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AN ASSESSMENT OF NOISE CONCERN IN OTHER NATIONS

VOLUME II

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CONTENTS

PHYSIOLOGICAL AND PSYCHOLOGICAL EFFECTS OF NOISE

LIST OF FIGURES

PHYSIOLOGICAL AND PSYCHOLOGICAL EFFECTS OF NOISE

This subject has been a focus of attention by a large number of research organizations throughout the world. This report can give but a review of a few foreign research efforts including, for example, the study of extra-aural effects of noise on the organism undertaken by Dr. Gerd Jansen, the theories of psychology of noise formulated by D. Broadbent and others, the research of E. Ts. Andreyeva-Galinina to credit unequivocally the existence of the "noise syndrome" and the pathogenis of noise by Dr. W. Klosterkoetter.

The Max Planck Institute. Working with Lehmann and others of the Max Planck Institute for Industrial Physiology in Dortmund, Jansen conducted studies on the effect of noise on primary autonomic reactions. He reported that under the influence of audible noise, primary vegetative reactions occur which affect the internal organs, blood vessels, and heart. However, Jansen's investigations, together with those of other workers at the Max Planck Institute, extended to effects on secondary vegetative reactions as well.

The secondary vegetative reaction is the conscious one that occurs in such familiar reactions as anger. The subject in Figure 1 was habituated to noise and consequently did not show a secondary reaction (adrenalin release.) The top line shows the increase in vascular impedance caused by the constriction of the blood vessels. Blood pressure and pulse frequency remain unaltered, but the quantity of blood released by the heart stroke is smaller. These effects remain during the entire noise period, and the return to normalcy takes place slowly.

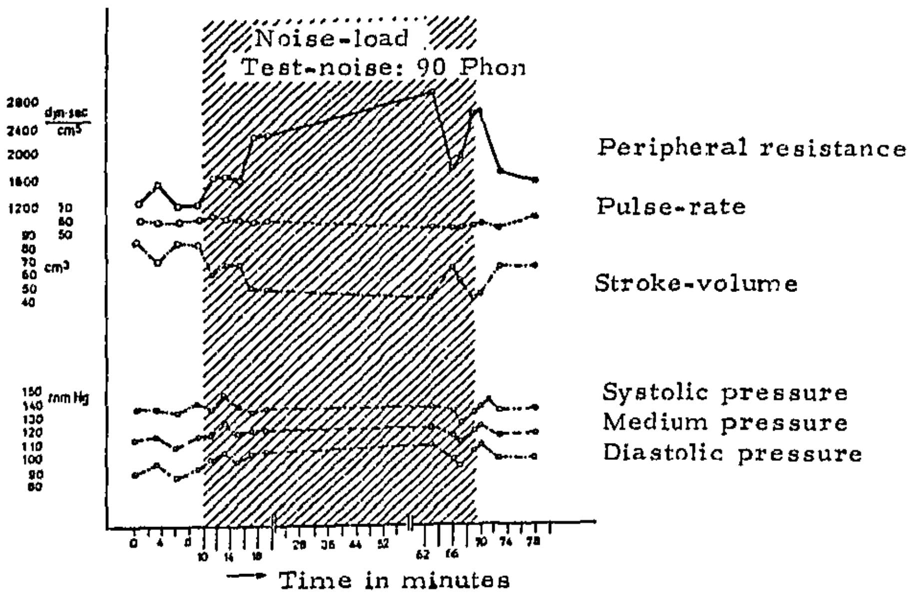


Figure 1. Circulatory System Reaction to Noise [3]

Jansen constructed a finger pulse monitoring apparatus to determine the effects of noise. Under the influence of noise the pulse beat continues 4-5 seconds, then its amplitude decreases and vascular constriction takes place. Meyer-Delius[1] of this institute also demonstrated a progressive decrease in pulse amplitudes for noise periods of 11, 20, and 40 seconds (Figure 2.) The implications of his experiment are that recovery time is a function of noise exposure time.

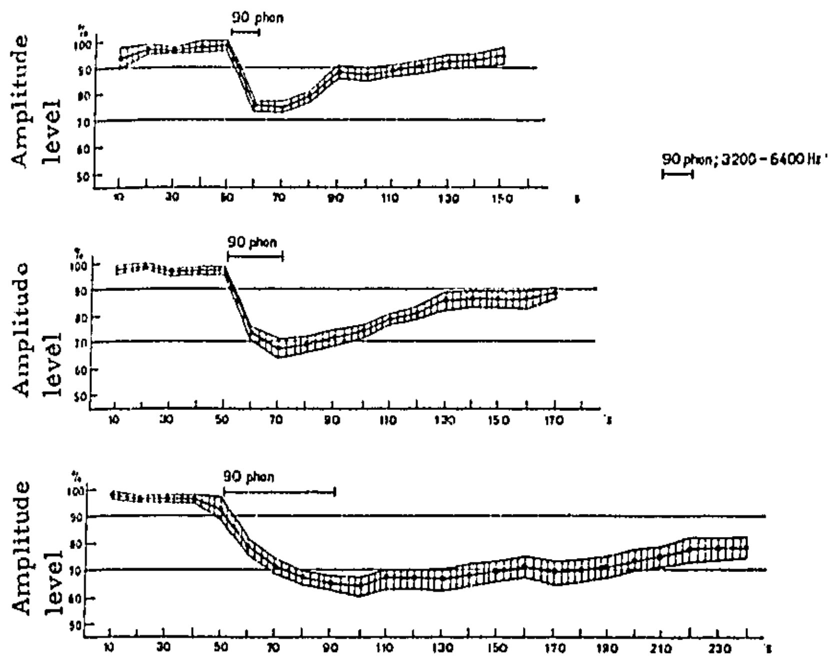


Figure 2. Finger Pulse During Noise[69]

In an effort to distinguish the primary vegetative and the fear reactions, Matthias conducted experiments among school children.[2] (Figure 3.)

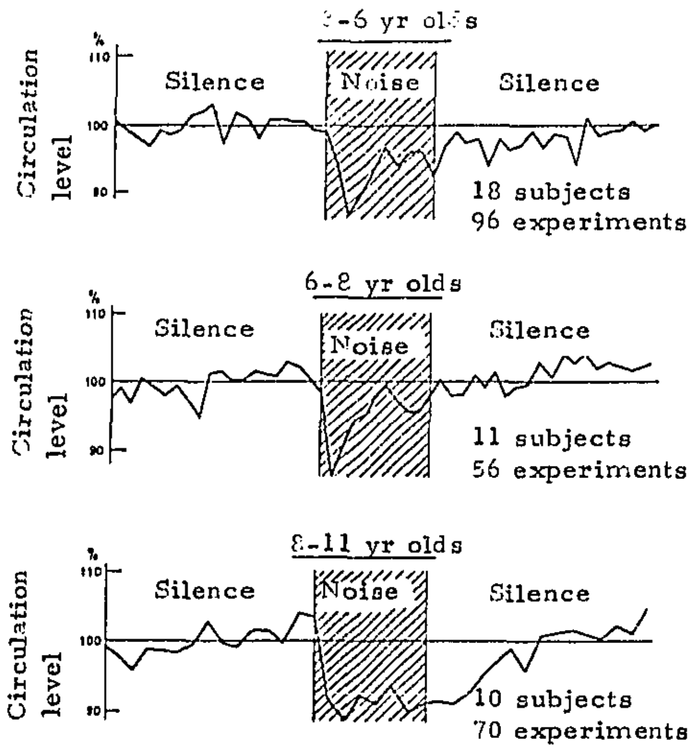


Figure 3. Noise-Induced Changes in Skin Circulation of Children. (Broadband noise 91 $\pm$ 2 DIN-Phon.)[2]

This study of the blood circulation shows that 8 to 11-year olds react in the manner of adults. The reaction of younger children demonstrably differs because it is a fear reaction. Working with Rey, Jansen[3] demonstrated the significance for the primary vegetative reaction of wide-band noise, noise in which the individual frequencies are scattered over the whole audible spectrum (Figure 4). Wide-band noise typically, is that of industrial steam machines and ventilators.

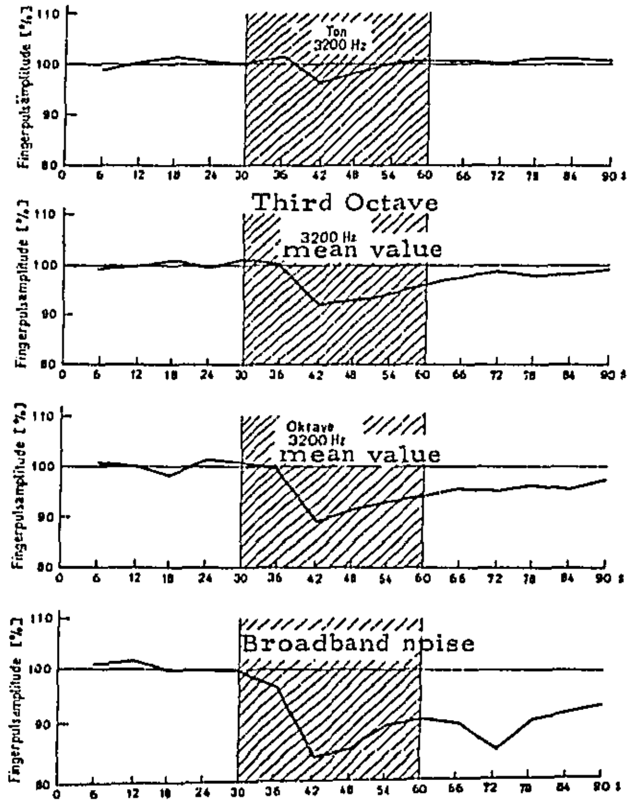
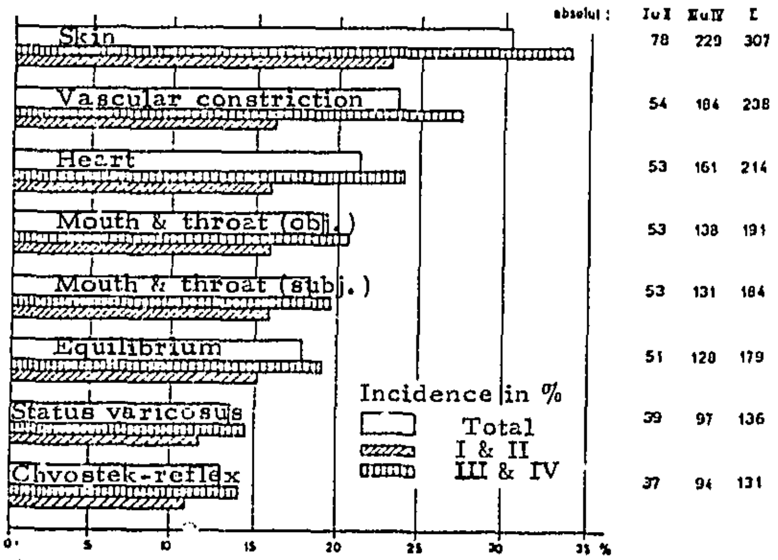


Figure 4. Effect of Broad-band Noise of 95 DIN-Phon on the Peripheral Circulation.[3]

Jansen also conducted a quasi-sociological investigation of the incidence of the effects of noise on two groups of metallurgical workers characterized as much, or little, exposed to noise. Figure 5 shows the vegetative disturbances of these 1005 subjects. The greater appearance of pallid skin and of the vascular constriction with which it is related in the strong noise group is statistically significant. Heart disturbances are more frequent in noise-subjected groups as are the unsatisfactory mouth and throat conditions determinable by examination. The effect of vascular constriction on the mucous membranes is such that the workers complained of incessant thirst but the other differences revealed do not seem statistically significant. This is an important early contribution to the opinion that long-term exposure to noise creates clinically detectable extra-aural changes.



Group I & II - 336 workers (little noise)

Group III & IV - 669 workers (much noise)

Figure 5. Vegetative Function Disturbances of 1005 Noise-Subjected Metallurgical Workers.[70]

The study on the influence of industrial noise on the organism by scientists of the Institute of Hygiene in Bucharest presented to the 1967 symposium on Ergonomics in Machine Design is an interesting complement to Jansen's work and reinforces his physiological results. Jansen and Klensch found that random noise and music of an equal intensity caused very similar blood circulatory responses.[4] The majority of subjects showed decreased cardiac output and volume flow. The similarity of the effects of noise and music corroborates Jansen's hypothesis that it is the intensity of the noise and not its emotional connections that control the somatic responses.

The first studies at the Max Planck Institute were limited to finger pulse amplitudes because experiments with this index are most easily conducted. Studies of primary vegetative reactions elsewhere in the system were conducted after establishment of the principle.[5] Their data show pulse rate changes at the end of the working day as compared with its beginning, in both bent and erect positions, as well as changes in the systolic and diastolic pressures in the same positions. Rheobasic and chronaxy changes were noted at the end of the working day. Plethysmographic investigation showed changes in time of return after application of a cortical excitant; motor analyzer changes were found; and cases of hypoacusia noted. The greater incidence of disorders among workers in heavy noise (light-noise workers = 100 percent) is given as respiratory, 190 percent; neurosensorial, 134 percent; locomotive, 133 percent; circulatory, 111 percent. While this study reads like an extension of Jansen, his work is not mentioned. The references cited show that the literature of Eastern Europe tends to base itself on the Russian authorities in this area of investigation. For example, the changes in diastolic and systolic pressures found are described as corroborating the data of Chepalin[6] and Arkadyevskiy.[7]

Lehmann established that dilation of the pupils occurs under the action of noise at 95-Phon. Because the vegetative reactions are most pronounced in sleep, the institute staff also used experimental animals and electroencephalographic methods to investigate the effects of noise on sleep. Jansen himself has announced his intensions to publish further in this field.

Jansen's experiments on noise-induced nervous stress[8] establish that the effect of noise is to create a higher activation of the organism, that is, a transition of the general state from trophotropy to ergotropy. In the transition measurable reactions occur in the heart and circulation, along with a heightening of the metabolism and the electrical musculation potential. The pulse amplitude decreases so sharply at 90 dB(A) that Jansen thinks this the limit of tolerance. Klosterkoetter questions whether or not the phenomena observed by Jansen might be caused by other stimuli. Jansen's study warns those responsible for industrial hygiene that of the 74 processes investigated "very many must be regarded in view of the critical curve as too much to impose on workers."

The research techniques used were ballistrography, plethysmography, and EEG. Observations of healthy subjects were conducted in a special soundproof chamber over several years. The noise intensities were 60 dB and higher and the frequencies 200 to 6000 Hz. (no reactions were detected at noise below 60 dB.)

Sharpest reactions occurred at intensities of up to 80 dB at a frequency of 2000 Hz., and at 90 to 110 dB at about 3000 Hz. Physiological reactions began to occur at intensities of 65 dB, while intensities of 75-90 dB caused distinct reactions and those occurring at 90-95 dB are described as "threatening."

Jansen's earlier investigations of the noise signature of office and factory machinery to construct a noise archive, the Versuch einer Klassifizierung von Industriegeraeuschen (Preliminary Classification of Industrial Noises) were a preliminary to this work. His collaboration with H. C. Micko on the study of noise on the performance of intellectual tasks of varied difficulty did not obtain fixed cause and effect relationships.[9]

Jansen provides several alternate schemes for classifying industrial noise, for example, a classification based on the maximum frequency between 100 and 8000 Hz of the main noise intensity. In classifying noises according to their origin, he describes as unconditionally damaging the noises generated by pneumatic hammers, turbofans, crushers, compressors, concrete mixers, centrifuges, etc. He asserts that distinct physiological changes can be created by the noise of automatic and semi-automatic lathes, wire-drawing machines, oil-spray burners, etc.

The main thrust of Jansen's work is the demonstration that noise induces a reduction in stroke volume to compensate for an increase in peripherial resistance in the precapillary region. The circulation does not, however, adapt to continuous exposure to noise by a return of the blood flow to its initial level. Peripheral blood flow continues to be reduced as a result of continuing vasoconstriction and increased resistance. These noise-induced vasoconstrictive, in pulse decreased amplitudes are related to the intensity of the noise and its band -width frequency itself is relatively unimportant. His investigations conclude that the level of the tolerance curve is 94 dB at 1000 Hz, falling by 1 dB per octave and that beyond these levels the possibility of harmful effects must be anticipated. The implications for noise control, as Jansen sees them, are that "...the results of research clearly justify medical demands for effective noise reduction so that health shall not be endangered. It is not uncommonly maintained by acoustic engineers that people can get used to noise. The research of the last few years has shown that the autonomic nervous system at least does not become accommodated in this way, even though phychological adjustment may be excellent." [10]

Some representative reactions to the physiological concept of the extra-aural workings of noise will be presented here in quotation form, to give the feeling of immediacy not communicable in paraphrase. Speaking for the European Public Health Committee of the Council of Europe, L. Molitor expresses a questioning uncertainty: "Numerous medical and psychological studies have been carried out without it having been possible to reach an unequivocal conclusion on the harmful effects of noise. Our fellowship holders did not succeed in obtaining precise data of lasting organic functional and mental disturbances attributable to the effects of noise during their investigations covering most of the member countries."[11]

However, in a report of the same year, S. Maugeri (Institute of Labour Hygiene, Pavia Institute, Italy) is described as doing sponsored research on the determination of the levels at which the action of noise takes place, how and when it causes psychic and intellectual fatigue, and the suitable ways of reducing or eliminating its neurovegetative and psychic effects. The report goes on: "Experiments completed in previous years have shown that noise effects a modification of cardio-vascular dynamics, a modification of the respiratory function, and a change in gastric secretions. Relating this problem to that of intellectual fatigue, the subject of another series of researches, it was observed that noise also modifies the reaction time and diminishes the productivity of labor. These noise-induced disorders are certainly the expression of the autonomic reactions. To study the noise-effects mechanism, the peripheral vasoconstriction and the galvanic skin resistance have been specially studied."[12]

J. Kubik (Chair of Hygiene and Epidemiology, Medical Faculty, Brno) is not certain that the theory can ever be made to yield rigorous results: "...Even if the further development of the neurophysiology and psychophysiology further clarifies the mechanism of non-specific noise, it is obvious that the resulting effect of noise in this sense will always depend on the inner factors (type and functional state of the central nervous system, psychological relation to the noise) as well as on the external factors (the physical parameters and overall characteristics of the noise, the length of exposure and others.) [13]

On the other hand, W. Lorenz, (Throat, Nose, Ear Clinic, Halle-Wittenberg University) accepts the extra-aural theory without reservation: "...Noise effects cause pathological changes of the inner ear and other pathological changes. Numerous noise-exposed workers complain about nervous irritability, headache, and sleep disturbances. Vegetative reactions may be manifested by nausea, vomiting, and certain disturbances of equilibrium, which cannot be defined precisely. The occurrence of chronic gastrides and gastro-duodenities in noise-exposed workers has been established. Noise also exerts a negative effect on the circulatory system and on the rhythm and depth of respiration. It may lead to humoral and hormonal changes, and in some cases, a fatal effect has been ascribed to jet-plane noise.[14]

While the extra-aural theory continues to meet this not always unqualified reception from the theorists of physiology, it is most striking that it should be so very seriously considered by the hard-headed engineers and operational managers of the two Germanys. In December 1970, the Economics Association of the Iron and Steel Industry (Wirtschaftsvereinigung Eisen-und Stahlindustrie) and the Association of German Metallurgists (Verein deutscher Eisenhuttenleute) released under their joint imprint a report "Man in Industrial Noise from the Point of View of Industrial Medicine" that is written by Jansen himself and, of course, predicates the extra-aural theory. Jansen's co-author, G. Schultz, has been identified with the preparation of the various Stahleisenbetriebsblaetter pertinent to noise control. While publication sponsorship does not mean blanket endorsement, obviously it indicates the interest of people who are continually and practically concerned.[15]

Consideration of the possible effects of noise not related to deafness will show the diffusion of Jansen's ideas, although again, he is not mentioned by name: "... Whether or not psychic effects are involved, the human organism reacts to noise with changes in heartbeat, blood pressure, skin circulation, respiratory functions, gastric secretions, and other body functions. Although a noise syndrome cannot be assumed, a significant influence on the vegetative system that regulates these reactions is clear. The evidence accumulates that such noise effects can injure the state of health. At present, no clear differentiation of the disturbances of the autonomic functions by their origin is possible, so that the attempt to limit noise from the point of view of its effects on the autonomic nervous system is not practicable."[16]

This depiction of the research area of the extra-aural effects of noise should not be finished without calling attention to the apparently little-known study prepared jointly by the Institute for Corticovisceral Pathology and Theraphy of the Deutsche Akademie der Wissenschaften (Berlin-Buch) and the Institute for Brain Research of the Academy of Medical Sciences of the USSR entitled Laermbelaestigungen, akustische Reiz, und neuro-vegetative Stoerungen (Leipzig, 1968).[17] The study team led by Nitschkoff and Kriwizka investigates in careful detail the hyper- and hypo-functions of vegetative reactions, the disturbance of the various regulating systems, and the histomorphological changes occurring in specific areas. The similarity of this work with Jansen's area of investigation does not need to be pointed out.

This extraction from the Preface shows the animating principle: "...In the course of the Technical Revolution, the problem of noise damage, noise stress, and noise control has gained immediacy. In the factory, on the street, on the rails, and in the air, in various industrial environments, in urban construction, yes, even in the modern home, noise is a constant accompaniment, so that noise trauma and noise stress have become a more widely prevalent cause of illness than we had realized. Physiological investigations show again and again that noise is one of the causes of the constantly augmented flood of stimuli to which the men of our times are exposed without protection."

The Leningrad Medical Institute of Sanitation and Hygiene.

The studies of Andreyeva-Galinina are described in the monographs Methodological Problems of Studying the Effect of Noise on the Organism (1962)[18] and The Control of Noise (1966).[19] Early in her studies, (1957), E. T. Andreyeva-Galinina expressed her conviction that the complex of symptoms developed under the influence of exposure to noise could be defined as a "noise syndrome" experienced first by the central nervous system and then by the auditory analyzer.

The institute's studies of industrial noise conclude that changes in the central nervous and cardiovascular systems, the auditory analyzer, and other organs are directly related to the intensity, duration, and spectrum of the effective noise, the initial functional state of the organism and the accompanying deleterious industrial factors. These changes in the nervous sytem consist of vegetative dysfunctions, astheno-neurotic or asthenic syndromes.

In order to standardize test conditions, the Institute abandoned industrial testing in the field to develop soundproof chambers in which to study the changes developing in the human organism under the effect of a broad band stable noise of 70, 80, 90 dB, octave bands (300-600, 600-1200, 1200-2400 Hz), noise with maximum sonic energy at frequencies of 300, 500, 700 Hz, as well as impulse noise of moderate intensity (60-80 dB).

Human and animal subjects were subjected to reflexometry, attention concentration studies, electroencephalography, electrocardiography, autoradiography, pulsotaxometry, tacho-oscillography, and determination of summation-threshold index, (oxygen consumption, change in weight of internal organs or in total weight.) Reflexometry indicated the change in the latent period of the pupillomotor reaction, the force of the effective response, and the occurrence of distorted reactions to strong and weak irritants.

Functional loads (rhythmic photic stimulation, pharmacological tests, EEG reactivity) were tested for objective evaluation and the subjects' subjective state also was studied. These tests established that the intensity of the reaction to a strong stimulus (90 dB) diminished by 26.7% as compared to the prestimulation level, whereas it diminished by only 2% in the case of a 70 dB noise. At 90 dB there was a 12% increase in duration of the latency period of the oculomotor reaction, at 80 dB--an 8% increase, and at 70 dB a 1.7% increase. A weak stimulus induced even more distinct changes in the latency period of optical motor reaction, particularly at 90 dB (21%); at 80 dB there was a 1.36% difference, and at 70 dB, only a 0.4% difference.

Attention span decreased the most at the higher noise levels (90 dB.) To determine the relationship between the changes discovered, the spectral composition of the noise as well as its level were studied.

Similar experiments using pulsing noise demonstrated that greater disturbances occur especially in the central nervous system under the effect of pulsating noise with slow (0-60 pulses per minute) and rapid (100-1500 pulses per minute) succession of pulses. Slow sonic stimuli with a 1000 millisecond interval between pulses lead to a decrease in force of the effector response by 39.1-40.4%. The latency period of the oculomotor reaction showed an almost 25% increase while attention span was 13% lower. Andreyeva-Galanina considers it firmly established that noise induces significant changes in the pulse rate, EKG, arterial pressure and other hemodynamic indices. A. L. Myasnikov, I. S. Ivatsevich, N. N. Pokrovskiy and other students characterize noise as one of the etiopathogenetic factors in essential hypertension, while E. A. Drogichina, L. L. Zaritskaia and others believe that it induces a drop in arterial pressure.

Tacho-oscillographic and pulso-tachometric investigations indicate that under the effect of white noise with an intensity of up to 90 dB there is a statistically reliable acceleration of the pulse, as well as an increase in maximum and minimum arterial pressure. Noise in octaves of 300 to 2400 Hz of the same level did not elicit significant changes in the cardiovascular system. However, exposure to pulsating noise with these parameters brought about even more distinct changes.

That aspect of the program of the Leningrad Medical Institute of Sanitation and Hygiene concerned with animals can be exemplified by B. D. Zeygel'shefer's 1966 experiments on rats and mice. He reported a decrease in summation capacity of the central nervous system, especially in the mice, but no change in the muscular strength and body weight of the animals. In view of the drop in hemoglobin and erythrocyte content, a subsequent study was undertaken of the permeability of the hemato-encephalic barrier for labelled phosphate and of phosphorous compound metabolism in cerebral structures under the effect of single and multiple exposure of albino rats. Andreyeva-Galinina and her associates assume a general decrease in intensity of metabolism or macromolecular phosphorus compounds in the brain structures. Electrophysiological experiments on rabbits established that the noises used induced marked changes in bioelectric activity of the brain structures studied distinguishable as two phases. The changes were related to the parameters of the stimulus. It was demonstrated that in the first (active) phase there was prevalence of low amplitude fast activity in the cortex (auditory, occipital, sensomotor) and subcortical (reticular formation of the midbrain, pons, nonspecific thalamic nuclei) zones. With continuation of the noise stimulus the cerebral action potentials became similar. The excitation characterizing the first phase gave way to, drowsiness and listlessness, indicative of development of the second (passive) phase.

On the basis of the data obtained from the use of rhythmic photic stimulation it is assumed that the decrease in physiological liability of the nerve structures studied, is indicative of development of generalized inhibition.

To determine the involvement of these chemoreactive systems in the response to noise, agents that selectively stimulate the adrenoreactive systems (adrenomimetic phenamine, and the adrenolytic agent that blocks the former, aminasine), as well as the respective excitatory and blocking agents for the cholinoreactive systems of the brain (invaline and amysyl) were administered intravenously to rabbits with electrodes imbedded in specific and nonspecific brain structures. After this the animals were exposed to broad band stable noise with an intensity of 120 dB. The results obtained indicate that during the first part of the experiment there was an increase in functional activity of the adreno-and cholino-reactive systems of the brain. With increasing exposure these systems developed gradually increasing inhibitions of impulse conduction. This is apparently at the basis of decrease in activating influences of the reticular formation of the brain stem and of the onset of inhibition.

Article 24 of the Fundamental Legislation of the USSR and the Union Republics on Public Health states that "It is the duty of the executive committees of the local soviets of workers' deputies, the other government agencies, the enterprises, the institutions, and organizations to carry out measures to prevent, reduce the intensity of, and eliminate noise in the industrial buildings, dwellings, and public buildings, in the courtyards, on the streets and squares of cities and other population centers. All citizens are obliged to observe the rules for preventing and eliminating noise under living conditions."
A writer in the Vestnik of the Academy of Medical Sciences of the USSR comments that this article points to the first occasion in history in which a state formally took upon itself the task of banning noise.[20]

Persons working under conditions of noise levels of 95 dB and over are required by the Ministry of Health of the USSR, Regulation No. 136 dated September 7, 1957, to undergo annual medical examinations.

The instruction is quoted in part illustrating the early influence exercised by Andreyeva-Galinina's concept of noise: "The neurologist should pay special attention to the state of the central nervous system. As a result of prolonged exposure to high noise level, disturbances in central nervous system functions may develop, affecting mainly the autonomic nervous system. Thus rapid fatigue, diminished work capacity, emotional instability, impaired memory and concentration, disturbed sleep, headache, giddiness may occur. Impairment of superficial sensation and of vibration sense, as in polyneuritis, is also seen. The syndrome may resemble as asthenic or astheno-neurotic reaction. Persons suffering from any significant disturbance in nervous system function should be transferred to less noisy jobs to avoid any further influence of high noise levels. The cardiovascular system including the blood pressure should be examined as hypotension is often observed in workers subjected to high noise levels for prolonged periods." [21]

Institute for Sanitation and Industrial Medicine, Klinikum Essen of the Ruhr University. Dr. W. Klosterkoetter presents a biological and medical examination of whether and under what conditions, noise is potentially pathogenic. He points out that the causal connection between the Temporary Threshold Shift and the Permanent Threshold Shift (irreversible damage to the hair cells of the organ of Corti) is generally assumed but that the pathogenesis is not fully explained. While it is statistically true that noise in increasing doses will bring about increasing Temporary Threshold Shift which in course of time is followed by Permanent Threshold Shift, prognostication in individual cases is not possible. The dip at 4000 Hz that marks noise-induced deafness can be precisely established by audiograms. Dieroff[22] sees the course of noise-induced deafness in these phases: many minor complaints including noise in the ears, pressure in the head, general depression, a long period of compensation, without major complaints, collapse, and then saturation, when further hearing loss proceeds very rapidly.

Klosterkoetter[23] exemplifies the dimensions of the problem for the industrial hygiene legislation of the modern state by reference to Schwetz and Stahl's study of Austria. He quotes Dieroff as saying that pulse noises are the most dangerous, particularly when the noise intervals are more than 2.4 seconds, so that the reflex contraction of the middle ear muscle has relaxed, and the sound energy freely enters the ear. Dieroff found peaks of 140-150 dB in metallurgical plants and says that hand hammers frequently reach 150 dB. Serial production of the necessary instrumentation now beginning will permit more accurate measurements. Klosterkoetter seems to approve of the use of the CHABA classification of noise.

Next to impulse noise, Klosterkoetter finds the problem of noise breaks most immediately interesting. The maximum level in noise breaks should be 70-75 dB. If this is difficult in practice, a 15-hour interval between work shifts is necessary. To calculate the necessary break, it is necessary to know the individual times of exposure and the noise intensity. Buerck[24] quotes approvingly the ISO proposal to limit exposure to 90 dB to 8 hours, 95 dB(A) to 2 hours-15 minutes, 110 dB(A) to 2 seconds, and 130 dB(A) to 0.5 seconds.

Noise breaks also rest on the hypothesis that there is a definite relationship between the Temporary and Permanent Threshold Shifts. Klosterkoetter's investigations reveal that a one-hour white noise of 105 dB(A) in the test frequency of 4000 Hz yielded a TTS of 48 dB; by dividing this noise into phases of 5 minutes of noise followed by 5 minutes of break, the TTS was 41 dB; in 20 minutes noise and 25 minute break the TTS was 44 dB; in 30 minutes noise and 30 minute break, 41 dB. The greatest decrease in Temporary Threshold Shift occurs in a regime of short periods of noise with short 70 dB(A) breaks. In Klosterkoetter's current experiments on the problem of the noise level, subjects are given 10 minutes of 105 dB(A) alternating with 10 minute pauses by 35, 70, 80, and 90 dB(A). Results show that diminishing the break level by 10 dB in this order of testing decreases the TTS by 2-3 decibels. For other practical problems see Dieroff[22] and Lehnhardt.[25]

Extra-aural effects of noise. These are less certain. Lehmann[26] and his associates, Nitschkoff and Kriwizkaja,[17] and Burns[27] (less strongly) agree that under the influence of noise, measurable changes in various neuro-vegetative hormonal-regulation cycles can be demonstrated. These include inhibition of the stomach peristaltic and salivary secretion, increased metabolic rate, expansion of the pupil, temporary increase of blood pressure, change in the resistance, and decrease of skin temperature and of the finger pulse amplitudes measured plethysomographically as the result of constriction of the blood flow and increased release of catecholaminen and ketosteroids. Strengthening of the skeletal muscle action potential was observed electromyographically, which indicates the general tension state of a muscle group. Electroencephalograms indicate the existence of a cortical "arousal effect," an elevation of the diffuse cortical excitation level, and with a latency period of 150-180 ms the noise specific evoked potential ("Averaging Analysis") in objective audiometry. (Keidel and Spreng, Baumann and Baumann.)[29] EEG's taken during sleep (Richter[30] and Jansen[30]) show a lack of depth.

In experiments with animals it was observed that the appearance of hypertension increased the release of the adrenal hormone, decreased the ascorbic acid content of the adrenal, and enlarged the adrenal gland, as well as changed the composition of the blood.[17] Treptow, Hecht, and Baumann[32] found blood sugar irregularities in dogs after exposure to noise. These phenomena are consequences of the tilting of the regulatory cycle Middle Brain Pituitary Adrenal Cortex and are considered stress reactions. Klosterkoetter's own unpublished experiments on rats did not give unequivocal results. With Hauss and Junge-Hulsing, Klosterkoetter is now investigating the question of the influence of noise on the metabolism of the vessel phonoplast. The method here is to measure the S_{35} in this material. Experiments with one group demonstrated that existance of tolerance and adaptation, and with the other, that sensitizing occurs, so that firm conclusions are difficult. Hauss[33] sees this influence a pathogenic basis mechanism for the origin of arterioscelerosis and of coronary heart attacks.

The physically and biochemically measurable activation symptoms found in man under emotionally neutral conditions at 65 to 70 dB(A) can be interpretated as an expression of the cortical, autonomous, and motor arousal reactions, that is, as an elevation of the excitation levels toward ergotrophy. Jansen[34] reports the vegetatively controlled skin circulation to be an exceptionally sensitive indicator. Klosterkoetter thinks that it responds too easily to other stimuli, e.g., mental tasks and has personally observed subjects who react by expanding rather than constricting the blood vessels. The central question is whether these vegetative effects occurring in the laboratory in reaction to noise of 65 dB(A) are potentially pathogenic.

It is accepted that workers are emotionally neutral to the noise of their working places: some are positively motivated because they receive additional compensation for working under noise. Epidemiological investigations by Jansen,[35] Graff, Bockmuehl, and Tietze,[36] and R. E. Mark[37] have discovered hypertense regulation disorders, other cardiovascular disturbances, and definite vegetative complaints, although none of the investigations is beyond criticism. Burns[27] thinks that it is not yet possible to impute any illness except deafness itself to noise. The vegetative responses to noise must be considered as arousal or activation indexes, without ascribing to them a definite pathogenic meaning. On the other hand, the innocent character of the noise-induced changes has also not been proved. The fact remains that in every society there are men with different sensitivities, with temporary or permanent health disturbances, who are overburdened and exhausted. According to Richter-Heinrich and Sprung,[38] men under hypertension in the early stage of regulation react with greater sensitivity to acoustic stimuli. Apparently they have a generally higher readiness for arousal.

Frequent disturbances of sleep by noise, however, can certainly be seen as potentially pathogenic. After sleep disturbances, increased vegetative disturbances and increased catecholamine release can be observed on the next day. Noise is particularly important in the beginning of sleep, when the <u>Formatio reticularis</u> demands a decreased flow of stimuli. Individual responses differ and the threshold is not always the same for the same individual. Steinicke[39] discovered that at 35 dB(A), 45 dB(A), and 60 dB(A), 23%, 42%, and 80% of the subjects were awakened.

Little is known on the ultimate pathogenic meaning of the qualitative changes in sleep, that is, shallowness and inhibition of the III and IV phases of sleep depth. Experiments in the sleep laboratory and epidemiological investigations in unfavorable noise milieus are required, but the first necessity is a determination of the parameters that will answer the question. The cortical reactions lying under the wakening threshold in addition are released at far lower sound levels than the known vegetative reactions. This fact leads to another important conclusion: noise can obviously disturb the trophotropic phases of the circadian rhythm of the 24-hour day and stimulate it toward ergotrophy. Too little is known about the eventual pathogenic meaning of rhythm and relation disturbances, but we must seriously consider the hypothesis that these are possibly risk factors, which in premorbid and morbid phases can exert an unfavorable influence.

Klosterkoetter sees the great hygienic problem in the psychic-emotional reaction to noise: this presumes a cognitive process, an evaluation and subjective processing, as a consequence of which, noise undoubtedly causes emotional stress. This can be done by real noise, or by noise expected, or by noise threatened in the future.

Psychological stress investigation has shown that emotional stress in addition to subjective health complaints and behavioral reactions also releases stereotype autonomic and biochemical reaction models like increased blood pressure, increase of pulse and breathing, vascular constriction, change in galvanic skin resistance, shortening of the blood coagulation time, and increased noradrenalin, adrenalin, and ketosteroid secretion. Individual reactions are largely determined by the psychic and vegetative model and by social factors. The connection of every emotional excitation with autonomic and biochemical reaction models is explained by the narrow anatomical and functional correlation of the limbic system with the hypothalamus. The causal connection between emotion and lesion has been proved by experiments on animals as well as man. Hypertension and the Ulcus vetriculi are well-known examples. According to Hauss,[33] chronic emotional stress is an important factor in arteriosclerosis.

A portion of Klosterkoetter's concluding remarks are quoted in full: "... Does noise which leads to psychic-emotional stress threaten health? My exposition should have proved that this question must unequivocally be answered in the affirmative, if the definition of health given by the World Health Organization is accepted. Disturbances of psychic and social good health by noise are evident; they are obvious in one's personal experience and in the observations of others. Noise can be an emotional stress factor. We are compelled to accept at complete value the complaints of individuals inflicted in this way, even if the psychologists and sociologists cannot statistically work the complaints over with the computer. It can be accepted that disturbances of sleep, of the circadian rhythms, of the biologically necessary trophotropic relaxation phases can lead to psychovegetative syndromes and illnesses needing treatment or that they are risk factors."

D. P. Davies, Department of Psychology, University of Leicester, argues that there is "little evidence to support the view that noise has adverse physiological effects, except on the auditory system, and these are difficult to differentiate from the effects of age." In speaking of the effects of long-term exposure to high intensity noise, Davies states[40] that hearing losses with age occur primarily in the higher frequencies. Proposals for damage risk criteria have emphasized that the levels for higher frequencies should be set at considerably lower intervals. Assessments of damage risk levels should be made for each frequency. Under continued exposure, recovery from the Temporary Threshold Shift becomes progressively weaker; permanent hearing loss results as a consequence of the damage to the Cortex. Davies quotes other experimenters that hearing loss is greatest in the early part of the exposure period. However, the relationship between duration of exposure and the hearing loss is different for different frequencies. He emphasizes that Sataloff, and Vassallo, have shown that the TTS is not an adequate forecast of the degree of impairment of the PTS and questions the usefulness of existing tests of susceptibility to noise effects.

Since noise is a stress factor, physiological and psychological changes resulting from long-term exposure to noise include abnormalities of endocrine and cardiovascular system functions There is little evidence that noise produces permanent changes in the adrenalin system although adrenal activity during actual exposure may be high. Davies cites Ashbel ("Effect of Ultrasound and High Frequency Noise upon the Blood Sugar Level," Bull. Hygiene, London, V. 40, pp 587, 1965), pointing out that there occurs a reduction of the blood sugar level which adversely affects the performance capacity of human subjects. He also calls attention to one of Jansen's studies on blood-pressure after long-term noise exposure which coincides with other findings. These changes follow exposure to all sorts of stresses, as shown in Graham's early study of the North African soldiers (Lancet, 1,pp 239-240, 1945.) Broad-band noise significantly inhibits peripheral circulation. Aubiee and Britton ("Anxiety as a Factor Affecting Routine Performance under Auditory Stimuli," J. Gen. Psych. 58, 1958) report that anxious subjects perform better in noise than those that are not anxious. Broadbent ("Non-Auditory Effects of Noise," Advancement of Science 17: pp. 406-409, 1961), shows persistence of peripheral vasoconstriction in response to noise may also result in impairment of performance in tasks requiring movement of the fingers.

Evidence about the psychological effects of long-term exposure and possible damage to mental health is inconclusive, since comparisons between individuals working in noise and quiet environments are likely to be contaminated in essential respects. Individuals susceptible to high intensity noise are also likely to select themselves out of such an environment.

In discussing short-term exposure, Davies cites E. A. Drogichina and co-author [41]Orlovska[42](1963) that even at comparatively low intensities (80, 70, and 65 dB in the frequency ranges 1250-2500 cps) and exposure durations of 15 minutes in one study and 110 minutes in the other, EEG abnormalities appear in some subjects.

Soviet industrial studies, according to Kryter, may show the possible harmful effects to man's nonauditory systems of long-term exposures; he mentions "...the data, collected for the most part in Russia, that indicates that workers in heavy, noisy industries suffer unusually high percentage of circulatory, digestive, metabolic, neurological, and psychiatric disorders." A summary of a recent article by Andreyeva-Galinina will represent some of the materials Kryter has in mind.

Studying workers in nail-making shops (97-106 dB noise intensities,) Khalimovich found that changes in the central nervous system actually occurred before changes in the auditory analyzer and were expressed as autonomic dysfunctions, as the noneural or asthenic syndroms. Svistunov's examination of workers engaged in the testing of electrical machines (94-120 dB at frequencies of 1250 and 2500 Hz) indicated that noise reduced the ability to concentrate and increased the latent period of the motor-conditioned reflex. Study of humans exposed to generating pulsing noise (stampings, presses, weaving looms, nail-making machines) by Suvarov establish a direct relationship between the subjects' functional state and the physical characteristics of the noise. Andreyeva-Galinina, working with Artakonova and Kadyskin, reported investigations recording the bioelectrical activity of the brain which reveal phasic phenomena, the degree of which depended on noise parameters and duration of exposure.

Her brief study concludes in this way: "Studies of the effects of various noise parameters on man have confirmed our opinion that noise must be studied as the etiological agent of noise disease. We are justified in stating that noise disease is a malady of the entire organism, the syndrome including lesions of the nervous system, the auditory analyzer, and intense metabolic and functional disturbances in all systems." (Andreyeva-Galinina, E. T. S., _et al._ Studies of the Effects of Noise on Man. _Gigiena i Sanitariya_, No. 5, 1969, 70-75.)

Institute of Physiological Chemistry, Silesian Academy of Sciences. The first in this institute's series of investigations of biochemical changes caused by acoustic and ultracoustic fields reports a decrease of the glucose level and an increase of the pyruvic acid level in blood, which is interpreted as the sign of a depressed glycolysis. The decrease in the values of serum surface tension determined in the majority of animals investigated is considered evidence of the mobilization of lipids reserves.[43] The second part of this study deals with the influence of the sound field on total lipid level, lipoproteids, serum proteins, and electrophoretic fractions in serum of guinea pigs. The increase of total serum lipid was ascribed to lipid reserve mobilization. An increase of serum proteins, a decrease of albumin, and a general increase of all globulin fractions were observed.[44] Serum glutamic-oxalacetic transaminase and aldolase increased in guinea pigs exposed to the continued action of strong acoustic and ultrasonic fields. However, the results do not prove temporary dysfunction of the liver of the subject animals.[45] The fourth article in this series reports that no influence of sound fields on the activity of erythrocyte- and serum-cholinesterase of guinea pigs could be found, confirming the error of the liver impairment hypothesis.[46] In further corroboration is the following study on the increased level of alanine and glutamic acids without statistically significant changes in the level of aspartic acid.[47]

The report on the influence of noise on the level of pyruvate, oxalacetate, citrate and alpha-ketoglutarate in guinea pigs found no changes in the level of oxalacetate and citrate but statistically significant changes in all the others. The pyruvate acid and alpha-ketoglutarate changes are interpreted as a metabolic block.[48] Studying the influence of mitotic activity in the corneal epithelium in guinea pigs, the authors report that a single exposure to an acoustic field causes a decrease in the number of dividing cells, that a marked increase in mitotic activity occurs after 12 to 24 exposures, and that immediately after 1, 12, or 24 exposures to noise, an inverse ratio between the blood sugar level and the number of dividing cells is observed.[49] Field study of working-men showed that noise and vibration affect the serum alkaline phosphataxe, aldolase, and lactic dehydrogenase activities.[50] Marked changes in the activity of malonate dehydrogenase also were observed in these persons. It is assumed that the stress factors noise and vibration produce changes in the sugar metabolism of the body.

The most recent report by members of this institute studies the effect of industrial noise on the behavior of DNA, RNA, and soluble proteins in the liver, as well as the relative weight of this organ in the guinea pig.[51]

The influence of noise on efficiency. This subject has relevance for the conduct of those modern military or industrial tasks which call, it has been said, for "an intense watch to make sure nothing happens." The psychological characteristic involved here is vigilance, the readiness to detect and respond to certain specific changes occurring at random intervals. The experiments typically involve the monitoring of dials and lights. The important variable is the kind of task performed, not the kind of noise present. In general, the adverse effects of noise occur in the performance of complex tasks, its beneficial effects in work on simple tasks. The study of the effect of noise on the working efficiency of the Moscow Post Office by Kovrigin and Mikheyev can be considered an illustration of the practical utility of the study of efficiency under noise.[52]

Discussion of the work of Broadbent and others of the Applied Psychology Research Unit on the investigation of the effects of noise on efficiency can be concentrated on these topics: noise in tasks where the signal remains constant until detected, unpaced tasks, the monitoring of single and complex displays for infrequent signals, individual differe nces, and noise in combination with other factors.[53]

Broadbent's theory as originally formulated explained that the subject under noise suffers brief interruptions in the intake of information from the vigilance task. These "internal blinks" occur after the stimulus input entered the nervous system, but before it was analyzed. This "distractibility " hypothesis has subsequently been modified in order to account for the beneficial effects of noise to include the effects of arousal. His current position, apparently confirmed by Woodhead's experiment on searching visual displays in intermittent noise, is that a too high arousal level impairs performance because of a reinforced tendency to make responses to frequently occurring but inappropriate stimuli.[54]

Traits of personality which determine individual noise annoyance susceptibility are largely unstudied, but Davies and Hockey[55] think it possible that the visual vigilance of extroverts may improve when working in noise, while introverted subjects show less change with noise and sleep stress. In tasks requiring monitoring of various aspects of visual display with different levels of priority, loud noise biases attention even more strongly to parts of the task already receiving priority. This narrowing of attention is due to the relative importance which subjects attach to the components of the situation. In attentional selectivity, the major effect of noise is not a simple improvement or impairment in overall efficiency, but a shift in the distribution of efficiency over the various components of the task situation. The results must be interpreted in terms of increased selectivity of attention with arousal.

In an experiment typical of this research area, Hockey has recently investigated the effect of loud noise on attentional selectivity. His subjects were navy personnel aged about 17 to 25. They were asked to keep a pointer aligned with a moving target, and, while doing this, to report when they detected a light-flash from any of six lamps equi-distant, at 80 cm, from the subject. Tests were conducted twice; in noise (100 dB, and in quiet (70 dB). The tracking (the primary task) improves in noise, as does the detection of the centrally located signals in the monitoring task, but peripheral signals are detected less often in noise. Results support the suggestion that loud noise affects behavioral selectivity.[56]

Noise increases the level of arousal in a way comparable to that of anxiety or the prospect of gain. R. Hockey[57] suggests that the effects of material incentive can be reproduced with loud noise, "...a point which itself may be of considerable practical value." Experiments with sleep-deprived subjects under conditions of noise show that the two effects do not add up and make the performance worse.[58] In fact, they tend to cancel each other out, and bring the level back to normal.

An important French contribution to vigilance study, Tarrier and Wisner, 1962, reports that rhythmical classical music at 90 dB impaired the detection rate significantly in a 90-minute visual vigilance task.[59] Faucheux and Moscovici of the University of Paris studied the effects of two different cognitive sets on group creativity with and without exposure to noise.[60] Edith Gulian of the Institute of Psychology in Bucharest studies effects of noise on auditory vigilance tasks.[61] S. Dornic of the Slovak Academy experiments on the effects of specific noise on visual and auditory memory span, which support the important hypothesis on the acoustic nature of information storage in immediate memory.[62]

The work being done in Sweden on changing attitudes toward noise by S. Sorenson (Institute of Hygiene, Karolinska Institutet, and the Department of Environmental Health, National Institute of Health) and by E. Johansson (Psychology Institute, Lund) should be mentioned. Carl-Eric Moreau has reported on the effects of auditory stimuli on the intellectual functions from the point of view of the military psychologists.[63]

The Symposium on the Psychological Effects of Noise, Cardiff, September 1967. D. E. Broadbent gave the leading address on the effects of noise on work performance. He depicted a general state of arousal or reaction which is increased by noise and by incentives, but decreased by a low activity rate and by loss of sleep. He presented for consideration by his auditors, the new approach to an understanding of noise and its effects by a comparison of these effects with other stresses. For example, noise reduces the effect of sleeplessness, so if noise is harmful, to work only in an aroused state, some individuals may be chronically more aroused than others. Dr. G. C. Atherley went on from the usual definition of noise as unwanted sound to include the following parameters: unwantedness, information content, structure and signification (innate and acquired), Hopkinson and Rowland's applied techniques developed from their studies on lighting, discomfort and distraction from glare to the subjective assessment of noise. It was found that while the degree of correlation between the physical measurements of sound level in dB(A) and subjective assessments of loudness was good, the correlation between sound level and annoyance, intrusiveness or distraction was poor. Dr. H. Eysenck emphasized the need for careful studies of noise employing personality variables, particularly the extrovert-introvert distinctions. Eysenck's own Maudsley Personality Inventory is a technique of the kind recommended.

The Cardiff conference is the second of the two English conferences to which W. Hawel (Max Planck Institute, Dortmund) contributed papers on the parameters of the subjective evaluation of noise annoyance. Like Sader, he argues that if experimental findings are to be applied to real life, the main components of real human life which he defines as personality, situation, and activity, must be accounted for and controlled by the experiment. With Starlinger, Hawel has also done work on catecholamine secretion under noise exposure.[64]

Dr. D. R. Davies repeated his blanket indictment of most studies of the physiological effects of noise as being methodologically contaminated. However, he does credit peripheral vasoconstriction with a longer persistence than the other responses, in line with Jansen's theories. Dr. D. J. Ingraham reported research in progress on a group of steel workers in South Wales to determine the incidence of psychological disorders in noisy environments.

"Colloquium ueber psychologische Fragen der Laermforschung" Berlin, February 1964. (At the Psychology Institute of the Free University of Berlin under the sponsorship of the Deutsche Forschungsgemeinschaft.)[65] While Dr. Hoermann of the Psychology Institute of the Berlin University presided, Dr. M. Sader of the Mainz University Psychology Institute, who was then in process of preparing for publication his thesis Lautheit und Laerm (Loudness and Noise) - Goettingen, 1966, gave the main talk on "... The Phenomonology of Noise Stresses." Other speakers were W. Schonplug, Psychology Institute, Frankfurt am Main University, on "Stimulus-Activation-Performance;" H. Zahn, Psychology Institute, Free University, Berlin, on "Noise and Vigilance;" G. Jansen, Max Planck Institut für Arbeitspsychologie, on "Evaluation of Sound as a Physiological Problem;" and A. von Eiff, Bonn University Clinic for Internal and Nervous Illnesses, on "Function-Specific Effects of Noises of Different Time Structures."

Sader contradicts that prevailing assumption that noise stress is not analyzable into its components and urges the investigation of real life situation rather than laboratory tests. In general, his emphasis is on the interrelationships of the physiological and psychological workings of noise, as against Lehmann and Jansen, who separate these two categories. Sader's talk at this colloquium commented on noise as masking desired acoustic information, noise inducing physiological effects by psychological suggestion, noise as an index of the overall situation, unspecific oversensitivity toward noise, and noise as an overall concept for primarily non-acoustic phenomena. In an interesting digression, Schopenhauer is discussed as an example of noise oversensitivity.

Schonpflug describes his study as an attempt to unite various aspects of the activation and motivation theories.[66] Zahm's talk is, in effect, a survey of the literature on vigilance and attention, reviewing the expectancy, activation and filter theories, and then discussing the place of noise within these theories. In the animated discussion after this report, the weight of opinion seems to fall on Broadbent's filter theory. A. W. von Eiff[67] has been associated with the electromyography of the muscular potential in noise research (as opposed to Jansen and Lehmann's emphasis on the finger-pulse amplitude.) He restated his opinion to the colloquium that not all body functions respond to noise, that the order or sequence in which noise is administered in experiments is of importance in the total situation.

Work of the Psychology Institute of the Free University of Berlin. In a recent article, Hoermann, Mainka, and Gummlich return to the controversy over the possible relationships between the physiological and psychological reactions to noise of different subjective values. They begin by repeating Sader's thesis that such a relationship does exist and its determination should be an immediate task of noise research.

For subjects in Group A, noise was the signal that they had made an error in a pseudotracking task, for those in Group B, the same noise was a signal that they were on target in their task. A third group heard the same noise without a task. The dependent variables were: (a) temporary threshold shift (TTS); (b) muscle tension as measured by electromyography; (c) subjective scaling of the amount of annoyance and disturbance induced by the noise and of the general sensitivity for noise of the subjects. Subjects who invest the noise with a positive emotional valence feel themselves less disturbed, less annoyed and, in general, less susceptible to noise than subjects who receive the same noise with negative valence. Muscle tension is highest for Group A, less for Group B, least for Group C. The amount of TTS is dependent upon the valence of the noise: noise with negative valence results in a TTS of 18.1 dB, whereas noise of neutral or positive valence leads to a TTS of only 11.0 or psychological and physiological reactions to noise of different subjective valence (TTS and EMG).[71]

With U. Osterkamp, Hoermann has also written "On the Influence of Continued Noise on the Organization of the Memory, and on "On the Influence of Interrupted Noise on the Organization of the Memory," (Zeitschrift fuer exp. und angewandte Psychologie, vol. 13, 1966). They conclude that the memory-organizing tendencies represented by clustering are influenced by noise. Under noise, persons with high susceptibility recall less and their recalls are less organized and require more time. With E. Todt, Hoermann has written "Noise and Learning," Zeitschrift fuer exp. angewandte Psychologie. With E. Luebcke, Gummlich has written "Evaluating the Annoyance of Changing Noise Levels," Schalltechnik, and with Luebcke and Mittag, "Attempts at a Subjective Evaluation of Noise" for the Fifth International Congress for Acoustics, 5th, Liege, 1965.

Notes on the influence of noise on communication. Studies on systems in which ease of effective communication is important have been executed. In general they can be said to confirm the subjective opinion that non-masking noise makes the task of speech perception more difficult. Broadbent has demonstrated that speech distortion or noise by requiring the use of extra-capacity in deciphering speech signals, reduces capacity for the performance of other on-going tasks. Experiments proved that while the two types of speech distortion tested set a similar top limit to articulation test performance, one type achieved that level more easily than the other, this has implications for the design and communications links with drivers and pilots. Tests devised by P. M. Rabbitt of the Applied Psychology Research Unit to investigate the ability to process the words received under non-masking noise on a cognitive level should also be mentioned. W. I. Acton has recently described an experiment in assessing the possibility of failure of speech communication due to hearing loss.[68]

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