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Ergonomics of human-system interaction —

Part 620:
The role of sound for users of interactive systems

Ergonomie de l'interaction homme-système —

Partie 620: Rôle du son pour les utilisateurs de systèmes interactifs

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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This document was prepared by Technical Committee ISO/TC 159, *Ergonomics*, Subcommittee SC 4, *Ergonomics of human-system interaction*.

A list of all parts in the ISO 9241 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

In physics, sound is a vibration that propagates as an acoustic wave, through a transmission medium such as a gas, liquid or solid. In human physiology and psychology, sound is the reception of such waves and their perception by the brain. Unwanted sound is referred to as noise and is often perceived as the most serious disturbance factor at office workstations. In many industrial environments, sound can be a serious threat to health in general, not limited to auditory effects alone.

While sound is a measurable physical reality, acoustic noise is a psychoacoustical concept. The main goal of this document is minimizing the impact of noise while operating interactive systems, for example on the behaviour of users, their well-being and/or performance. This can be accomplished by technical measures, organizational means, interventions at the personal level and any combinations thereof.

The overall concept T-O-P (technical – organizational – personal) indicates the reasonable order of measures that can be taken to control the impact of the acoustic environment on human work. In this context, technical solutions have priority over organizational measures and personal protective equipment (PPE).

Psychoacoustics is the branch of psychophysics involving the scientific study of sound perception and audiology – how humans perceive various sounds. More specifically, it is the branch of science studying the psychological responses associated with sound (including noise, speech and music). This document deals with the undesired effects of sound, which can be classified as follows:

— impaired hearing;

— undesired responses of the central and autonomic nervous system;

— hindrance of verbal and other communication;

— reduced performance and cognitive functioning;

— annoyance.

Acoustic satisfaction of a space cannot be guaranteed without consideration of each of the three principle parameters of architectural acoustic design, formalized and established in the early 1900s by Sabine.[28] The three principle parameters are known as the ‘ABCs’ of architectural acoustics: A for absorption – Sufficient absorption in the built environment; B for blocking – Sufficient isolation of the built environment; and C for control – Control of sound levels in the built environment. For a given space, various measures in combinations can be taken to control the acoustic environment to achieve satisfaction. In ISO 9241-6 such measures are briefly listed and partly explained. Experience now suggests that a more thorough consideration of the acoustic environment is required because of the changes to work organization and tasks.

Controlling the acoustic environment is considered part of the T-O-P concept. It can comprise, for example:

— reducing the rating level

  — insulation in structural components;

  — reducing noise emission from equipment;

  — increasing sound absorption;

  - reducing the ambient noise level;
- optimizing the signal-to-noise ratio
  - reducing the sound level in speech frequencies;
- sound reduction within use environments
  - sound-absorbing ceilings;
  - partitions;
  - adequate distances between workstations;
  - reducing reverberation.

While all these measures are of a technical nature (T of the T-O-P principle, Figure 1), the impact of sound events on persons and work can require organizational measures, such as holding small meetings dedicated to certain tasks outside the workspace. The final argument comprises measures at a personal level, including training to cope with adverse environments.

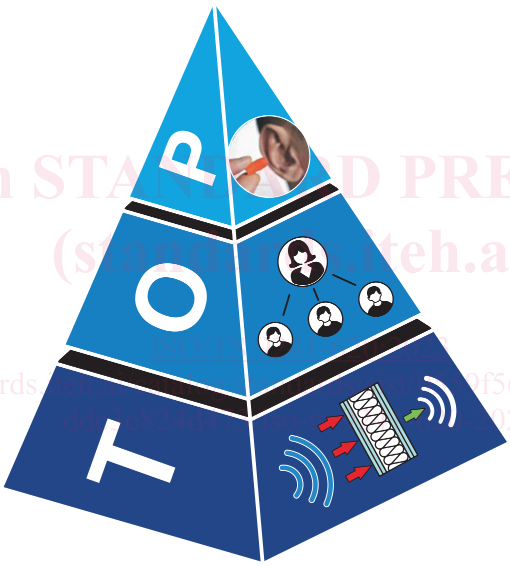


Figure 1 — T-O-P principle for controlling the impact of the acoustic environment on human work

Ergonomics of human-system interaction —

Part 620:
The role of sound for users of interactive systems

1 Scope

This document provides users with a summary of the existing knowledge about ergonomics considerations for the influence of sound in use environments on humans. It describes how unwanted effects of sound (noise) can be controlled. The main goals for controlling the acoustic use environment are reducing the rating level of sound in general, optimizing signal-to-noise ratio and sound reduction within the workspace.

This document also provides users with organizational measures that can be taken if and when technical measures do not help sufficiently. Also included are measures on a personal level.

This document deals with sound events that can cause extra-aural effects. Noise-induced hearing loss prevention and the ways to eliminate or reduce hazardous noise exposure are not covered by this document.

The intended users of this document include:

— developers of systems, products and services;

— public and corporate purchasers;

— occupational health and safety professionals;

— architects and interior designers;

— human resource professionals;

— usability, ergonomics or human factors professionals;

— users of interactive systems.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1
irrelevant speech effect
ISE
negative effect of verbal sound level

3.2
rating level
L_{AR}
equivalent continuous A-weighted sound pressure level during a specified time interval plus adjustment for tonal character and impulsiveness

Note 1 to entry: ΔLT = 0 dB or 5 dB according to subjective assessments

where

Δ is difference;

L is level;

T is tonal.

Note 2 to entry: Impulsiveness is specified only if the difference of the measured sound level with and without impulses exceeds 2 dB.

[SOURCE: ISO 9241-6:1999, 3.19, modified — Notes to entry replaced.]

3.3
background noise level
$L_{p,B}$
A-weighted sound pressure level present at the workstation during working hours with people absent

Note 1 to entry: The A-weighted background noise level $L_{p,B}$ is expressed in dB.

3.4
total noise sound pressure level
L_{NA}
sound pressure level that contains all noise components affecting the listener during use, such as noise generated by building systems, operating equipment or the audience, and which is determined at ear height for the area in which people are normally located

Note 1 to entry: The A-weighted total noise sound pressure level L_{NA} is expressed in decibels.

Note 2 to entry: If not otherwise specified, noise is determined according to DIN 45641 as the A-weighted equivalent continuous sound pressure level averaged over the time that is representative for the disturbance.

3.5
impulsive sound
sound with a rapid rise and decay of sound pressure level, lasting less than one second and causing an increase in the sound level of at least 6 dB(A)

3.6
reverberation time
T
time required for the sound pressure level in a room to decay by 60 dB once sound excitation has stopped

Note 1 to entry: The reverberation time is expressed in seconds.

3.7
speech transmission index
STI
metric ranging between 0 and 1 representing the transmission quality of speech with respect to intelligibility by a speech transmission channel

[SOURCE: IEC 60268-16:2020, 3.3]

Note 1 to entry: Speech transmission channel can also be the use environment.

3.8
sound pressure level
SPL
logarithmic measure of the effective pressure of a sound relative to a reference value

4 Sound and noise

4.1 How sound and noise impact users

Hearing (audition, auditory sense) is one of the five basic senses used by humans to perceive the physical environment, alongside sight (vision, visual sense), taste (gustation, gustatory sense), smell (olfaction, olfactory sense) and touch (somatosensation, somatosensory sense). Even if its sensor, the ear, seems to function independently from those of the other senses, they all function in concert. Sight and hearing, or those sensory aptitudes that can collect information from a distance (relatively speaking), are called far senses. Hearing is the only sense that can detect objects or events beyond the (optical) horizon.

Evolution has programmed human beings to be aware of sounds as possible sources of danger. The hearing as the far sense gives notice of things that cannot be seen but that could be important. It plays an alerting function. Even if this function is not needed in most use environments, it cannot be switched off or ignored. While the sense of sight is relatively inactive during sleep, hearing remains on. The alert function requires that hearing is almost non-directional compared with sight. It is possible to look away or even close the eyelids, watch certain objects while ignoring others, but there is no mechanism to ignore acoustic events.

The directionality of the human auditory system is limited to sound localization. The brain utilizes subtle differences in intensity, spectral and timing cues to allow sound sources to be localized. Thus, even if someone tries to ignore a certain acoustic event there will be a response. Although people tend to get used to noise exposure, the degree of habituation differs for individuals and is rarely complete.

Adverse effects of sound events can be of a different nature. The simplest effect is characterized as annoyance without further consideration of the genesis and aftermaths. Other effects can be of a physiological and/or psychological nature (see Table 1).

Table 1 — Classification of factors that affect individual annoyance with noise[15]

Factors that affect individual annoyance with noise	
Primary acoustic factors	Sound level
	Frequency
	Duration
Secondary acoustic factors	Spectral complexity
	Fluctuations in sound level
	Fluctuations in frequency
	Rise-time of the noise
	Localization of noise source
	Physiology
Non-acoustic factors	Adaptation and past experience
	How the listener's activity affects annoyance
	Predictability of when a noise will occur
	Is the noise necessary?
	Individual differences and personality
SOURCE: Canadian Centre for Occupational Health and Safety (CCOHS). *Noise – Non-Auditory Effects*. Available from: https://www.ccohs.ca/oshanswers/phys_agents/non_auditory.html. Reproduced with the permission of CCOHS.	

Recent research supports earlier results regarding the association of ambient sound and heart rate with longitudinal data that demonstrate that the real-world ambient signal-to-noise ratios are associated with lowered heart rates, suggesting that sound conditions which reduce the auditory perceptual load and listening effort de-stress the human cardiovascular system.[16],[27]

If many people work together in close proximity, as is the case in multi-person offices, disturbances to activities and annoyance reactions from staff due to various environmental factors become particularly evident, in particular since working practices often require switching between communicative exchange and focused work.

The resulting annoyance reactions can occur in the following forms:

— disturbance component “annoyance”;

— impairments of well-being, irritation, tension, exhaustion;

— changed communication behaviour (withdrawal, avoiding interactions).

The most disturbing characteristics of speech-specific noise are the information content and the uncontrollability, whereas uncontrollability and unpredictability of the noise play a big role in the case of noises from office environments. Only approximately 30 % to 40 % of the annoyance effects resulting from noise can be explained by technical-acoustic factors. The predominant part originates from moderators of annoyance (see VDI 2569).

4.2 Types of sound events

The type of sound has a bearing on how it is to be measured, what type of sound-level meter setting should be used and what descriptors and other data should be presented.

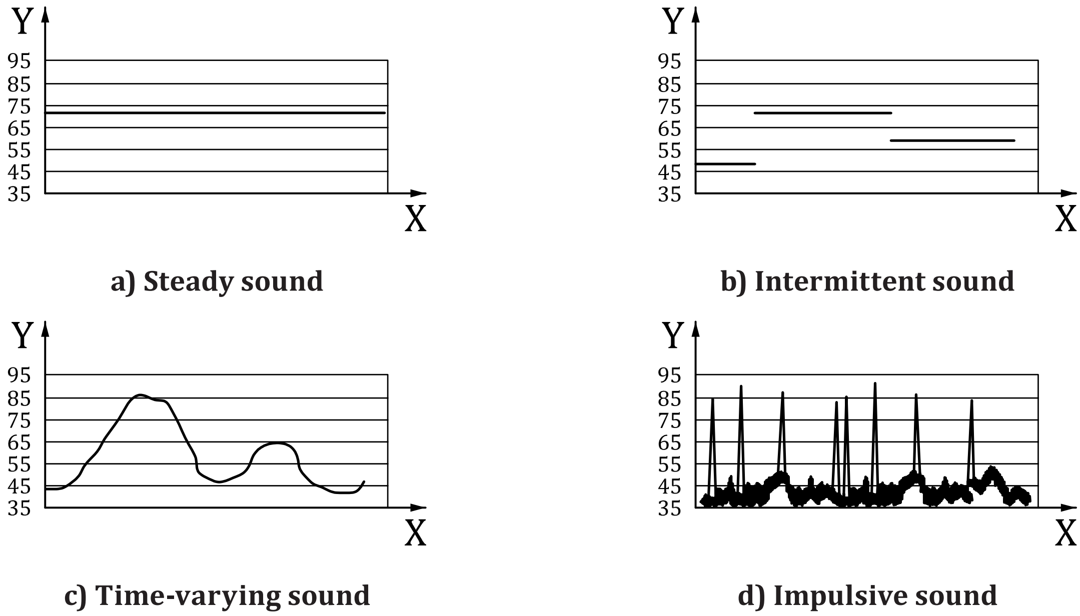
Sound events are generally classified into the following categories (Figure 2):

a) steady sound levels (e.g. air conditioning);

b) steady but intermittent sound levels (e.g. printers that print in bursts);

c) time-varying sound (e.g. traffic sound over a specific time period);

d) impulsive sound signals that can include one or more impulses (e.g. ringing telephones, high-impact printers).



Key

X time

Y sound pressure level, dB(A)

Figure 2 — Types of sound events

Sound level descriptors or metrics differ according to the type of sound events. Most metrics, for example A-weighted sound pressure level, have been developed for non-impulsive sound events. For characterizing impulsive sound levels, different methods are used.

4.3 Interference with the task

The impact of sound from sources other than speech is normally considered by its sound pressure level (L_{pA}) or the equivalent continuous A-weighted sound pressure level (L_{Aeq}). If the sound includes impulse noise, a certain margin is added to the level [e.g. +2 dB(A)].

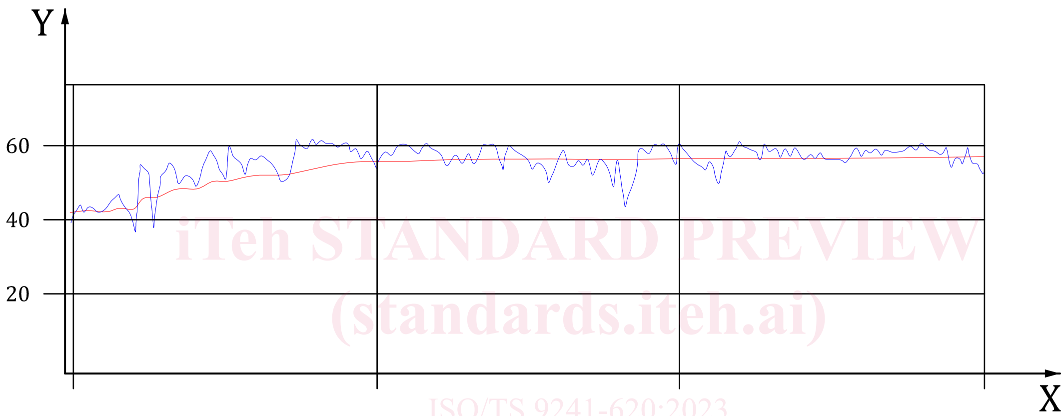
Speech sounds and speech-like sounds lead to losses of performance of the working memory. This effect does not necessitate the understanding of speech; an unknown foreign language or a musical piece can also have adverse effects. In this context, it is essential that the sounds are not mandatorily perceived as noise and that, despite focusing the attention on the material to be memorized, the irrelevant speech effect (ISE) can occur. This disturbing effect can already occur at A-weighted speech levels from 35 dB if they are clear speech signals.[30] The disturbing effect is due to the spectro-temporal structure of the speech or music sound, which results in this sound gaining access to the cognitive system (see VDI 2569)

The interference of speech with the user performance can be a result of the disturbing effect on the “inner speech”. Ambient noise can affect both reading and typing, because most users “speak to themselves” during these tasks. As for the mechanism for such effects, some research indicates that masking the relevant information with ambient sound is responsible.[28] The role of inner speech in human communication has been investigated (see Reference [20]). Inner speech, also called self-talk or internal monologue, is a person’s inner voice that provides a running verbal monologue of thoughts while they are conscious. Inner speech plays several crucial roles in reading.[18],[31] Reading is a complex process that involves the interaction of two levels of processing: decoding individual units and using text as a whole to establish broader meaning. Both can be affected by ambient sound, but the effect seems to be much stronger if the ambient sound is speech or speech-like.

The characteristics of sound events are very different for environments with "normal" noise sources, such as street noise or machine noise, than for those environments dominated by speech sound. While for the first the concept of a sound "level" can hold true (Figure 3), in the latter each sound event is separated from the others (Figure 4). In these studies, the base level without any work activity was 33 dB(A); single events were up to 65 dB(A) in the recorded session. The highest recorded level was 75 dB(A) with a speaker at a distance of 11 m. Whereas in acoustics, mostly a level of 65 dB(A) for normal speech in one meter from the speaker's mouth is assumed.

In real work environments, speakers can emit sound levels between 45 dB(A) and 75 dB(A) while telephoning, depending on the task and the quality of the sound transmission from the opposite side. In contrast to earlier landline phones, mobile networks do not guarantee a certain transmission quality. In addition, users do not speak in rooms with controlled acoustic conditions.

A "silent" train compartment in modern trains has noise levels beyond any recommended environments for acceptable telephone communication. However, those levels are still lower than those in cars or aeroplanes. While communicating with people in such environments, the speaker adjusts her or his speech level to a certain degree to the level of that noisy environment.



Key

X time

Y sound pressure level, dB(A)

NOTE The red line approximates the sound "level".

Figure 3 — Typical sound event with slow changes in the level