vibrations of 800-2200/min, and amplitude of 177-1300 microns. Andreyeva-Galanina et al. (1972) found alterations, often paradoxical ones in the oculo-cardiac reflex (lack of the pulse reaction), and concomitantly an increase in the ortostatic reflex. In persons working for a long time in noise, they found hyperactivity of the sympathetic segments of the nervous system, expressed through the inhibition of the pilomotor reflex. These symptoms are clearly manifested in workers exposed to the high frequency noise (over 10 KHz) in weaving mills (Reinhold et al. 1972).

According to Andreyeva-Galinina et al. (1972), Angeleri et al. (1972), and Suvorov (1972), these alterations can be integrated into 2 main syndromes--the astheno-vegetative and the astheno-neurotic. The rate of appearance and their severity increase as a function of noise exposure duration and intensity.

Many authors agree, however, that there is no correlation between neurosis and occupational hearing loss. The coincidence of an asthenic-hysteric syndrome occurring after long-time noise exposure in Ss with neurotic symptoms, as a decrease in psychophysical output in Ss with emotional lability suggest that intense noise can activate latent neuroses (Berner 1965, Angeleri et al. 1969) and may represent an aggravating factor of an already existing neurosis (Cosi 1973). There are though data (Sirl 1969) showing that even a moderately intense noise (65 dB) induces neurotic feelings (as determined by means of the Knobloch neuroticism questionnaire).

2.3. Electroencephalographic (EEG) changes

There are relatively few studies about EEG characteristics in animals and even fewer in workers systematically exposed to noise.

Current data show that there are characteristic alterations in the EEG. Thus Angeleri et al. (1969) found desynchronized tracings of a labile type in persons working in weaving mills and metallurgy plants, who were exposed an average of 12 years to 80-100 dB noise with concentrations of energy in the 4200-9600 Hz range. Drogichina et al. (1965) found differences in the background EEG between noise-acclimated persons and a control group. In the former, the alpha index was smaller by 20% in 4 of the Ss, in 2 of them it was missing completely; in 6 Ss a long-lasting theta activity was noticed. Under noise action, after the habituation of the orienting reaction, the slow waves predominated thus corroborating previous studies (Dimov et al. 1960) on long-term noise-exposed workers.

Apostolov and Kiriakov (1973) reported the results of the EEG examinations of people working in a weaving mill (steady, 103 dB, broadband noise) and a metallurgy plant (impulsive, 110-113 dB noise), who were subjected to different functional tests (hyperventilation, etc.). It was found that the EEG presented pathological modifications (among others a decrease of amplitude under 30 uV) in 75% of the cases, being more frequent (86%) in weavers than in metallurgical workers (68%).

Other authors (Horvat et al. 1964) found in riveters submitted to the joint action of noise (110-115 dB) and vibration a normal tracing in only 1 out of 12 subjects. The remaining 11 bioelectrical tracings were flat, arhythmic, and of low amplitude. The alpha rhythm was practically absent. A weak reactivity was found in case of hyperpnea and intermittent light stimulation. Further investigations on 25 operators from a thermal power station subjected to 91-98 phons of noise also showed EEG alterations, such as: interhemispheric asymmetry, irritative discharges localized in the left posterior temporal area and a marked reactivity to hyperpnea and intermittent light stimulation (Horvat et al. 1969).

French authors report similar results. Thus, Bugard et al. (1964) found flat EEG tracings and general disturbance of cerebral electrogenesis in subjects with symptoms of chronic fatigue associated with impaired hearing.

The results of EEG investigations, although pointing to a certain cerebral dysfunction, are still too few and unsystematic to allow a firm conclusion about noise effects on the brain bioelectrical activity.

3. Effects of noise on the cardiovascular system (CVS)

Alterations in the functional state of the CVS were noticed by many authors, either in laboratory studies (Fuchs-Schmuck 1966, Fuchs-Schmuck & Simon 1969, Quaas 1970, Quaas et al. 1970, Jansen 1973) or directly in industrial settings (Krasilishchivkov 1967, Grandina & Constantinidis 1969, Pawlicka, Kalicinski, Kordecki, Nowak, Proniewska & Simonowicz 1972), although some authors did not find significant changes in blood pressure (Hrubes 1966, Menishov & Zagurskaya 1971) or in the electrocardiogram (Chemin et al. 1970). An important though disconcerting point is that the direction of these alterations is not univocal. However, this fact fits in with the wide individual differences observed in hearing as well as in all other reactions towards noise. Moreover, it was established that the cardiovascular modifications depend on age and noise exposure duration, less on noise intensity and spectrum.

Meinhart & Renker (1970) compared 207 persons with different noise related ailments to a representative sample from the community at large. They found that in the noise group 28.9% suffered from cardiovascular troubles, as compared to 7.59% in the control group. These disorders were classified into hypertension, hypotension and vegetative cardiac disease. The cardiovascular alterations began after 5-10 years of exposure to noise and the number of ill persons continued to rise steadily for those exposed up to 20 years. For those exposed for more than twenty years a qualitative leap occurred. It was suggested that noise-induced CVS dysfunctions could lead in time to hypertension and to a coronary insufficiency (Rusinova & Radionova 1968).

An important question was whether there is a connection between the lowering of auditory acuity (due to cochlear neuritis) and circulatory disorders (Shatalov et al. 1969). This investigation was carried out on 806 workers exposed to 90-120 dB broadband high frequency noise from mechanical engineering and synthetic fibers plants and showed that the auditory troubles were preceded by clear-cut increases in arterial pressure. After an initial hearing loss was diagnosed, no further significant changes in arterial pressure occurred. The variations of maximum and minimum arterial pressure as a function of the hearing state and of age, in females and males, are shown in Table 8.

3.1. Shifts in CVS as a function of the physical and temporal characteristics of noise

It has often been stated that intermittent noise has a more detrimental effect than a continuous one on performance efficiency and on health.

Table 8

Blood pressure changes depending on hearing acuity

(modified after Shatalov et al 1966)

Hearing acuity	Up to 40 years of age							over 40 years of age						
	No Ss	Maximum			Minimum			No Ss	Maximum			Minimum		
Men		Mean	σ	t	Mean	σ	t		Mean	σ	t	Mean	σ	t
Unchanged	234	120.5	13.4	2.7	75.5	10.9	1.7	76	130.5	21.9	5.3	83.6	12.4	3.7
Diminished: slightly	87	122.5	14.4	3.1	78.0	10.6	3.0	91	127.5	14.9	5.4	71.2	15.2	1.7
average	13	121.5	9.9	1.8	76.9	9.5	1.3	42	130.5	16.6	5.2	81.2	10.5	2.7
considerably	-	-	-	-	-	-	-	-	-	-	-	-	-	-
control goup	63	115.8	11.99	-	73.3	8.3	-	26	113.0	11.06	-	75.1	8.3	-
Women														
Unchanged	152	121.9	11.8	6.4	77.6	8.4	6.2	45	182.0	22.3	1.7	80.7	11.43	1.3
Diminished: slightly	35	123.1	10.9	4.9	78.3	8.4	4.3	25	135.2	28.9	1.7	80.8	10.8	1.2
average	-	-	-	-	-	-	-	6	133.0	23.4	1.1	81.7	9.84	1.0
considerably	-	-	-	-	-	-	-	-	-	-	-	-	-	-
control group	98	112.5	11.18	-	71.1	8.1	-	23	122.8	20.2	-	76.9	115	-

Shatalov (1965) compared the hemodynamic shifts evoked by continuous 85-95 dB, 114-120 dB and 105-122 dB broadband high frequency noises(Group 1, 368 workers) with those evoked by an intermittent, broadband, 85-111 dB noise (Group 2, 221 Ss). He found that Ss subjected to continuous noise manifested vascular dysfunctions (labile arterial tension, downward trends in venous pressure, reduced peripheral resistance, bradycardia) while Ss in intermittent noise manifested different symptoms--tendency toward hypertension (rising arterial pressure, increased velocity of the pulse wave propagation in elastic type vessels, and more frequent occurrences of capillary spasm).

Mariniako (1966) noted that in workers at test stands, subjected to intermittent and pulsed noise the arterial pressure either diminishes (more often) or increased, but that after the first half hour a partial recovery often occurred. A gradual heart rate deceleration (up to 56 beats/min.) set in after 3 1/2 hours of work and continued to the end of the shift.

Svistunov (1969) also found a prevalence of hypertensive symptoms in persons working a short time in noise. In workers subjected to intermittent noise (generated by electrical machines) there was a threefold increase in arterial pressure as compared to those working in other noises.

Several studies carried out on workers exposed to noise of various spectra showed that broadband noises have no differential effects on the CVS of either adults (Janicek & Folprechtova-Stenzlova's 1967, studies on 486 foundry employees) or adolescents (Ponomarenko 1966).

Studies of the variations of arterial pressure and heart rate in clino- and ortostatism during the working day in 132 boilersmiths (exposed to 90-127 dB braodband noise, and to vibration with a frequency of 800-2200/min and an amplitude of 177-1300 microns) show either an acceleration (in 53-42% of the Ss) or a deceleration (in 39-46% of the Ss) of heart rate, as well as an increase or a decrease of the arterial pressure (Barhad et al. 1969). Their findings corroborate data provided by other authors with respect to the CVS lability, associated to functional alterations of a spastic-atonic type (as stated by Dumkina 1966, in 172 turret lathe workers).

EKG modifications are usually not significant and are often equivocal,showing either a shortening or lengthening of the R-R interval, an increase of the electric systolic time and of the systolic index, and a displacement of the S-T segment higher or lower than the isoelectric line (Andreyeva-Galinina et al. 1972). In textile workers Krivoglaz et al. (1967) found a diminished amplitude of EKG waves, an anomalous change of the T wave, and an increase of the systolic phase duration (QRST). These data were associated with certain characteristic physical symptoms (a slight increase in the dimensions of the heart cavities, a functional systolic sound at the peak of the heart) and suggested that these persons suffer from a distrophy of the myocardium often associated with an arterial hypotension. Maugeri and Odescalachi (1968) found that for people with unquestionably diagnosed cardiopathies, especially with infarct, pathological EKG shifts are accentuated after long-term noise exposure.

Recently, Evdokimova et al. (1973) carried out a large-scale investigation in a tire plant. The 194 investigated persons were divided into four groups according to intensity and type of noise exposure; Group A--56 were exposed to a 85 dB continuous noise; Group B--61 were subjected to a continuous noise of 108 dB; Group C--40 were exposed to a 82 dB noise, but 13% of the time they heard impulses of 94 dB, which made an equivalent noise of 87 dB; Group D--37 worked in a 91 dB background noise but 20% of the time an intermittent noise was heard too, which raised the equivalent SPL to 96 dB.

The rheoencephalogram recorded in the fronto-mastroidian lead showed alterations of the cerebral hemodynamics in 60% of the Ss, but the characteristics differed in the various groups.

Thus, in Group A, the rheographic index (RI) increased (RI = 2.82) and the alpha index (AI) also increased (AI = 12.8); in Group B, RI = 1.61, AI = 9.7. In Group C, RI increased, but had a different shape than in Group A; in Group D, RI decreased and AI increased.

It follows that the joint action of continuous noise and physical work load evoked functional changes of an hypertensive type, particularly with respect to the alterations of the arterial tone. In the case of the 108 dB noise, the functional shifts increased at the expense of a decrease in the venous tone and a difficult venous backflow.

Thus it is suggested that the hemodynamic is of an atonic (asthenic) type and that noise has a direct action in the vasomotor center (also see Fusco et al. 1965, Maugeria & Odescalchi 1967).

3.2. Shifts in CVS as a function of age

In different age periods the CVS is differentially sensitive to noise stress. Two age periods manifest particular reactions; teenagers, and people over 50 years.

A great number of studies have been devoted to the study of teenager's CVS reactivity. Thus, Timokhina (1965) found in pupils apprenticed in a metallurgy plant, 3 hours/day for 3 years in a 95-105 dB white noise, a decrease in blood pressure. Their blood pressure did not return to normal until 3 hours after work ended. When noise was less intense (74-84 dB), no modifications were usually detected. Ponomarenko (1966) studied youngsters (15-16 years) trained as milling machine and lathe operators, subjected to a 85 noise with a concentration of energy between 1000-2000 Hz. He found that even after 1 hour of work there was a decrease of the maximal arterial pressure of about 8 mm Hg noticeable in 82% of the Ss, while the minimal arterial pressure rose in 72% of the Ss by 5 mm Hg on the average. A comparison between the values obtained at the end and at the beginning of the shift showed a deceleration of heart rate of about 17 beats/min, a diminishing of systolic pressure by 8.5% while the diastolic time and the time of the cardiac cycle increased by 0.17 and 0.20 sec., respectively.

Geltyshcheva (1972) emphasizes that noise-induced cardiovascular modifications depend not only on noise intensity, but very much on the activity characteristics. She compared 16-19 years old teenagers (lathe and milling machine operators) and found different trends in persons who make vs. those who make no physical effort during work; in persons who make physical effort the maximal arterial pressure decreased and the minimal arterial pressure increased, while in the other group there was a decline of maximal and a rise of minimal pressure. It was established that no complete recovery of the CVS occurred after 5 minutes of rest. In rheoencephalographic investigations she found a marked reaction on cerebral circulation in an 80 dB stable noise. This indicated that standard noise parameters set for adults are unsuitable for teenagers. The author suggested a maximum SPL of 65 dB as the most acceptable SPL for teenagers (Geltyshcheva 1971).

These results are corroborated by Tsysar's (1967) research on the joint action of braodband noise (81-58 dB) and vibrations on 98 young workers (16-18 years old) and in pupils (15-17 years old) in a training school. The author found only very slight shifts in the CVS during the day, but during the load task the systolic pressure of those Ss exposed only to noise rose by 19% while the diastolic one was lowered by 15%. Similar recordings repeated 1 year later showed no modification in heart rate, a slight (less than 5 mm) decrease of blood pressure (systolic and diastolic), but the pulse recovery time and the arterial pressure during the day increased more in Ss exposed to noise and vibrations (4.5-4.7 mm) than in those subjected only to noise (3.5-3.6 mm).

Thus, teenagers' CVS reacts toward the joint action of noise and vibration through a relative lowering of the recovery capacity and the heightening of functional inertia to the standard effort, without modifications in heart rate and blood pressure during the course of the working day.

Detailed statistics of blood pressure dynamics over a 5-year period were evaluated on a sample of 846 operators (mostly women) between 16-47 years working for 1-5 years in winding and weaving mills, under a 99-102 dB and 87-88 dB noise. A comparison with a control group selected from the local population showed no differences as a function of noise intensity (Table 9). However, an analysis of variance applied to the data showed statistically significant differences in shifts of the systolic pressure for age groups 16-19, 30-39 and 40-49 years (Andrukovich 1965).

Another study was performed in mechanical engineering plants by Pokrovskii (1966) on 995 workers. They were divided according to the noise they were exposed to. Group A (408 Ss) had been exposed to 80-85 dB of steady noise with minimal energy in the mid-frequencies, while Group B (587 Ss) had been exposed to high frequency, 90-95 dB, impulse noise. Table 10 shows the shifts in arterial pressure in the 2 groups according to age. In Ss within the range of 17-20 years there is a predominant decreasing trend (hypotension, etc.). The diastolic pressure does not vary depending on noise. Thus, the blood pressure may shift in both directions under noise influence.

Rusinova and Radionova (1968) in an 8-year follow-up study on spoolers subjected to mid- and high frequency, 92, 117 dB noise found a higher level of hemodynamic pressure and an increased lability in the load task. The most unfavorable indices were exhibited by workers over 40 years old, in whom essential hypertenstion appeared twice as frequently as in other workers, of the same age, but working under different conditions.

It was also established that the blood pressure dynamics on different shifts varied as a function of age (Skok 1964). Between 30-39 years there were only slight modifications from one shift to another but in other age groups the highest rate of alterations occur during the morning shift.

3.3 Shifts in CVS as a function of noise exposure duration

Drogicina et al. (1965) made a comparative investigation on a control group, nonadapted to noise and on persons working for a long time in noise and in whom asthenic and vegetative dysfunctions had been established. They showed that shifts in heart rate and blood pressure are different for those exposed to a 110 dB, high frequency noise. In noise-accustomed Ss, a heart rate acceleration of 15-30 beats/min. and a

Table 9

Dynamics of blood pressure over 5 years as a function of age (after Andrukovich, 1965)

Category	Age	no subjects	Hypertension % against age				Normotensive	Hypotension % against age				Mean values in mm.	
			systolic	systolic + diastolic	diastolic	Total		Systolic	systolic + diastolic	diastolic	Total	M	σ
Textile worker	16-19	1o9	-	o.9	-	o.9	78.8	7.1	8.1	5.1	2o.3	1o4/62	9.8/7.9
	2o-24	126	o.8	1.5	o.8	3.1	67.9	1o.o	12.7	6.3	29.o	11o.1/65	1o.6/8.3
	25-29	176	1.2	1.7	-	2.9	7o.7	11.1	1o.2	5.1	26.4	11o.5/65.3	9.9/7.9
	3o-39	292	2.9	3.3	2.9	9.1	67.o	12.o	7.o	5.o	24.o	115/71	12.1/8.1
	4o-49	143	6.3	12.6	6.3	25.2	71.7	-	3.1	-	3.1	119.8/74	12.2/8.2
Local population (females)	16-19	1313	o.1	-	o.4	o.5	63.8	21.6	9.o	4.3	35.7	98.6/54	9/9.8
	2o-24	2o26	o.1	o.3	1.o	1.4	53.2	15.7	15.3	14.4	45.4	1o7.o/64.1	11.5/5.9
	25-29	1174	o.5	-	1.2	1.7	53.o	15.o	16.3	14.o	45.3	1o5.4/64.5	6.3/9.1
	3o-39	267o	2.4	2.4	3.o	7.8	63.o	11.3	1o.5	7.4	29.2	111.4/66.2	14./11.5
	4o-49	1789	12.5	7.2	3.3	23.o	54.6	7.3	7.2	7.9	22.4	117.3/68.8	146/11

Table 1o

Blood pressure alterations depending on age and noise characteristics (after Pokrovski, 1966)

Groups	Age							
		7 - 2o years		21 - 3o years		31 - 4o years		over 41 years
	No subjects	Number of subjects with deviations of blood pressure from the norm	No subjects	Number of subjects with deviations of blood pressure from the norm	No subjects	Number of subjects with deviations of blood pressure from the norm	No subject	Number of subjects with deviations of blood pressure from the norm
Group A (8o-85 dB, stable noise)	58	8(13.8± 4,53%)	165	18(1o.3±2.36%)	137	12(8.8±2.37%)	48	6(12.5±4.76%)
Group B (9o-95 dB, impulse noise)	42	12(28.6±6.97%)	212	46(21.7±2.83%)	2o6	33(16.6±2.55%)	127	18(14.1±3.o8%)
t		1.66 (1.66%)		3.o8		2.o6		1.o35
p		89.o%		99.7%		95.4%		68.3%

constant blood pressure were recorded. On the other hand, those not exposed to noise exhibited only slight heart rate modifications (an increase of 3-9 beats/min.), but a heightening of systolic (by 20-25 mm) and disastolic (by 10-15 mm) pressure.

Still, Elias (1971) comparing peripheral blood circulation in boilershop workers and a control group exposed to industrial noises of 110-112 phons, did not find differences in the plethysmograms between the groups. No particular characteristics which could point to adaptive modifications brought on by habituation to noise were found in the workers. On the contrary, the same reactions were recorded in both groups. Hermann and Lentge (1967) also studied the adaptation of the CVS to work in noise. They compared truck drivers subjected about 78% of their working time to a 85-95 dB or higher SPL, depending on the type of the truck, but who previously had worked in quiet jobs (Group A), persons who had been driving trucks for a very long time (Group B), and a control group (C). For 10 years they recorded the blood pressure during the same month and found in 3.7% of the Ss (among them 3 older men) a clear-cut pathological increase, of over 140 mm Hg. In Group A, in 26.3% of the Ss they found a slight increase of blood pressure but in Group B this percentage is much lower, which shows that the low frequency noise present in trucks is not detrimental for the CVS. These data are detailed in Figure 9.

Relevant research is that carried out by Janicek and Folprechtova-Stenzlova (1966) on 944 foundry workers. Blood pressure recorded at the end of the shift showed that for workers exposed to up to 100 dB no significant differences arise as function of noise exposure duration. When the noise exceeded 100 dB, blood pressure rose significantly with increased noise exposure duration.

Shkarinov and Evdokimova (1970) studied the relation between the functional changes in the cerebral blood supply and the acoustic sensitivity to noise using rheoencephalographic techniques. They compared 2 groups of workers (176 persons): Group A were operators in grinding mills, exposed to 108 dB, steady noise; Group B were operators working with automatic machines, which generated impulse noises of 105 dB, complex spectra. It was found that the rheographic index decreased with noise exposure duration similarly for the 2 groups, but that after 11 years it diminished more in Group A. In Group B the same process occurred after 15 years of working in noise. The decrease reached the lowest point after 20-25 years. The alpha index also has a slight tendency to decrease with noise exposure duration. Important is the fact that the alterations

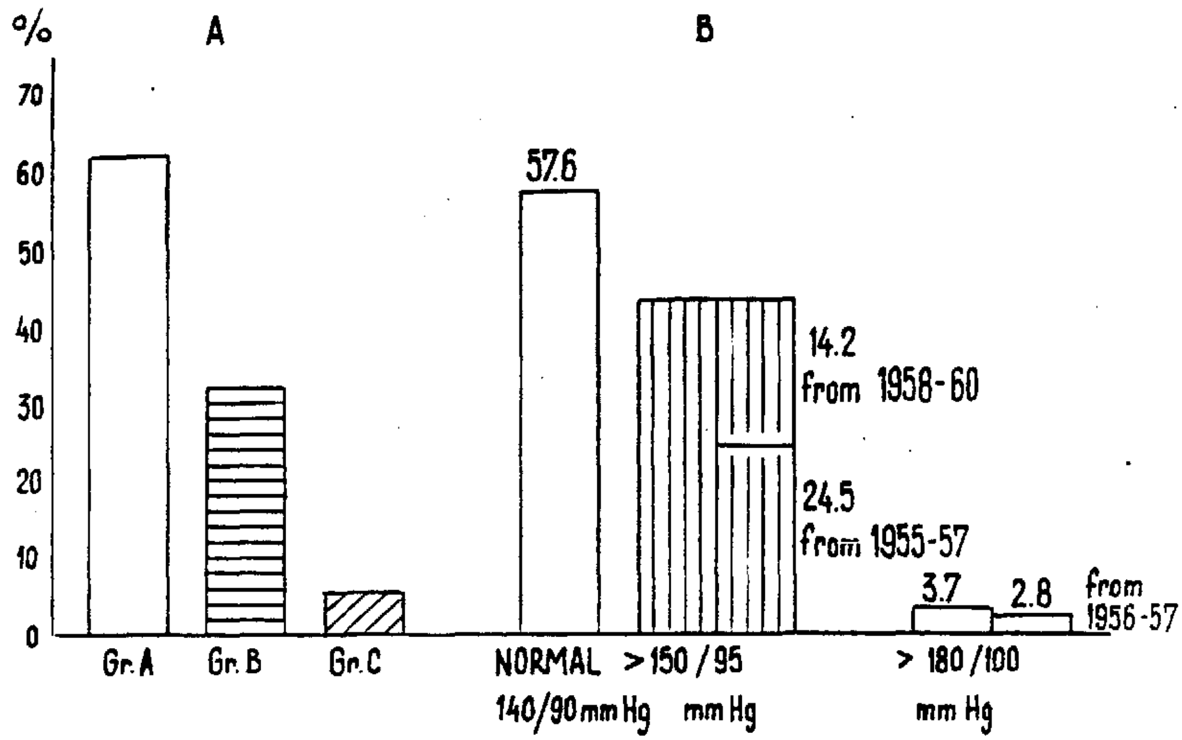


Figure 9. Noise-induced modifications of the cardiovascular system.

A. Percent of persons with different noise histories (see text);

B. Modifications in blood pressure depending on past noise history.

in cerebral blood circulation appeared earlier than alterations in the auditory system, the extent of these changes depending on the acoustic energy.

3.4 Alterations produced by noise in blood cell composition and blood coagulation

Some investigators have studied the effect of noise on blood cells, although this problem has been rather neglected in field studies, and even the laboratory ones are scarce. As one example, Kubik & Seres (1966) report that 85 dB of high frequency (1200-4000 Hz) noise elicited eosinopenia.

Experiments on animals exposed to relatively high frequency noise, 2000 Hz, 93-96 dB, show phasic changes of antithrombinic activity and an increase after 30-90 days, due to a heightening of free heparin (Mihailova & Byshevsky 1969). When comparing different noise intensities (80 and 96 dB) with respect to their influence on blood coagulation, it was found that at 96 dB the plasma tolerance for heparin increased, as did the prothrombin consumption (Mihailova 1971).

In a study on boilermakers exposed to a 85 dB noise, Ivanov (1969) found that the erythrocyte sedimentation rate decreased, but more studies of this type are still required to corroborate the results.

These field researches point up the fact that noise elicits functional cardiovascular dysfunctions which often precede functional modifications in hearing. Andreyeva-Galanina et al. (1972) consider that these dysfunctions are consequences of alterations in the reflex action of the nervous system which controls the circulatory system and which, in turn, can lead to more stable changes of the vascular tone. It seems (Taccola & Franco 1973) that in the angiospastic reaction provoked by noise other nervous centers (the diencephalic ones) also intervene.

4. Noise-induced alterations of other functions of the organism

4.1. Modifications of the digestive functions

Noise-exposed people complain often about digestive troubles, which amounts to an increased morbidity in this respect. A large-scale comparative study in a big mechanical engineering plant, where 10 sections similar in all respects (work characteristics, etc.) except the noise level (5 sections had a high, and 5 sections a low SPL) showed that workers exposed to intense noise exhibited a great incidence of gastrointestinal diseases (Maugeri 1973). It seems that the stomach is particularly sensitive to the harmful action of noise and Maugeri suggests that this adverse effects acts through psychological mechanisms of an emotional type.

Tarantola et al. (1968) found in the X-rays taken on a group of workers followed for 10 years, marked alteration of different parts of the digestive system in 65% of the cases, even after only 2-3 years. They stated that the most frequent diseases were the gastroduodenitis and the duodenal ulcers. The authors suggest that the joint action of noise and vibration elicit a gastrointestinal hypervagotonia.

Hermann and Lentge (1967) note the presence of digestive disorders in 3.8% of the truck drivers exposed for 40-78% of their working time to a 95 dB low frequency noise and who had formerly been exposed to noise (worked under noise conditions). An even higher rate of incidence (4.5%) was found in those who previously have been truck drivers, while an incidence of only 1.9% appears in the control group (Figure 10).

Krivoglaz et al. (1967) studied the secretory function of the stomach. They usually found a diminished secretion. An increased secretion was not found very often. In one-third of the examined persons decreased acidity was found, while an increase was rather uncommon. The fractionizing of the stomach content indicated a secretory inhibition in one-third of the patients. On the other hand, new laboratory studies involving short exposures (30 min.) to a 95 dB industrial noise and where the gastric acidity (pH) was determined by means of a radio-probe, without mechanically stimulating the stomach, showed in 7 out of 9 Ss a clear-cut increase of gastric secretion (Maugeri 1973). A similar finding was reported by Oginski et al. (1973) on animals exposed to the broadband, 100-130 dB noise of a pipe rolling mill.

It has also been established that the expelling function is affected by long-term noise exposure, particularly in the direction of its slowing down. X-ray examinations usually show a hypotony of peristaltic movements (Krivoglaz et al. 1967).

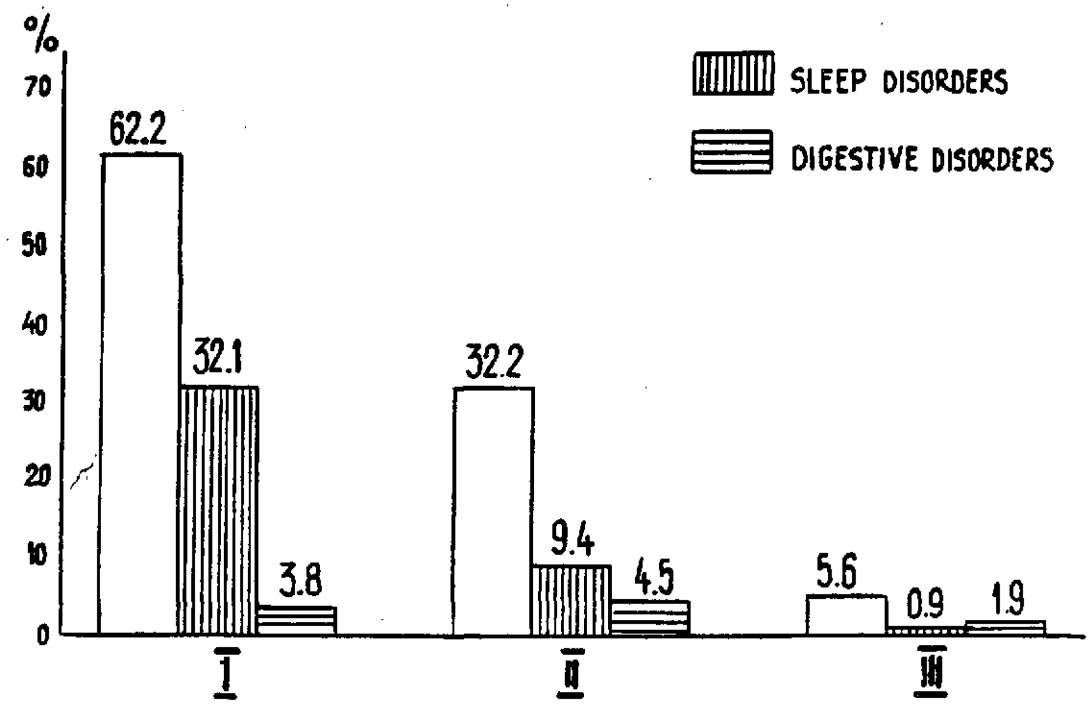


Figure 10. Noise induced gastrointestinal and sleep disorders in truck drivers. The white columns indicate the percent of persons referred to against the whole sample.

I. Individuals who previously have been working in noise;
II. individuals who previously have been driving their own trucks;
III. the control group.

Such divergence between field and laboratory studies are rather common and they show the need of further comparative studies.

4.2. Endocrine and biochemical modifications

The effects of noise on the endocrine system have been studied more in animals than in man, and more under laboratory conditions (pure sounds) than in the field. However, as an exception, in Romania much attention has been paid to the noise-induced changes of the normal biochemical and enzymatic processes in workers exposed in factories to industrial noises.

Neither in man, nor in animals has there been a concordance of results about the effects of noise, some authors finding a decrease in the hypophyseal adrenocorticotrophic activity (Bondarev et al. 1970, Sinitsina & Bondarev 1970) or an activation of the anterior pituitary and increase of the adrenocorticcotrophic hormone with a subsequent excitation of the adrenal glands (Favino 1973).

Investigations in 100 workers exposed to 40-10,000 Hz, 82-86 dB noise, and peaks of 105 dB due to impulses associated with vibration (600/min., 167-200 microns), show that after 4 hours of work there is an increase of 53% in noradrenaline excretion as compared to a control group ($t = 2.3$, $p < .02$) and a 42% increase in adrenaline. Total catecholamines rise by 31% and the adrenaline/noradrenaline ratio diminishes by 21% when compared to the initial level (Anitescu et al. 1973).

In another, 80 workers (welders, grinding machines operators, etc.) exposed to a 98-127 dB, 40-10,000 Hz noise and to vibrations, after 4 hours of work a significant increase (28%, $t = 3.2$, $p < .01$) was found in the values of the vanylmandelic acid compared to the initial morning values; a decrease of 15% of the 17-ketosteroids as well as creatinuria was also found. After a nights rest, in the noise-exposed Ss, ketosteroid level is still diminished by 15% as compared to the control group (Anitescu & Contescu 1972).

Favino et al. (1971) studied supervisors exposed to a 90-95 dBA and workers exposed to a moderate (60 dBA) level in a wool carding section. They found that as compared to values measured in the morning there was a decrease in corticosteroids later in the day for the supervisors and much lower levels for the worker. Similar results were reported by Cadariu et al. (1968) in a laboratory study using pure tones. He found a decrease in 17-OHCS in 52-76% of the Ss.

Arguelles et al. (1962) state that the endocrine reactions to noise vary depending on mental health: neurotic (anxious) persons have more intense reactions than balanced ones, as shown by a clear-cut increases of 17-OHCS in blood plasma and of urinary corticosteroids. Schizophrenics had no reactions at all.

Changes in other hormonal functions were also reported. Miclescu-Groholski & Anitescu (1970) showed variations in amylasuria (a decrease) and amylasenia (an increase) after 7 hours of work under the joint action of noise (90-127 dB, 40 Hz-15 KHz) and vibrations, while other data show an increase in amylasuria in 41-65% of the Ss exposed to pure tones (Cadariu et al. 1968) and an initial increase of urinary amylase during the first hours of work (41.6 u.w.), followed by a rapid decrease towards the end of the working day (11.5 u.w.) (Cadariu 1973). Thus, the duration of noise exposure seems to play an overwhelming role in the direction of hormonal changes.

Alteration in blood sugar have also been reported. Thus, under the joint action of noise and vibration on board ships, Rumiyantsev and Mehel'son (1971) found an increase in blood sugar during the first 15 days (from 96 to 106 mg%) and a subsequent decrease (to 81.9 mg%) under further noise and vibration exposure.

Anitescu et al. (1973) found in field investigations a significant increase of 34% in the urinary K+ and A. Constanta et al. (1971) showed in healthy workers exposed to the joint action of noise (98-127 dB, 40 Hz-10 KHz) and vibration an increase of 20% in acid phosphatase after 7 hours of work. This indicates a dysfunction of the anaerobic metabolism of glucides.

Basic metabolism changes have been noted as a result of noise exposure, but Pinter (1969) emphasizes that they vary according to differences in the autonomic nervous system. In a sample of Ss suffering from the Basedow disease there is first an increase and then a decrease, while in persons with characteristic vegetative dystonia there is a progressive increase of the basic metabolism.

Among the symptoms of noise sickness, body weight loss is one of the most general. It had already been found in animals that an intense (106 dB) noise leads to an inhibition in growth and a loss of body weight of 15-57% in comparison to the control group (Sheitanov 1965). A complex experiment was set-up to test this question on human beings by Udalov et al. (1967). They found that after 3 hours of noise exposure (110 dB, broadband noise with a concentration of energy in the 150-3000 Hz range) and a meal very rich in proteins and vitamins the nitrogen metabolism remained invariable. Significant changes appeared though in the metabolism of the aminoacids: whereas after a meal their amount is usually augmented, under noise conditions their amount diminished (particularly the glutamic acid) and was smaller than in the control group which had not received the special meal.

An important decrease in vitamins of the Group B was also found. No significant differences in performance due the enriched diet could be established. These results suggest that an increased protein and vitaminic value of the meals could have beneficial effects in preventing noise sickness but that immediate effects on performance are hardly to be expected.

5. Summary Comments

The data presented in this section point to an increased morbidity in noisy industrial settings in comparison to quieter ones. Predominantly noise adversely affects the neuro-vegetative system, eliciting functional disorders which also influence the neuro-psychological homeostasis. The neuro-vegetative dysfunctions often lead to, or favor the appearance of neurotic cymptoms, frequently of an esthenic type. Up to now no proof has been offered that noise directly induces neurosis.

Linked to the neuro-vegetative disorders are the alternations observed in the cardiovascular system both peripheral and central although with respect to the latter precise data are still lacking. Functional changes have been observed in the electrocardiographic tracings, too.

Digestive, endocrine and biochemical dysfunctions have also been noticed, and many observations have been made concerning noise-induced disturbances of other functions of the organism.

All these alterations are dependent on the physical and temporal characteristics of noise as well as on the exposure duration, age and job characteristics of the persons working in noise.

The results of the investigations undertaken in order to elucidate the adverse effects of noise on health in industrial setting are still fragmentary and insufficiently precise. They substantiate though the suggestion that health is endangered by long-time noise exposure even before modifications in hearing are seen. The most well-grounded conclusion still seems to be that noise provokes an imbalance of the biological homeostasis which in the long run could lead to pathological alterations.

IV. A short survey of the influence of ultrasonics and infrasounds on man

Ultrasounds and infrasounds of high intensity are increasingly often met in industrial settings, but their biological action on man is only beginning to be recognized (see Kaprova, Alexeyev, Kadyskin, Suvorov, Malyshev & Pronin (1972). There are still very few studies devoted to the analysis of their action and many more are required in order to get a comprehensive view of their psychophysiological effects.

Complaints about the effect of ultrasounds can be fairly frequent. This was shown by Milkov et al. (1968) in an investigation on 224 workers of 20 plants, exposed to a spectrum ranging from 18 to 23 KHz, more frequently 20 KHz and a mean SPL between 89-112 dB. The most frequent complaints of these persons are headaches, vertigo, fatigue, and high irritability.

Roshchin et al. (1967), in a clinical study on over 300 persons exposed to ultrasounds (20-25 KHz, 120-130 dB) or high frequency sounds, 12-20 KHz, 70-100 dB, with a concentration of energy at 16 KHz, transmitted through air and/or a solid medium, found frequent and strong headaches, located particularly in the frontal, nasoorbital and parietal areas (55%), increased tiredness (48%) which appeared immediately after starting work, drowsiness during the day and very deep, but interrupted, sleep at night (68%). In one-third of the workers, a change in excitability (an increase or a decrease) was observed. Young workers complain about memory loss, especially of recent events, hyperosmia, and strong photophobia.

In workers subjected to ultrasounds (21 KHz, 110 dB) who complained of headaches in the frontal and parietal areas that intensified after 2-3 hours of work in noise, the synchronization of the EEG tracing occurred simultaneously with (1) the slowing down of the rhythm by 1-2 c/sec, (2) an increased amplitude, and (3) a hypersynchronism of the alpha rhythm (Apostolov & Kiriakov 1973).

Roshcin et al. (1967) state that there are clear-cut alterations of central and autonomic neurodynamics in ultrasonic exposed people. They found in these persons higher (and only seldom lower) auditory, visual and vestibular pain thresholds, which shows a decrease in active cortical inhibition and an increase in the defense inhibition. They also noticed in those with a long work history under such conditions important symptoms of neurological disorder--the diencephalic syndrome: thermoregulatory alterations (feverishness or chills, thermoasymmetry), anorexia attaining complete indifference toward food, etc., and sometimes a sensation of insatiable hunger. Very often sympathicohumoral and metabolic alterations are encountered. An increased muscular mechanical excitability, changes in the basic metabolism with a weight deficit up to 8-10 kg.. and hypoglycemia, was shown by Ashbel (1965) who noticed a decrease of blood sugar from 82 mg% to 66 mg%, etc. After being subjected to ultrasounds (115 dB, 25 KHz), an initial eosinopenia is replaced by a 30% increase in the amount of easinophils (Grognot 1965). In people subjected to ultrasounds (with an average of 20 KHz), nervous system disorders of the vascular vegetative dysfunction type, varying as function of SPL, were found (Milkov et al. 1968). This can be seen in Table 11.

Workers exposed to ultrasounds manifest specific cardiovascular symptoms. Thus, Ilinitskaya & Palitsev (1973) found in workers subjected to a 21 KHz, 110 dB noise decreases of arterial pressure up to 114-106 mm, pulse deceleration (to 79-67 min.) and electrocardiographic (EKG) alterations. The latter included a decrease of wave P amplitude in 80% of the observations, an increase of T wave in 91% of the observations and slight modifications of the P-Q segment. Changes in the morphology of PR and QRS waves of the cardiac cycle and an inversion and reinversion of the. T wave were reported also by other authors under the action of ultrasounds (98-160 dB, 18-20 KHz). Very significant is the fact that opposite modifications of the EKG were recorded in persons supervising the acoustic devices vs. those who made physical efforts, which suggests that a psychological factor is involved in this differentiation (Yiazburskis 1971).

The systematic investigations of Roshchin et al. (1967), already mentioned in connection with the ultrasound-induced nervous system alterations, show in 46% of the Ss a deficit of the vascular tone, and a disturbance of cutaneous-vascular reflexes associated with the vaso-motor reflexes. In the EKG a slowing down of the QRS conductivity was established.

In an attempt to systematize the results, Roshchin et al. (1967) distinguish 3 stages in the development of ultrasound-induced disorders: (1) a preclinical stage characterized by fatigue, drowsiness, certain vestibular shifts, and initial neuro-circulatory alterations not yet pathological; (2) the initial stage of the disease, when central nervous system and diencephalic alterations are still reversible; and (3) finally, a stage where the sickness symptoms are clearly manifest, when the diencephalic paroxism is associated with vestibular and brain stem disorders. In this stage the vegetative polyneuritis, the muscular atrophy and other trophic disorders are well represented.

Table 11

Frequency of neurological symptoms (%)(after Milkov et al.1963)

Basic symptoms	Group A (53 Ss) 1o7 - 121 dB	Group B (47 Ss) 81-1o2 dB	Group C (81 Ss) 7o-98 dB.
Inhibition of cochlear reflexes	47.2	38.3	49.4
Inhibition of abdominal reflexes	28.3	2o.8	4o.7
Threshold shift of pain sensitivity	45.3	29.8	22.6
increased	15.1	8.5	12.7
decreased	3o.2	21.3	9.9
Alteration of vibration sensitivity	34.o	43.2	39.2
increased	5.7	16.2	14.9
decreased	28.3	27.o	24.3
Alteration of the vestibulo autonomic reaction	68.o	49.6	74.5
increased	3o.5	19.2	28.2
decreased	37.5	3o.4	46.3
Alteration of cutaneous temperature	24.1	35.7	24.1
increased	24.1	7.1	2o.7
decreased	-	28.6	3.4
Alterations of the capillaries	66.6	67.7	84.2
contractions spastic tendencies	6o.o	38.7	47.3
atonic spastic state	6.6	9.7	31.6
lack of tone and tendency toward lack of tone	-	19.3	5.3

Finally, it should also be mentioned that performance modifications were noticed. Thus, Dobroserdov (1967) studied the effects of low frequency ultrasounds (20 KHz) and high frequency acoustic oscillations (12.5-16 KHz) on lathe operators. He found that RT varied as a function of SPL: ultrasounds of 120 dB, and high frequency 100 dB noise elicited a significant increase in motor latency, a much smaller increase was found at intensities of 100 dB and 80 dB, respectively. It can therefore be stated that ultrasounds (120 dB) are physiologically active and cannot be discarded as having a biologically indifferent influence.

Even less data are available about the effects of infrasounds. People exposed to the action of infrasounds complain about fatigue, sleep problems, headaches, etc., but Andreyeva-Galanina et al. (1970) consider that these symptoms cannot be associated solely to the infrasounds. A complex study of the biological effects of infrasounds (3-48 Hz, 60-70 dB) was performed by French investigators in an industrial enterprise, for 4 months (Fecci et al. 1971). The authors investigated the circulatory, respiratory and endocrine functions as well as blood reactions and found no pathological shifts, although differences were noted between the working days and the weekend. For example, EKG alterations and statistically significant differences ($p < .01$) between the values of blood pressure and heart rate at rest (Monday after 48 hours of rest) and during work periods were noted. Similarly, infrasounds induced significant decreases of 17-ketosteroids during activity vs. rest (13.54 mg vs. 14.04 mg, $p < .05$). The chief alterations were found in the CNS and expressed in the EEG such as sleep tracings, particularly of Type I (drowsiness) and sometimes Type II. Of the 50 Ss investigated, 7 exhibited total lack of sleep; 1 headaches and neurotical feelings; and another, restless sleep and neuroticism.

The facts stated in the few investigations carried out in ultra- and infrasound effects preclude any firm conclusion. Apart from certain EEG particularities (which require further confirmation) there seems no specific reactions to these sound frequencies at high or low SPL, when compared to the audible frequency range at rather high intensity.

V. Absenteeism, accidents, and turnover due to noise

Only few data are available at present concerning noise-induced accidents in industrial settings. There are data which suggest that persons working in noise and more or less afflicted by hearing loss are not more accident prone than normal hearing people (Schwetz 1966). Job analyses of noisy workplaces in a petrochemical plant do not evidence more accidents than in quieter sections (Toader 1973).

Hartig (1966) comments that even though only few examples of noise-induced accidents have been reported as yet due to failure of attention, their possible occurrence certainly cannot be excluded.

In order to check the relationship between noise exposure and accidents in a big factory, Quass (1970) followed a group of persons working in noise and a control group for 5 years. He found a significant higher weighting of the "inattention" factor in generating accidents in the noise-exposed group than in the control one. Maximal statistical significance was reached at certain years (2, 10, and 11), at certain hours of the shift (2nd and 6th) and on certain days of the week (Monday and Saturday). The possibility that the accidents were brought forth by otological components (unheard signals) could not be verified and was ruled out.

Data about turnover are also extremely scarce. One investigation showed that 80% of the workers leaving a chemical plant blamed noise as one of the main reasons. As a matter of fact, comparative statistics over 3 years (1970-1972) on compressor workers (exposed to intense, 90 dB noise) and mechanics shows in the former a turnover index of 1.9, 4.6, and 4.7% vs. 27.5, 24.7, and 23.1% in the latter (Toader 1973).

More studies have been devoted to absenteeism, but data vary depending on the industry, on the interaction of noise with other noxious agents, etc. Odescalchi (1967) reports that in a group of 50 Italian industries (textile, steel and mechanical), the number of absences is annually higher by 14-15% in those where an intense noise is prevalent, than in the other, quieter ones. The indirect cost of this absences is about 700 million lire a year for about 2000 workers of medium qualifications.

A recent study of sick leave in workers in a chemical plant for 1972 and 1973 yield very inconclusive results when comparing those working in noise and a control group. In 1972, 20.97% of the workers exposed to noise had sick leaves vs. 32.50% in the control group, with 9.39 vs. 8.12 days lost/year;

in 1973 30.64% of the workers in the noise group had sick leave vs. 20% of the control one with 8.52 bs. 7.25 days lost/year. No statistical significant differences were found between the noise and the control group. One possible reason for this result was the fact that the persons in the latter group were exposed to other noxious factors (Gulian 1974).

A study of absences as a function of their causes was performed by Nardo & Majeron (1964) in a metallurgical plant in which workers were exposed to a 90-95 dB noise which reached 105-108 dB due to impulses. For their study they classified workers (85 Ss) according to their working place as follows: (a) the cold rolling section, mean age 35.3 years, 8% women; (b) the foundry section, mean age 31.7 years, 95% women; and (c) the mechanical section, mean age 36.2 years, 19.3% women. The authors found the highest rate of absences due to sickness in the cold rolling section, the highest rate of absences due to accidents in the foundry, and the highest number of absences due to leave in the mechanical section. In Table 12 absenteeism as a function of cause is presented and Figure 11 illustrates the evolution of absences due to sickness for the first 6 months of 1963. Finally, a detailed analysis of sick leave for a 1-year period showed that the number of absentees with firmly diagnosed organic illness was 187 (equivalent to 3445 days lost), while that due to psychoneuroses was 28 (equivalent to 814 days lost); the number of ill absentees in whom no organic prejudice could be found was 79 (equivalent to 1197 days lost). It emerges that a great number of the absences were due to neuroses, which at least partially can be attributed to the noxiousness of noise.

More recently, another follow-up study in the textile industry tried to classify the absentees according to sex, age and workplace (Ghezzi & Pucci 1969). Although no data relative to noise level are available in the study, it is well-known that in some sections of the textile industry the SPL is high, while in other sections, for example, dyeing and printing, noise is moderate in level. The data are collected from 44,308 industrial medical cards in 171 factories, absentees being estimated on the basis of the number of the working days lost by each worker. The average absenteeism due to all causes was 22.53 for men and 39.29 for women. Absenteeism for disease was responsible for more than half of the absences in the decade 1955-1967; in 1955--12.51; in 1957--17.68; in 1967--18.38. For men, leaves for disease in 1955 equaled 8.01, in 1967--13.03; for women, in 1955 they were 13.82, in 1967--21.66.

Also, absences due to accidents increased from 0.79 days in 1955 to 1.19 days in 1967. Table 13a and 13b describe the distributions of absences as a function of workplace,

Table 12

Number of absences in the first 6 months of year (days lost/worker) (after Nardo & Majeroh, 1964)

Month	Disease			Accidents			Leaves		
	Cold rolling	Foundry operator	Mechanic	Cold rolling	Foundry operator	Mechanic	Cold rolling	Foundry operator	Mech[illegible]
January	2.86	2.64	2.22	0.12	0.46	0.07	0.21	0.16	0.3[illegible]
February	3.16	2.61	2.36	0.08	0.40	0.08	0.16	0.17	0.[illegible]
March	4.35	3.09	2.90	0.22	0.45	0.10	0.22	0.13	0.3[illegible]
April	3.11	2.24	1.59	0.26	0.30	0.09	0.58	0.28	0.[illegible]
May	2.29	2.27	1.55	0.13	0.45	0.10	0.32	0.30	0.4[illegible]
June	1.80	2.05	1.37	0.34	0.47	0.08	0.32	0.32	0.4[illegible]

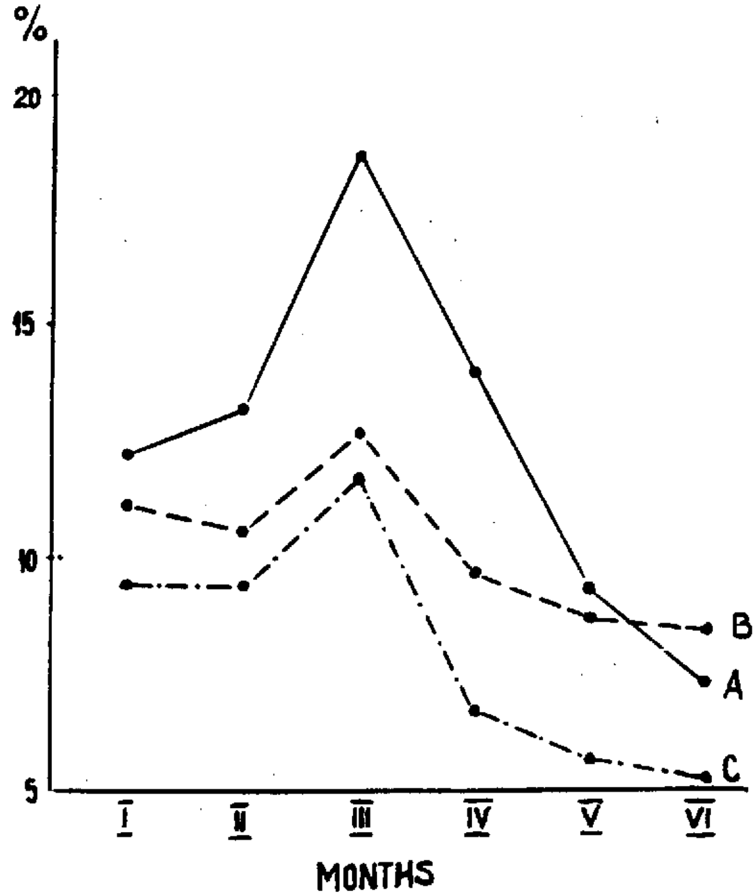


Figure 11. Absenteeism as a function of sick leaves (percent days of absence against the number of worked days).

I. January
II. February
III. March
IV. April
V. May
VI. June

A. cold roll operators
B. foundry operators
C. mechanics

Table 13 A

Frequency distribution of absences depending on the working place(men) (Days Lost/Worker) (after Ghezzi & Pucci, 1969).

Working place	No. subjects	Disease	Accidents	Leaves	Vacation	Unmotivated absence	Disciplinary suspension	Military term	Total
CARDING	722	17.48	3.18	1.84	1.19	0.74	0.05	0.62	25.00
SPINNING	2057	14.92	1.74	2.06	1.29	0.85	0.04	3.48	24.38
DRESSING	856	13.67	1.60	1.96	1.16	0.61	0.02	4.64	23.66
WEAVING	3.315	12.46	1.69	1.88	1.66	0.63	0.03	6.63	24.98
DYEING	1568	13.24	1.98	1.63	1.05	1.21	0.04	2.47	21.62
PRINTING	658	13.49	2.00	0.92	0.41	0.30	0.02	2.74	19.88
FINISH	1287	12.17	2.06	1.51	1.42	0.82	0.07	2.69	20.74
AUXILLIARY SERVICE	3317	11.38	1.87	1.54	2.16	0.51	0.02	2.28	19.76
OFFICE	582	11.01	1.96	1.34	5.83	0.18	0.00	0.98	21.29
TOTAL	14.362	12.93	1.86	1.70	1.69	0.68	0.03	3.53	22.42

Table 13 B

Frequency distribution of absences depending on the working place (women) (days lost/worker) (after Ghezzi & Pucci, 1960).

Working place	No subjects	Disease	Accidents	Leaves	Vocation	Unmotivated Absences	Disciplinary suspensions	Pregnancy	Total
CARDING	304	20.27	1.91	2.74	1.38	0.65	0.01	9.25	36.21
SPINNING	5634	23.22	1.06	3.06	1.03	0.95	0.06	11.84	41.22
DRESSING	4917	21.56	0.70	2.89	1.37	0.82	0.03	13.99	41.36
WEAVING	9311	21.51	0.85	2.87	1.12	0.76	0.03	13.05	40.19
DYEING	570	20.51	1.00	2.32	0.93	1.30	0.03	13.65	39.73
PRINTING	362	19.68	0.44	2.07	0.49	1.12	0.01	12.40	36.21
FINISH	2951	19.29	0.65	3.10	1.44	0.74	0.02	10.59	35.83
AUXILLIARY SERVICE	2212	18.30	0.46	3.25	1.09	0.69	0.01	9.44	33.24
OFFICE	394	10.58	-	1.68	9.17	0.15	0.01	7.61	29.20
TOTAL	26.655	21.41	0.80	2.92	1.28	0.81	0.03	12.27	39.25

separately for men and women, taking into consideration the days lost by disease, accidents, leaves, disciplinary measure, and military service (or pregnancy). From the point of view of the present report, it is interesting to note that the maximum number of absences occur in the carding department where noise reaches a high SPL.

The random character of the observations as well as the many other factors intervening in causing accidents and increasing turnover prevent a firm conclusion about the action of noise on their incidence. With respect to absenteeism, particularly sick leaves, the situation is clearer. Absenteeism is not widespread and to the extent it exists, it is usually linked to illness. Thus, inasmuch as a noisy environment favors the development of certain diseases, absenteeism is an inevitable consequence.

VI. Concluding Observations

The survey of noise effects on health and performance level in industrial setting evokes a complex picture, far more complicated than that achieved in laboratory studies, and, inspite of the methodological shortcomings, far more relevant. It should be noted, however, that most investigations in industrial settings, particularly those devoted to the study of behavior or work output have a mixed, field-laboratory character.

Several characteristic features can be outlined, which in turn, could be suggestive of some appropriate measures necessary to be adopted in order to remedy and, especially, to prevent the adverse effect of noise.

In discussing the adverse effects of noise the wide range of intervening factors as well as their complex interplay should be stressed.

Noise action depends first of all on its physical and temporal characteristics. But as is clearly evident from this review, age and exposure duration are at least as important, if not more so. The effects of noise also vary as a function of work characteristics and the individuals' involvement in their work, as well as on their health and the psychophysiological individual differences. Finally, it should be remembered that in industrial settings noise is usually associated with other noxious agents (vibration, low or high temperature, etc.) and that it is rather difficult to isolate the effects of noise alone.

There are complex psychophysiological (psychosomatic) consequences of exposure to noise, but it is nearly impossible to detect their primum movens, although the central nervous system is necessarily involved in all noise-induced modifications.

Noise obviously induces an increased fatigability, manifest both behaviorally and physiologically. A great number of studies have shown a decreased capacity of focusing attention and a slowing down of motor reactions after several hours of noise exposure; when fatigue is very deep, the alteration of strength relationships, i.e., of the adequacy between stimulation and response intensity sets in.

Alterations in the central nervous system such as the decrease in FCT, the low bioelectrical (EEG) reactivity, the inhibition of several reflexes, as well as an increased muscular excitability testify that fatigue is a consequence of noise exposure. Autonomic disturbances (among which the cardiovascular ones are very frequent) and the presence in a great number of noise-subjected persons of an astheno-vegetative syndrome fully corroborates this conclusion.

Last, but not least, the fact is that a great majority of persons working in noise complain about a growing tiredness. Since subjective and objective indices very rarely agree this is a strong argument relating fatigue to noise.

In noisy industries a higher morbidity was established in comparison to quieter industrial settings and to the population in general. Several diseases occur at a higher rate in noise-exposed workers, particularly the psychosomatic ones, such as the neuro-vegetative syndrome, cardiovascular dysfunctions, ulcers, as well as endocrine and metabolic disturbances. This phenomenon is also linked to the high irritability witnessed in noise-exposed people and acknowledged by them, which manifests itself in an increased noise annoyance and higher neuroticism level.

Undoubtedly, a direct action of noise on the nervous and cardiovascular systems cannot be ruled out, but it is obvious that an indirect, psychological influence is also responsible for the high morbidity found in noise-exposed persons. It is all the more surprising that up to now no definite relationships have been established between noise and mental health, the disturbances being chiefly found at the neuro-vegetative level.

Thus, the answer is positive to the implicit question upon which this review was predicated "is noise a noxious factor for the health and the working capacity of people working in industrial setting?" Noise is a stressing agent inasmuch as it disturbs, irritates, annoys and induces organic and functional disorders.

This clear-cut assertion might seem at variance with certain results of performance studies. But these, even in real life situations, albeit in laboratory ones, are not sufficiently relevant in this respect. Performance can be maintained at a relatively high level for many reasons, among which the motivational (financial and/or moral) and the technical (high automatization) ones are the most common. In some jobs it is fairly difficult to fail, as the human element is only an accessory of very complicated machines. That is one reason why accidents happen so seldom in noisy environments. Attention is indeed impaired by noise, but different warning devices are used (alarm bells, lights, etc.) which attract attention and thus prevent accidents. Therefore, the inconclusive and contradictory results obtained in studies of performance are not a strong enough argument against considering noise as a stressing agent, especially if we are interested in the workers' well-being.

Moreover, since noise effects are often not immediately evident and the adverse effects increase as a function of noise duration, short-term studies can disclose only temporary alterations, if any. In this type of research, the physical properties of noise alone are seldom decisive. The task difficulty and particularly the extent to which higher mental operations are involved play a very important role in the kind of results obtained. The fact that complex mental operations are not commonly required in noisy departments of industrial settings is another possible explanation for the lack of performance decrement.

The estimate of the effects of noise on work output is very difficult. In this connection another question arises: can one adapt to noise: No ultimate and simple answer can be offered. The data gathered in this survey show that we can hardly speak about a genuine adaptation, especially physiological adaptation. And since noise annoyance increases with years of exposure one cannot make a case for psychological adaptation either. The organism reacts unfavorably towards noise from the very beginning and there is a progressive increase with time in these adverse reactions, even though the kind of reaction can change. It appears, therefore, that noise exerts a cumulative negative effect on one's state of health.

On the other hand, people work in noise for years and the dysfunctions reported usually do not prevent them from reaching retirement age precisely under these noisy conditions. It follows that a certain adaptation does occur, that a new psychophysiological homeostasis is building up. The facts show, though, that there may be a health cost of this adaptation in the majority of individuals working in noise.

One of the most important facts to be uncovered is that noise-induced functional disturbances and illness appear prior to hearing impairment. Thus, there is no parallelism between hearing loss and health deterioration. Due to this, the entire problem of occupational health in noisy environments has to be viewed in a new perspective because it means that hearing loss appears at rather advanced stages of "noise sickness." As a matter of fact the data reviewed here support the existence of such a nosological entity and point to the necessity of taking prophylactic measures immediately after the first neuro-vegetative dysfunctions occur and not wait for a diagnosed hearing impairment.

Some methodological requirements emerge from this survey. There is a stringent need for the unification and standardization of the methods employed in noise studies. This should go so far as to have a precise and detailed set of indicators, standard and comparable tasks, etc. Since behavioral indices yield more or less ambiguous results, psychophysiological indicators, checked as to their diagnostic and predictive value, should be used. A minute analysis of jobs and the environment is also necessary. Analyses of persons exposed to noise should be made by age groups, by years of noise exposure, and by any other criteria generally accepted.

Hearing loss in noisy industrial settings is only one aspect of a more complex occupational disease. Perhaps it is the more conspicuous result of noise exposure, but it certainly is not (up to a certain limit) the most disturbing for the workers. Psychological disturbances accompany not only hearing loss but also the noise-induced neuro-vegetative and cardiovascular dysfunctions.

The complex consequences of noise exposure call therefore, for a new holistic view of noise effects.

VII. Summary

The present review covers the literature of the last 10 years devoted to the study of the extra-auditory effects of noise. Specifically, it deals with effects of noise on human performance and health in industrial settings as well as with other consequences due to noise exposure. It is restricted to the European, non-English literature and within it, mostly to that available in the socialist countries.

The effects of noise on performance are discussed as a function of noise characteristics, age, and noise exposure duration. The two latter factors seem to be more important for performance deterioration than the former ones.

Noise disturbance to physical and mental health are considered. It is emphasized that in noise-exposed workers, the morbidity is higher than in the industrial population as a whole. Studies on central nervous and cardiovascular system changes under noise are reviewed, as well as other functions which seem to be adversely affected. A short survey on the effects of ultra- and infrasounds is also presented, and data available on absenteeism, accidents, etc. in noisy industries are discussed.

It is stressed that the extra-auditory effects of noise, although not so obvious, are in the long run as harmful and dangerous for health and the general well-being of noise-subjected persons as the auditory ones.

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ABBREVIATIONS

- "Gigiena truda i professional'nye zabolevaniya" = "Gig.truda"
- "Gigiyena i sanitariya" = "Gig.san."

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