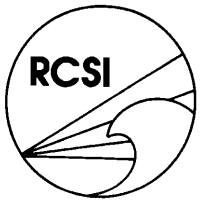

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Effects of Noise on Humans

By: Robert E. Lee
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Effects of Noise on Humans

by
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Summary

Noise can affect humans directly by reducing one's ability to hear. The government standards of the Walsh-Healy Act do not provide sufficient protection. There are indications that noise, even at intensities often found in the home and community, causes some hearing loss. Noise disturbs sleep, causing waking if sufficiently loud and decreasing the amount of essential "Rapid Eye Movement" sleep at lower levels. Noise also has indirect effects, interfering with speech and warning signals, causing distraction, reducing efficiency and inducing fatigue. The World Health Organization estimates these effects as costing business $4,000,000 per work day. Noise causes transient physiological changes such as constriction of capillaries, increased heart rate, decreased bowel activity, and decreased flow of saliva and digestive juices. The evidence is contradictory as to whether repeated, long-term exposure to these transient changes can cause permanent effects such as high blood pressure and ulcers.

Effects on Hearing

It is well established that high intensity sound will cause hearing loss. Consequently the federal government, in the Walsh-Healy Public Contracts Act, sets standards of permissible noise levels for firms having government contracts exceeding ten thousand dollars (1). This Act specifies permissible noise levels for various times of exposure. The maximum levels specified are 90 dBA (decibels measured on the A-weighted scale)(4) for 8 hours/day, or 92 dBA for 6 hours/day, and proceeds similarly to higher intensities for shorter periods of time to the extreme of 115 dBA for 15 minutes or less (1). It also specifies procedures for combining different intensities for shorter periods of time.

Since few home or community situations exceed these levels for appropriate durations the specific procedures detailed in the Walsh-Healy Act will not be discussed here. Since the Act might appear to suggest that the noise levels permitted in the Act are undamaging and thus condone high noise in the home and community, the effectiveness of the standards in the Act will be evaluated.

The Walsh-Healy Act "embodies the implicit presumption that practically all noise exposures are interrupted at least a few times a day" (2). Obviously community noise cannot equal the level permitted for industrial noise or the worker leaving the plant for lunch would not experience a break in his noise exposure. Also the exposure to community noise would not necessarily be limited to a maximum of eight hours since life in the community is less defined than the eight hour work day.

Furthermore, it is questionable whether the Act provides the protection for hearing which a citizen might expect. A Labor Department spokesman, evaluating the Act, states, "The Act defines an impairment as a hearing loss which begins to interfere with the understanding of speech in sentence form. Notice that the definition does not imply the ability to recognize every syllable or even every word. It means that impairment is the beginning of difficulty in getting the sense of a sentence as a whole." (3) This implies 25 decibels of damage "at the three test frequencies of 500, 1000, and 2000 Hz* which are the most important ones for the understanding of speech". (3) This degree of damage, 25 decibels, means that the threshold for a person with impaired hearing to understand 50% of the "gist" of sentences requires a sound pressure more than 17 times larger than normal. The noise intensity levels permitted under the Walsh-Healy Act are set because of their effects in the lower frequency ranges mentioned above since these are most important for speech understanding. "Initially, hearing loss occurs in the upper frequencies. As a rule this loss is for frequencies above 3,000 Hz" (5) Some authorities maintain that to hear speech completely all sounds up to 6,000 or even 7,000 Hz are essential and that listening becomes fatiguing if less than 90 percent of the words are correctly heard (5). The Act therefore fails to protect nonfatiguing ability to communicate verbally. Since music and warning sirens contain significant energy of higher frequences (6) the Walsh-Healy Act can be seen to tolerate loss of enjoyment of music and even ability to hear sirens and lessen understanding of the sounds of higher pitched female and childrens' voices (7).

Furthermore, even this degree of damage is not intended to be prevented in the entire population. The Labor Dept. spokesman continues, "Because of the normal variability among people, it is never possible to set a standard for exposure...which will protect the whole of any population which is exposed. Generally, threshold limits are set with the intention of protecting 90 percent or more of an exposed population." (3) Even this 90 percent protection may not have been achieved. The same government spokesman said that one set of data indicated these levels would cause impairment to about eight percent of the exposed population, but another study, which he personally judged to be better data, showed that this exposure to 90 dBA for a working lifetime, would cause about 16 percent of the population to be impaired (3). Thus, it must be concluded that the noise levels permitted by the Walsh-Healy Act will allow 8 to 16 percent of the population to be so severely damaged in their hearing that they will begin to experience difficulty in understanding sentences.

There is some evidence to suggest that many of the noises and sounds encountered in normal life tend to impair hearing and that this, rather than aging, is the cause of loss of hearing with age. The Mabaans, an African tribe, live on the Egyptian-Sudan border where the typical noise level is only 40 dB, (8) indicating quite quiet life. "Among the Mabaans, who live in an atmosphere of virtual silence, the hearing of even men in their seventies and eighties is the equal of healthy youngsters of ten." (8) This is not hereditary, as Mabaans who move to the city lose this hearing acuity. In industrialized countries, including the United States, hearing decreases with age, a phenomenon called presbycusus. Glorig (9) reports 18 decibels of hearing loss, at 4000 Hz (where loss begins) between the ages of 25 and 55 for a group of men not occupationally exposed to noise.

Womens' hearing is far less impaired with age than is mens'(11). By age 60 men have lost 32 dB at 4000 Hz while women have lost only 17 dB (10). Similar discrepancies exist at other frequencies (10). Since the hearing of the Mabaan male is not significantly worse than that of the female, (11) this difference is apparently not directly due to sex.

* Hz is the abbreviation for Hertz, a unit of frequency meaning one cycle per second.

All the facts listed above, concerning industrial vs. nonindustrial society, and male vs. female hearing are consistent with the hypothesis that the general noisiness of our society causes significant damage to hearing. This is not a proven hypothesis, however, since other hypotheses fit these facts. For example higher blood pressure due to tension can be hypothesized as causing this hearing loss. Loss of elasticity in the capillaries of the ear, affected by diet factors such as cholesterol level, have also been advanced as the cause of all these effects (11). Still, a Dutch physician inadvertently left a wool and earwax plug in a patient's ear for 32 years. When discovered and removed in 1962, the accidentally protected ear had much better hearing than the exposed ear, which had "normal" loss of hearing due, supposedly, to aging (11). While this single case does not disprove the other explanations of hearing loss, it does support the contention that normal noise levels may be causing the so-called "normal" loss of hearing with age.

Non-Auditory Effects

A. Speech Interference

Noise has effects other than the direct effect of causing loss of the ability to hear. The most direct and indisputable effect is interference with speech. This is so well documented that a quantitative scale, the "Speech-Interference-Level", has been devised. Recommended speech interference levels are available for various enclosures such as theaters, bedrooms, offices, etc (12). Interference with speech is not exactly related to sound intensity level in dBA because some sound frequencies are more important than others and also because some speech sounds are given with greater intensity. Nevertheless speech interference correlates closely enough with noise to permit specifying noise intensity in dBA which will cause a given amount of interference. Such a relationship, even though not exact, is very useful. See Figure 1.

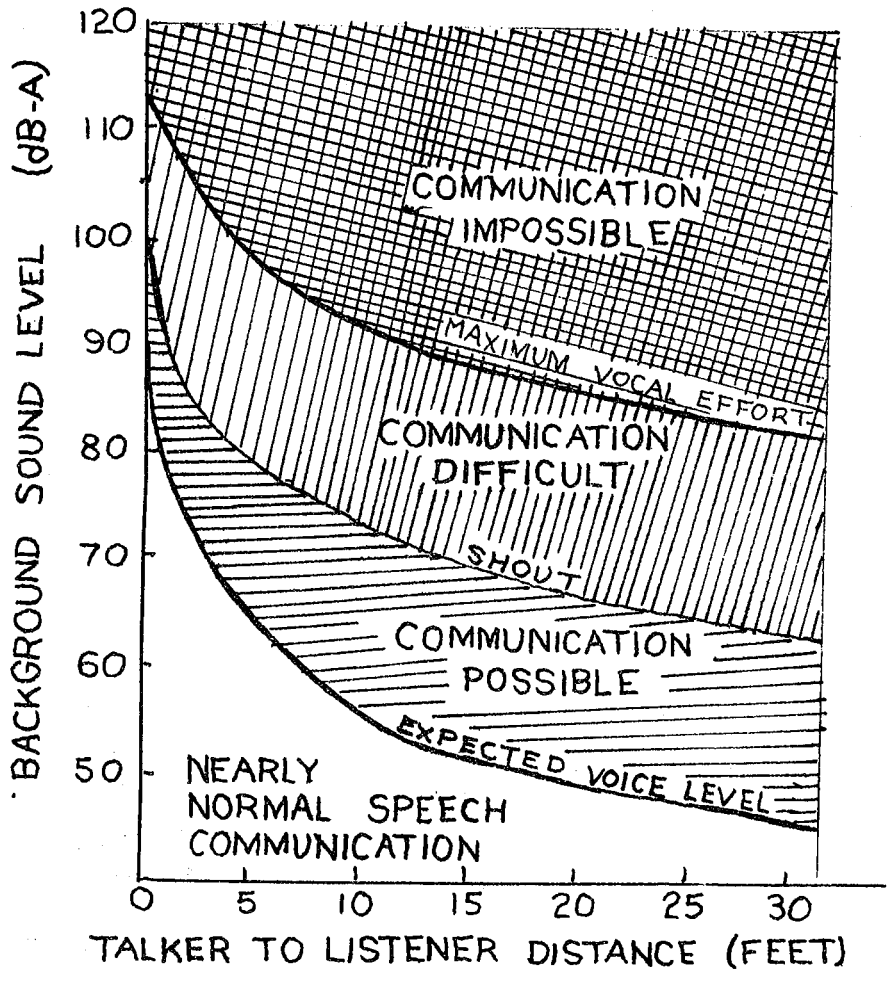


Figure 1. Quality of speech communication in relation to background sound level and the distance between talker and listener (16).

B. Digestion, Respiration, Heart

Another physical effect of noise is found in the digestive system. Noise, particularly when sudden and unexpected, causes a strong response in the sympathetic nervous system. This results in a decrease in saliva flow and digestive juices, as well as in decreased bowel activity (13).

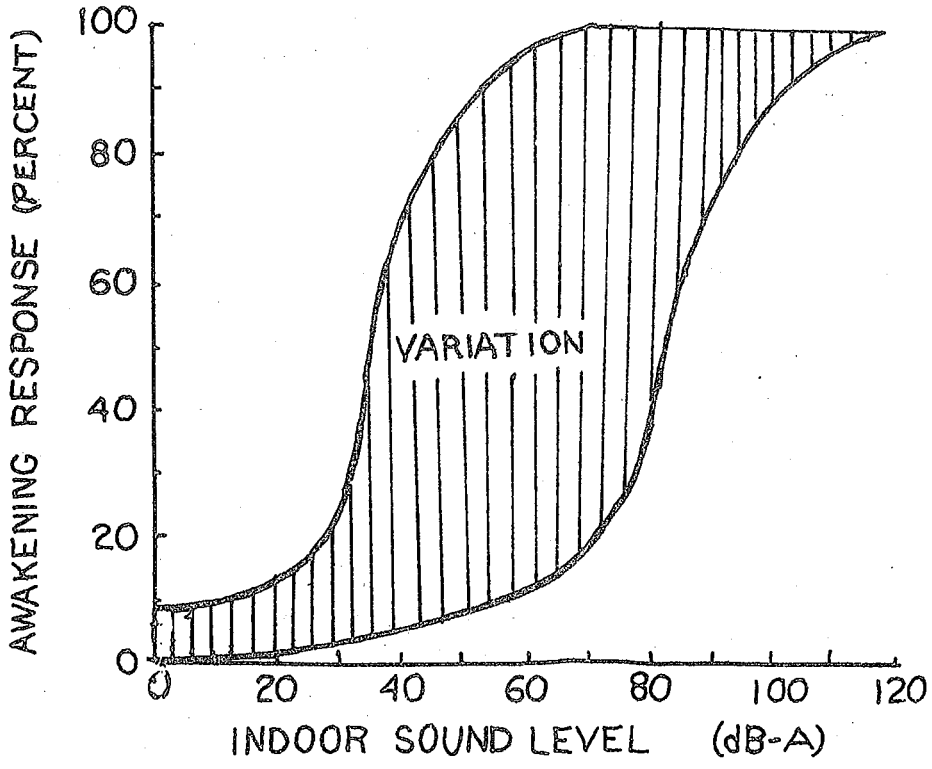
Since the above effects depend on the unexpected surprise element in noise they create a situation in which noise is apparently beneficial. A steady, droning noise, such as from an air conditioner, masks other noises and either eliminates or reduces their effect(21). Thus the added noise, in these peculiar situations, makes the noise less disturbing to the subject, although there is actually more total noise.

Other physiological effects appear more controversial. The President's Council on Environmental Quality reports "Noise is known to produce various temporary changes in man's physiological state, in particular a constriction of the smaller arteries. This can mean a speeded up pulse and respiration rate...Continued exposure to loud noises could cause chronic effects such as hypertension or ulcers...Research is still necessary to permit quantitative prediction..." (14). Glorig, (15) however, reports "Studies of these effects to date have failed to reveal any harmful results as far as health is concerned". He does go on to admit the temporary effects and need for further research. He cites a German investigation of 1000 steel workers exposed to 90 to 100 dBA noise for three years, which showed a statistically significant increase in vascular disorders and alterations of heartbeat rhythm as well as a contradicting study of men working in turbo-jet noise of 120 dBA which showed no such effects (15).

C. Sleep

An obvious effect of noise occurs when the sound level actually wakes a sleeper. The level of sound causing awakening varies with time of night and depth of sleep. There is also variation between individuals in their response to sound while sleeping and variation for a given individual due to degree of tiredness. A typical variation in the percent of sleeping persons who are awakened by a noise is shown by the spread between the two curves of Figure 2 (16). These curves show the percent awakened by a given sound level, in dB A, measured in the room with the sleeping person. If the source of the sound is outside of the house the sound level just outside the house would have to be approximately 10 dB-A louder if the windows are open and 20 dB-A louder if they are closed (17) than the value on this scale.

Figure 2. Percent of sleeping individuals awakened in response to a brief indoor sound of a given level.



D. Psychological Effects

The effects of noise on a person who is sleeping are also psychological. The depth, continuity and duration of sleep are all affected by noise, including the dream stage. This dream stage, characterized by "Rapid Eye Movements" (REM) is essential and disruption of this stage, even though the person does not wake, can lead to a generalized excitable state. Cumulative effects of long term partial deprivation of REM sleep may even lead to acute psychotic breakdown (18).

Noise may cause other psychological effects. One study by Glass and Singer (19) showed that following exposure to noise, particularly unpredictable and/or uncontrollable noise, humans are less tolerant of frustration. Their research concerned frustration in problem solving but may be applicable to the noise and frustration of driving in heavy traffic. Bragdon (20) discusses a number of other studies, one of which found that short-term noise exposure caused students to have difficulty completing math and reading tests and another of which found no such effect. Similar contradictions between studies are also discussed by Bragdon in connection with other tasks. In general, he finds that the following conclusions still appear valid. Generally, performing a manual task is least affected by expected noise while unexpected or unfamiliar noise reduces efficiency (20).

Tasks requiring higher-order mental facilities, such as problem solving and creative thinking, are highly susceptible to noise (20). There is still some controversy about quantifying some of the psychological effects but there is little doubt they exist. The World Health Organization, a U.N. agency, estimates that office noise causes inefficiency amounting to $4,000,000 every workday, through misunderstanding of messages, fatigue, absentmindedness and mental strain (20).

In conclusion it can be said that noise, at the levels encountered in the home and community, may be the cause of so-called "normal" hearing loss with age. It is not proven to cause ulcers or heart trouble but may do so. It is known to cause stress and frustration and to interfere with sleep. Its effect on office efficiency is estimated at millions of dollars a day. Its effect on home and community life is not available in dollar value but is presumably substantial.

References

(1) Federal Register, Vol 34, No 96. Tuesday, May 20, 1969.

(2) L. L. Beranek, Noise and Vibration Control, McGraw-Hill, 1971 p 546

(3) F. A. Van Atta, "Federal Regulation of Occupational Noise Exposure" in Sound and Vibration, May 1972, pp 28-31

(4) R. E. Lee,"Noise: Definition and Typical Values",R.C.S.I. Bulletin #146

(5) C. R. Bragdon, Noise Pollution: The Unquiet Crisis, U. of Penna. Press, Phil. 1970, p 77

(6) Ibid. p 66

(7) A. Bell, Noise, An Occupational Hazard and Public Nuisance, World Health Organization, Geneva, 1966 p 24

(8) R. A. Baron, The Tyranny of Noise, St. Martin's Press, N.Y. 1970, pp 77-78

(9) A. Glorig, A. Summerfield and J. Nixon, "Distribution of Hearing Loss in Non-Noise Exposed Populations" in Proc. of the Third International Congress of Acoustics, Elsevier, 1959, vol 1, p 150 as cited in reference (7) p 42

(10) A. Bell, loc. cit. pp 42-44

(11) R. A. Baron, loc. cit. pp 82-84

(12) A. P. G. Peterson and E. E. Gross, Handbook of Noise Measurement, pp 61-65

(13) C. R. Bragdon, loc. cit. p 71

(14) Environmental Quality: The First Annual Report of the Council on Environmental Quality, U. S. Government Printing Office, Washington, D.C. 1970, pp 126-127

(15) A. Glorig, "Non-Auditory Effects of Noise Exposure" in Sound and Vibration, May 1971, pp 28-29

(16) Effects of Noise on People, U. S. Environmental Protection Agency Report, NTID 300.7, Dec. 31, 1971 as cited in "Prevention and Control of Environmental Noise Pollution", New York State Dept. of Environmental Conservation, Nov. 1972, p 19

(17) L. L. Beranek, loc. cit. p 579

(18) C. R. Bragdon, loc. cit. p 80

(19) D. C. Glass and J. E. Singer, "Behavioral Aftereffects of Unpredictable and Uncontrollable Aversive Events" in American Scientist, Vol 60, July-August 1972

(20) C. R. Bragdon, loc. cit. pp 82, 83

(21) A. Bell, loc. cit. p 34