Technical Note

Guideline: Listening tests for measurement of the relative annoyance and the annoyance potential of noise

Performed for Uddannelses- og Forskningsministeriet
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Title
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Resume

These guidelines provide procedures for listening test that will contribute to reliable and reproducible results of the relative annoyance and the annoyance potential of various types noise heard in specified contexts.

Listening tests is a way to obtain the assessments of the perception and/or the reaction to sounds. No physical instrumentation can give such results directly. Several "tools" are necessary for performing listening tests: Listening facilities, stimuli, assessors, attributes, systems for stimulus randomization, presentation and collection of assessments and finally statistics for data processing.

In this guideline, the main requirements to each of the above mentioned "tools", for obtaining a qualified listening tests, are listed.

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Content

1. Scope

The intention of these guidelines is to provide procedures for listening test that will contribute to reliable and reproducible results of the relative annoyance and the annoyance potential of various types noise heard in specified contexts. Perceptual attributes related to annoyance will also be considered.

Listening tests are a way to obtain the assessments of the perception and/or the reaction to sounds. No physical instrumentation can give such results directly. Several "tools" are necessary for performing listening tests: Listening facilities, stimuli, assessors, attributes, systems for stimulus randomization, presentation and collection of assessments and finally statistics for data processing. When humans are used as measuring instruments variations and spread in the individual assessments are unavoidable, but qualified planning and use of the "tools" will minimize the spread and increase the reproducibility. Statistical processing of the data will qualify the results and give information on the uncertainty of the results.

In this guideline, the main requirements to each of the above mentioned "tools", for obtaining a qualified listening tests, are listed. More details about the topics may be found in textbooks, see clause 13, Bibliography.

Guidelines for specific fields of application are given in appendices.

2. Field of application

This guideline is related to listening tests on the annoyance from noise, e.g. environmental noise, neighbour noise, noise from products etc. Results of listening tests according to these guidelines may be used for comparison of situations, products and/or working conditions.

In general measurements of annoyance shall be performed as surveys (questionnaires or interviews) of persons who are exposed to the noise in their daily life or in common use scenarios. The technical specification ISO/DTS 15666, see section 3 Normative references, provides specifications for socio-acoustic surveys and social surveys which include questions on noise effects. The scope of this ISO Technical Specification is restricted to surveys conducted to obtain information about noise annoyance "at home".

The present guideline recommends using the same scale for measurements of annoyance as ISO/DTS 15666. Nevertheless, when listening tests are performed, either in the field (indoor or outdoor) or in the laboratory we may expect other results than obtained in the former mentioned socio-acoustic surveys, as among other things the context is different. Therefore, the results from measurements of annoyance in listening tests are called the annoyance potential. This may correlate with results measured by results obtained as socio-acoustic surveys. It is assumed that the relative annoyance assessments will correlate with "real life" annoyance issues for similar types of sound sources.

The context is important for any assessment of annoyance. Therefore, the context shall be defined, imagined or simulated (visualized and /or auralized) if the test is not performed in the real relevant context.

Examples of use cases for this guideline may be assessment of:

- Different noise types, designs…indoor or outdoor
- tonal content from wind turbines
- influence of traffic pattern and spectra
- sound insulation of walls against neighbour noise
- sound insulation of windows or façade insulation against traffic noise
- impact sound insulation
- ventilation noise
- …

3. Normative references

ISO 5492:2008. Sensory Analysis Vocabulary. ISO 2008.

ISO 6658:2017 Sensory analysis - Methodology - General guidance.

ISO 8586:2012 Sensory analysis -- General guidelines for the selection, training and monitoring of selected assessors and expert sensory assessors. Corrected version 2014.

Technical specification ISO/TS 15666:2003(e): Acoustics — assessment of noise annoyance by means of social and socio-acoustic surveys. ISO 2003.

IEC. 60268-13, Sound system Equipment – Part 13: Listening tests on loudspeakers. International Electrotechnical Commission, 1998.

IEC 60942:2017 Electroacoustics - Sound calibrators.

IEC 61672-1:2013 Electroacoustics - Sound level meters - Part 1: Specifications.

EBU Tech. 3276. Listening conditions for the assessment of sound programme material: monophonic and two–channel stereophonic. European Broadcasting Union, 1998.

Recommendation ITU-R BS.1116-3: Methods for the subjective assessment of small impairments in audio systems. ITU 2015.

ITU-R Rep. BS.2300 (2014). "Methods for assessor screening", International Telecommunication Union, Geneva, Switzerland. https://www.itu.int/pub/R-REP-BS.2300

4. Definitions and terms

Attribute: A property that can be perceived (perceptual, affective or connotative). It may or may not be prominent.

Descriptor: A word or phrase that describes, identifies, or labels an attribute. (A clear distinction between the attribute and its descriptor is not always made).

Perceptual measurement: An objective quantification of the sensory strength of individual sensory attributes of a perceived stimulus. The tests are normally made with a panel of trained persons who understand the attributes and how to rate them. The main purpose is to give information about the character of the sound as perceived by the hearing sense. The characteristics of the perceived stimulus are rated in objective terms without asking the assessors for preferences or annoyance.

Affective (or hedonic) measurement: Subjective measurements of preference, liking, annoyance or of connotative attributes. The tests are normally performed with a group of naive (untrained and without experience in listening tests) test persons who are representative of the relevant target group (consumers, users, average citizens etc.). The main purpose is to give information about reactions to the sound in a given context.

Listening test: A sensory evaluation where persons in a systematic way are presented to stimuli of sound and requested to give their assessments in a prescribed manner. Listening tests may be either objective (perceptual – what do the persons hear) or subjective (affective – how annoyed are the persons/what do they prefer). A distinction between these two types of tests shall be made.

Sample: A (time limited) representative selection of the sound, music or noise of interest.

Stimulus: That can excite a receptor. In this case the acoustic presentation to the listener of the sound under test and any added background sound.

Auralization: A procedure designed to model and simulate the experience of acoustic phenomena rendered as a sound field that can create a realistic sound perception of these phenomena for a listener.

Socio-acoustic survey: A social survey in which noise-induced annoyance is assessed and values of measured or calculated noise metrics are attributed to the subjects' residential environment.

Annoyance: An emotional and attitudinal reaction from a person exposed to noise in a context.

Annoyance potential: The annoyance of sounds measured in a listening test. The listeners should be presented to a scenario for the sound.

NOTE – Reliable measurements of noise annoyance may not be obtained in listening tests (in the field or in the laboratory), and it is uncertain to which degree annoyance potential correlates with noise annoyance. If the test persons are presented to the context of the sound by instructions, by pictures, by simulated surroundings or similar, it is believed that the annoyance potential of different sounds correlates with the annoyance of these.

Relative annoyance: The annoyance of one sound compared to other sounds in the same context or simulated context.

Scenario: A context for the perception of the sound that is described or simulated for the test person (by pictures, video, virtual reality, sound) or a context that the test person is asked to imagine (imagine that you hear this sound while sitting …).

Simplified background noise: A pink noise signal with a frequency weighting so that the spectrum is similar to average outdoor or indoor background noise spectra – see clause 17 Appendix 4.

Assessor: Any person taking part in a sensory test. A naive assessor is a person who does not meet any particular criterion in relation to testing.

Expert assessor/ Expert listener: A selected assessor with a high degree of sensory (listening) sensitivity and experience of sensory (listening) methodology, who is able to make consistent and repeatable sensory (listening) assessments of various products or sounds.

Listening Panel: Group of assessors chosen to participate in a listening test.

Masking: The decrease in the intensity or change in the characteristics of the perception of one stimulus by the simultaneous exposure of other stimuli.

5. Stimuli

5.1 Recording of stimuli

Recording techniques should be chosen according to the intended reproduction mode.

Binaural recording technique, with an artificial head and torso with microphones in the carefully designed artificial ears, is recommended headphone reproduction. It gives a realistic impression of the recorded sounds both in the timbral and spatial domain. Due to differences especially in the pinnae between the artificial ears and the ears of a real person there are imperfections especially in regard to the localization of sound sources and the spatial impression. For recordings in free or diffuse sound fields an artificial head without ear canals should be used i.e. the recording microphones are positioned at the entrance to ear canal point, EEP (e.g. Brüel & Kjær type 4100).

For stereo reproduction over loudspeakers the A-B stereo technique – also called time difference stereo may be used. The recording can be made with two omnidirectional measuring microphones which facilitates easy level calibration with an acoustic calibrator. The spacing between the microphones should be 20-40 cm.

To record the sound stage for surround sound reproduction (5.1, 7.1, 10.2…) special microphones with multiple microphone capsules or special sound field microphones are needed. Calibration of such recordings may only be obtained by making a parallel measurement with a sound level meter or a parallel recording with a measurement microphone including recordings of a calibration signal.

Recordings of context relevant background sounds or soundscapes should also be made. It is worth considering whether these shall be part of the recording of the samples or whether they should be recorded separately.

5.2 Auralization of stimuli

Visualization is used in the sense of "making visible". Similarly, auralization is used in the sense of "making audible".

Auralization is a procedure designed to model and simulate the experience of acoustic phenomena that can create a realistic sound perception of these phenomena for a listener.

Often, the auralization is created to make an upcoming or imagined scenario audible.

Auralizations may e.g. be used to give an audible experience of the sound from a planned road, the effect of a noise barrier or the effect of a new noise-reducing asphalt pavement. Auralizations can also be used to illustrate how the noise from a road can vary, for example in upwind or downwind situations from the road or with an increased traffic intensity or another traffic composition.

In building acoustic contexts, auralizations can be used to give an audible perception of the sound insulation of different types of walls, the sound of the impact attenuation of different floor constructions or the acoustic properties of rooms such as reverberation time.

When auralizations are made for listening tests the auralized sound samples should be accompanied with a sound file suitable for calibration of the playback levels.

5.3 Acoustic context

For assessment of annoyance the context is important. The primary noise source is often heard together with background sounds. Addition of background sounds in listening tests should be considered, as they provide information of the context and they thereby also give a frame of reference (level, spectrum and localization wise) for the noise under investigation.

It may be an advantage to have separate files with background sound files, so a relevant mix with the noise stimuli can be presented to the listeners. It may also be relevant to play the background sound continuously during the test, independent of the stimulus presentation, to obtain habituation to the acoustic context.

5.4 Calibration of recordings and sound files

Level calibration is needed to be able reproduce the sounds at calibrated and specified levels during the listening test. Recordings and sound files should be calibrated and accompanied with a calibration file, preferable made with reference to an acoustic calibrator fulfilling IEC 60942:2017.

For the reproduction of recordings and the sound files the calibration signal is used to adjust the reproduction equipment to the same level as the original level or another well-defined level.

For reproduction over loudspeakers a supplementary pink noise file with a specified A-weighted sound pressure level is more useful than a calibration tone for adjustment of the playback level, due to room acoustic phenomenon's related to playback of tones.

5.5 Reference stimuli

When listening tests are performed for investigation of the annoyance potential of special sound characteristics (audible tones in noise, impulse prominence, amplitude modulation…) or noise from various sources (different mans of transportation, wind turbines…) neutral reference sounds may be useful. The annoyance potential of the stimuli may then be quantified as the sound pressure level of a neutral reference sound giving the same annoyance.

Often road noise is used as the neutral reference sound. For this purpose, the traffic on the road should be dense without clearly audible single vehicles and the road noise should recorded at such a distance from the road that the level variations from vehicle pass-byes is negligible.

The simplified outdoor background noise described in clause 17 Appendix 4 may also be used a neutral reference sound.

5.5.1 Anchor stimuli and data aggregation

If we want to combine data or compare results from different listening tests, it is necessary that there are some recurring stimuli, which can be used as fixed reference points – so-called anchor stimuli.

Two or three (preferred) anchor stimuli may be chosen, within the relevant stimuli range, in a way so that their characteristics is assessed respectively high, mid and low for most attributes. The anchor stimuli shall be assessed on an equal basis with the other systems, i.e. normally as part of a randomized blind test

The anchor systems serve two purposes:

- To set the same frame of reference for the test to make the assessors use the scales in a similar way from one test to the next.
- To take any changes of the assessments of the anchor systems into account in the statistical analysis of the data (data aggregation).

If the assessment of the anchor systems has changed since the last test, the results of one of the tests might be transformed (rescaled) according to this change, so that the results from the two tests are comparable.

6. Listening facilities

6.1 Listening room and listening booths

Listening tests in a laboratory may be performed by use of loudspeakers or headphones. For loudspeaker reproduction a listening room shall be used while for headphone reproduction a listening booth or other facilities with low background noise may be used.

Depending on the purpose and loudspeaker setup, the listening room may be an anechoic chamber or a listening room for loudspeaker reproduction as specified in e.g. EBU Tech. 3276, IEC 60268-13 or BS. 1116-1, see clause 3. The reverberation time must be short and lie within specified limits, and the reverberation time should be the same at all frequencies (however, a weak increase is permitted at low frequencies). The background noise must be low, so that unintended sound does not interfere with the listening test. The background noise (including noise from ventilation, computers and other technical equipment should not exceed NR 15 or preferable NR10 corresponding to an A-weighted sound pressure level of $L_{pA,F}$ of approximately 20-25 dB. Whether listening over loudspeakers or headphones the maximum background noise level at the ears should ideally be at least 5 dB below the minimum sound pressure level of the stimuli in all critical bands.

For loudspeaker reproduction the listening experience depends on the interaction between the room (if not anechoic) the loudspeakers and the listening position. Therefore, care should be taken that the effect of any changes in these are controlled and minimized.

If the test is to be carried out using headphones, a listening booth may be used. There is no requirement to the reverberation time. It is sufficient that the background noise at the ears is less than required above, any attenuation by the headphones taken into account. Good lighting and ventilation are needed and with the ventilation on, the background noise inside the booth should comply with the requirements above.

The visual impression of the listening facilities should be neutral, or preferably as close as possible to the context under test. The impression should not be dominated by special sound absorbers, technical equipment and installations. These may be hidden behind curtains, if necessary.

6.2 Sound reproduction equipment

Several sound reproduction modes may be relevant, may it be mono, stereo, surround sound or other multichannel sound reproduction systems.

For obtaining a realistic perception a rather simple method is to use binaural stimuli presented over headphones.

A 3D spatial impression of the sound sources is obtained, but the precision of the localisation depends on the recording system used and the individual test person. Head movements during the listening test may decrease the realism (unless headtracking systems are used) because the acoustic scene moves with the head.

Open circum-aural headphones are recommended for best fit and least (individual) leakage problems that may cause increased uncertainty at low frequencies (i.e. below 200 Hz).

Stereophonic or other multichannel reproduction modes with loudspeakers may also be used. The number and positioning of channels may depend on the type of scenario.

The sound reproduction system shall be able to reproduce all relevant frequencies for the noise type under test. For some sources and especially for noise types transmitted to indoor situations reproduction of the low frequency content shall be considered.

The system (loudspeakers or headphones) should at least have a flat (+/-2 dB) frequency response over the range 40 Hz-16 kHz, measured in one-third octave bands using pink noise in the listening position. This may be obtained by equalization. If lower frequencies are of relevance for the test, the frequency range shall be extended downwards correspondingly.

No audible distortion of the original stimuli should be present at the sound pressure levels used in the test.

Any electrical noise heard in the listening position should conform to the same requirement as for the listening room, see clause 6.1.

6.3 Calibration of play-back level

The sound field at the listening position should be calibrated with a sound level meter fulfilling IEC 61672-1:2013.

Calibration of the recommended circum-aural headphones may be performed on a calibrated head and torso simulator (e.g. Brüel & Kjær type 4100) or other types of ear and pinna simulators measuring at or referring to the sound pressure level at the entrance to ear canal point (EEP).

If the same two channel stimuli are used for listening on headphones and stereo loudspeakers, the level on the headphones should be 3 dB higher to get the same annoyance response, see reference **Error! Reference source not found.**.

Note – There are several articles and reports that describes, that measured at the entrance to the ear canal (e.g. by a HATS) the level of headphone reproduction should be approximately 6 dB higher than for loudspeaker reproduction to give the same loudness perception. The level difference seems to vary between 2-8 dB depending on factors as room size, reverberation time and type of sound source. This is called the “missing 6 dB”. Attention should be given to this issue, which is not solved in general in this guideline.

7. Assessors

Assessors are persons taking part in a listening test. A Listening Panel is the group of assessors chosen to participate in a listening test.

Listening tests may be either objective (perceptual – what do the persons hear) or subjective (affective – how annoyed are the persons/what do they prefer).

Affective or subjective listening tests i.e. measurements of annoyance or preference, are normally performed with a group of naive (untrained and without experience in listening tests) test persons who are representative of the relevant target group (average citizens, neighbours, consumers etc.). The main purpose is to give information about how these people react to the sounds in a given context. The assessors should be representative regarding age, gender, education, type of residence etc. whatever is relevant for the actual test. Guidelines for the number of test persons are given in normative reference ISO 6658:2017. The type of test described in clause 8.1 may be characterized as a rating test. For this type of test 20 or more assessors are recommended.

In objective or perceptual listening tests, the task for the assessors is to give an objective quantification of the sensory strength of sensory attributes of the stimuli. The tests are normally made with a panel of trained persons who understand the attributes and how to rate them. The main purpose is to give information about the character of the sound as perceived by the hearing sense. The characteristics of the perceived stimulus are rated in objective terms without asking the assessors for preferences or annoyance.

If perceptual listening test is performed by naive assessors, the spread of the results is larger, and there is a risk of misunderstood attributes. If affective listening tests are performed with trained listeners, there is a risk that the results are not representative or there may be an untypical bias due to higher sensitivity to details of the stimuli.

Trained assessors are persons that are trained to make perceptual assessments. Expert assessors are selected assessors with a high degree of listening sensitivity and experience of listening who can make consistent and repeatable sensory listening assessments of the stimuli. For more guidance see clause 3, ISO 8586.

These assessors should be selected on basis of normal hearing, hearing ability with regard to relevant attributes and their ability to verbally describe listening perceptions. Their ability to make consistent and repeatable sensory listening assessments of the stimuli should be tested e.g. with the e-gauge methodology, see clause 3, ITU-R Rep. BS.2300.

8. Attributes and scales

8.1 Scales for annoyance

According technical specification ISO/TS 15666 the following questions and answering scales shall be used when performing socio-acoustic surveys:

Thinking about the last (..12 months or so..), when you are here at home, how much does noise from (..noise source..) bother, disturb, or annoy you; Extremely, Very, Moderately, Slightly or Not at all?

Figure 1
Verbal scale to be used for socio-acoustic surveys according to Technical specification ISO/TS 15666.

Next is a zero to ten opinion scale for how much (..source..) noise bothers, disturbs or annoys you when you are here at home. If you are not at all annoyed choose zero, if you are extremely annoyed choose ten, if you are somewhere in between, choose a number between zero and ten.

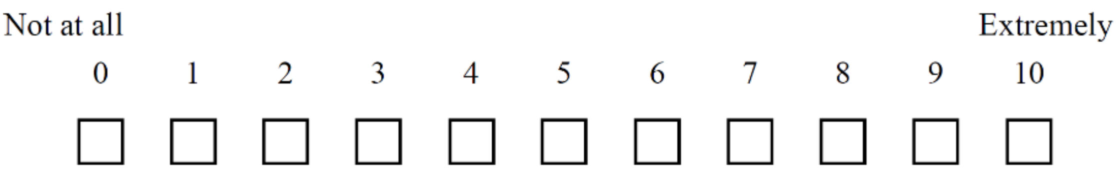

Figure 2
Numerical scale to be used for socio-acoustic surveys according to Technical specification ISO/TS 15666.

The scale labels for the verbal annoyance scale in other languages than English can be found in Appendix 3 – Scale labels for noise annoyance in other languages.

When performing listening tests on annoyance potential or relative annoyance the above-mentioned scales should be used[1]. Together with the results it should be mentioned that the results were obtained in a listening test, whether in the field or in the laboratory.

8.2 Perceptual attributes

When we want to describe the characteristics of the sound, we can assign meaningful words or labels to the attributes we hear. A clear distinction between the attribute and its descriptor is not always made and will not be made here either.

The perception of the intensity of the attributes can be quantified on scales e.g. as shown in Figure 3.

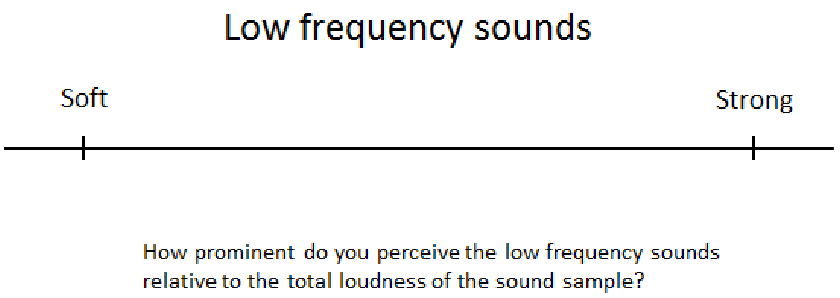

Figure 3
Example on an answering scale with attribute name, scale labels and question/definition suitable for trained/expert assessors

Well-defined and unambiguous attributes is a basis for reliable assessments of perceptual sound characteristics within a panel. Attributes should have good discrimination power among stimuli (i.e. a large span of mean values and small confidence intervals).

Common agreed upon and well-defined attributes facilitate communication of perceived sound characteristics in an objective and consistent manner.

Qualified attributes may be found either by a word elicitation process with assessors or from lexicons of predefined attributes. Avoid pulling words out of thin air.

8.3 Finding and selecting consensus attributes

The work with consensus attributes is often starting with a word elicitation. This is normally done with a small group of assessors experienced in the actual field of application. A subset of stimuli representing the stimuli intended for testing are presented to the assessors.

[1] Except for test types as pairwise comparisons and similar test types without intensity scales.

During a discussion, possible attributes which characterises the products and discriminate amongst them is found. Consensus is sought for selecting the most relevant set of attributes, their definitions and possible labels for the answering scales. Prior to the test the whole group of assessors should be trained in the use of attributes and scales.

8.4 Language issues

Listening test (instructions, scale labels, attributes and their definitions etc.) should be made in the native language of the assessors. If listening tests are made in more than one language, translation of attributes and their definitions need to be accurate and convey the same subtle meanings of the descriptors. If attributes are developed in one language they should be translated into the other language by a professional. To confirm the correct translation, a reverse translation back to the first language should be performed by another person, to ensure the correct meaning has been maintained during translation.

9. Context considerations

As mentioned, the context is of major importance for the annoyance assessments. The context shall be defined, imagined or simulated (visualized and /or auralized) if the test is not performed in the real relevant context. In clauses 5.3 and 6.1 is briefly mentioned how acoustic and visual context can be taken into account.

Normally the assessors also have to imagine part of the context, e.g.

- What am I doing and where, when I hear the sounds
- How long will the sounds last
- How often will they occur

This shall be described as part of the instruction to the assessors.

Example:
In order to simulate the context of the occurrence of neighbour noise, the participants were instructed as follows: “Close your eyes and imagine that you are relaxing at home and hear the sounds from your neighbours. Imagine that the sounds will appear approximately every 10 minutes with the same duration as in this test“.

10. Test administration

Many types of listening tests and test methods exist. Further information on this topic can be found in normative reference ISO 6658:2017 and references [1] and [12] in clause 13 Bibliography. The type of test described in clause 8.1 may be characterized as a rating test, but for most test types the guidelines in the following clauses will apply.

10.1 Blind tests

Normally the tests should be performed according to a double-blind paradigm so neither the test leader nor the assessor knows the characteristics and the order of the presented stimuli.

An exception from this may be studies e.g. where the interaction between visual and acoustic stimuli are sought.

10.2 Randomization of stimuli

For each assessor a randomized presentation order of the stimuli should be used in order to avoid order effects.

10.3 Test duration

To avoid listener fatigue and loss of concentration the session for each test person should not be too long and should include pauses. Listening sessions should not exceed 1-2-hours, with pauses each 20-30 minutes.

10.4 Length of sound samples

The length of the stimuli should be long enough so that the assessors can form an impression of the characteristics, imagine the sounds in the scenario and give their assessment. The stimuli should preferably be uniform and not so long that variations lead to changing perceptions and assessments during the replay of the stimuli (unless that is the purpose). Durations of about 20 seconds are a good starting point. The samples may be looped to give the assessors more time to the assessments if needed.

10.5 Instruction of test persons

All assessors should have the same instruction. The instruction may influence the results of the test. A written instruction shall be at hand for the assessors and the test leader shall carefully go through the written instruction with all assessors in the same way.

Instructions, scale labels, definitions etc should be in the assessors native language to ensure that semantic details of wordings are maintained and understood by the assessors, see 8.4.

10.6 Familiarisation

The purpose of familiarization is to make the assessors acquainted with the range of stimuli they will be exposed to, before they make any assessments.

The aim is to give the assessors an idea of which variations they can expect during the test and make the assessors more confident in the scale usage, which otherwise might change during the test.

The selected stimuli for the familiarisation session should be representative of the full range of conditions that they would hear in the full test.

10.7 Debriefing

Debriefing, i.e. a short talk or an interview of the assessors after the test, will often give knowledge on issues and details which may not be part of the listening test. Also clues for bias and ways to improve the test may be uncovered in a debriefing session.

10.8 Physical measurements

If correlation between the listening test results and physical measurements or characteristics are sought, the measurements should be related to the stimuli presented to the assessors. Correlations to other data characterising the source of the stimuli may be obtained, but the correlation is expected to be lower.

11. Statistical analysis

Practical overview of the purposes for statistical analysis (basic check list):

- Check data quality
- Check assessor’s performance (if needed)
- Check attribute performance
- Check assumptions (if needed)
- Testing the hypothesis – answering the question
- Summarising the data
- Specify accuracy and significance.

The statistical analysis is used first to monitor the assessors and the data quality – e.g. by checking whether the listeners can differentiate between different stimuli, and whether they can reproduce their own assessments in a blind test. Even with trained listeners under optimal listening conditions, there are differences in the individual assessments, but they should ideally be smaller than the differences between the stimuli in the test. See e.g. ITU-R Rep. BS.2300 in clause 3

Secondly, the primary aim with the statistics is often to calculate the mean values and the associated uncertainties, e.g. by the 95 % confidence intervals. A general rule of thumb can be used; if the confidence interval for one stimulus overlap the mean values for another stimulus, it is not certain that there is a significant difference in relation to the attribute in question. However, a formal test of which stimuli really are different, and which are not, may be performed by a Tukey's honest significance test.

A statistical variance analysis (ANOVA analysis) can show which differences in the results can be ascribed to the variables in the test or which differences can be ascribed to the to the listeners, and any interactions between these factors.

12. Report

In this clause topics that should be included in a full report on a listening test are listed. The list is in accordance with the guidelines for reporting in reference [12] in clause 13.

Front page

The first page of the report should provide formal information:

- Laboratory Name and Address
- Document identification
- Test type (and method)
- Name and address of the requester
- Summary of the purpose, the main results and conclusion
- Signature and date
- Terms of distribution of the report

Introduction

The background for the test, the objectives and purpose and the involved parties shall be mentioned.

Methodology

The method(s) and test types used for the listening test should be described by reference to the standard or other references (e.g. this guideline) where the method is described. The variables, the test design and data collection procedures should be mentioned.

Measuring objects and stimuli

The test objects and the stimuli should be described in a unique manner, so they can be unambiguously identified. The operating conditions for the sound sources, the transmission path etc. should be specified. The selection, preparation and production of stimuli should be stated together with technical information (number of channels, sample rate bit depth…). Any equalization applied should be stated.

Equipment

The instrumentation and software used for recording (if any), reproduction (headphones, loudspeakers, soundcards, amplification systems …) and analysis should be stated by type, make and model. The calibration procedure of the system should be stated. For accredited measurements last calibration date for traceable calibration of the equipment shall be stated. Special equipment may be described in an appendix.

Location

The location of the listening test should be mentioned, and the acoustical characteristics should be stated in relevant terms. The properties of the listening room or listening booths could be stated in an appendix (e.g. by size, reverberation time, background noise level and fulfilment of standards). For field testing (concert venues, product sound, noise annoyance…) appropriate descriptions and parameters must be given.

Assessors
The criteria for selection of test persons should be stated. The training of assessors (if any) should be mentioned. The type of assessors should be stated according to ISO 5492 and ISO 8586 it may be naive assessors" (e.g. average citizens/consumers) who do not have to meet any precise criterion, or "Selected assessors" are assessors who have been selected and trained. The number of assessors, their gender and age (at least as average, minimum and maximum range or standard deviation) should be mentioned. Any exclusion of assessors by post screening of the results shall be stated.

Physical measurements
The procedures and methods for any physical sound/noise measurements performed (e.g. sound pressure levels, frequency characteristics, distortion…) or psycho-acoustic metrics (loudness, sharpness, roughness, fluctuation strength…) on or related to the stimuli (background noise, reverberation time…) should be stated.

Test administration
Time, dates and duration of the listening sessions should be stated. Information about the amount of information given to the test persons about the purpose of the test, sound sources/situations of use etc. may be relevant. Instructions to test persons, graphical user interfaces and questionnaires (if any) may be shown in an appendix.
The test conditions (field test, real devices, loudspeaker/headphone reproduction...)
The test sequences and experimental design methods applied could be mentioned here (or under the method clause).
The test conditions (sound pressure levels of stimuli, non-acoustical cues, individual or group test/jury, etc.) should be described.

Analysis and discussion
The types of analysis performed, statistical methods employed and discussions (if any) on the path from raw data to end results and conclusions should be described.
Any correlation between physical measurement results and the results of the listening test may be analysed and discussed.

Results
Results should be given in a short and conclusive manner. Graphs should be clear with axis titles and units and appropriate text should be added to graphs and tables.
Uncertainties (e.g. in the form of 95 % confidence intervals) on the results should be indicated where relevant. In interpretation of the results the uncertainties should be considered.

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14. Appendix 1 – Applications for sound insulation against airborne sound

14.1 Neighbour noise

Neighbour noise is perceived through partitioning building elements between the neighbours. The sound insulation is physically measured by technical means e.g. pink noise and/or a tapping machine in the sending room. These types of sounds are optimized for the physical measurements and are not very representative for the types of sounds that are annoying in practice and therefore not ideal for listening tests either.

To be able to make comparable listening tests we need to use standardised and well-defined daily life types of sound sources. In this section a number of these and their usage are defined.

14.2 Neighbour noise standard stimuli

The test scheme shall include 5 types of sounds: People talking (a male and a female voice), toilet flush, party sounds (people talking, laughing and music) and music. These types of sounds are amongst the most annoying sounds from neighbours, see reference **Error! Reference source not found.**.

The music should be pop music with prominent bass and heavy drums with main components down to 50 Hz. In the L_{eq}- third octave band spectrum of the music sound sample in the 50 Hz 1/3 octave band should be less than 6 dB below the arithmetic mean level of the 1/3 octave bands 63-160 Hz. The L_{eq} in the 40 Hz 1/3 octave band should be less than 12 dB below the arithmetic mean level of the 1/3 octave bands 63-160 Hz.

	L_{Aeq}, dB	L_{AFmax}, dB	L_{eq}, dB	L_{Fmax}, dB
Male voice	65.0	74.2	69.8	76.5
Male and female voice	65.0	74.0	68.7	76.8
Flushing toilet	70.0	79.5	70.6	80.7
Party noise	80.0	86.5	81.7	86.8
Music	85.0	91.3	91.3	96.6

Table 1
The A-weighted and the linear sound pressure levels of the sound samples on the sending side.

The 1/3 octave spectra (L_{eq}) of the sound samples shall be as shown in Figure 4 and Table 2 with a tolerance of +/- 2 dB. The samples should be selected for a best possible fit and may be equalized thereafter to fit within the tolerances.

Note: The numbers in Table 1 and Table 2 are found from the work in references [6]and [7]. As the difference (in Table 1) between the L_{Aeq} and the L_{AFmax} and the difference between the A-weighted and linear levels depends om the exact piece of music the L_{AFmax} values and the linear levels should be updated with more general representative values in the final version of this guideline. This can be done by averaging 10 pieces of the type of POP music as described above. The same procedure should be used for the other sound sources. The L_{Aeq} values shall be maintained after the update. The spectra specified in Figure 4 and Table 2 should be updated in the same manner.

For measurements of annoyance potential, it is recommended to adjust the L_{Aeq} of the sound samples at the sending side to the (natural) levels indicated in Table 1 with a tolerance of +/- 1 dB. The tolerance of L_{AFmax} is +/- 2 dB. For measurement of the relative annoyance, it is recommended to increase the levels by 10 dB, see reference **Error! Reference source not found.**.

Note: When the sound samples from the sending side are attenuated by e.g. walls the levels of the stimuli on the receiving side are rather low, which may make it difficult or impossible to assess and compare walls with high sound insulation. Two alternative strategies are considered:

1. *Play-back at natural levels:*
   Realistic assessments of annoyance potential may be obtained, but some stimuli may be inaudible on the receiving side of the walls.
2. *Play-back at increased levels:*
   Unrealistic high annoyance potentials but probably a good relative discrimination among the walls (measurements of relative annoyance).

Taking the low levels on the receiving side into account, special attention shall be given to the background noise during recordings of stimuli and during the listening test. The background noise level should ideally be at least 10 dB below the sound pressure level of the stimuli in all critical bands or at least in all critical bands of relevance for the test.

The samples on the sending side may be used for recordings in the receiving room in the field or they may be used to auralize the effect of e.g. different types of walls. It is recommended that the reverberation time of the receiving room (in the field or in the auralized stimuli) is near 0.5 s (0.3-0.7s). The stimuli presented to the assessors are then the combinations of the sound samples on the sending side and the effects of the insulating walls and the reverberation in the receiving room.

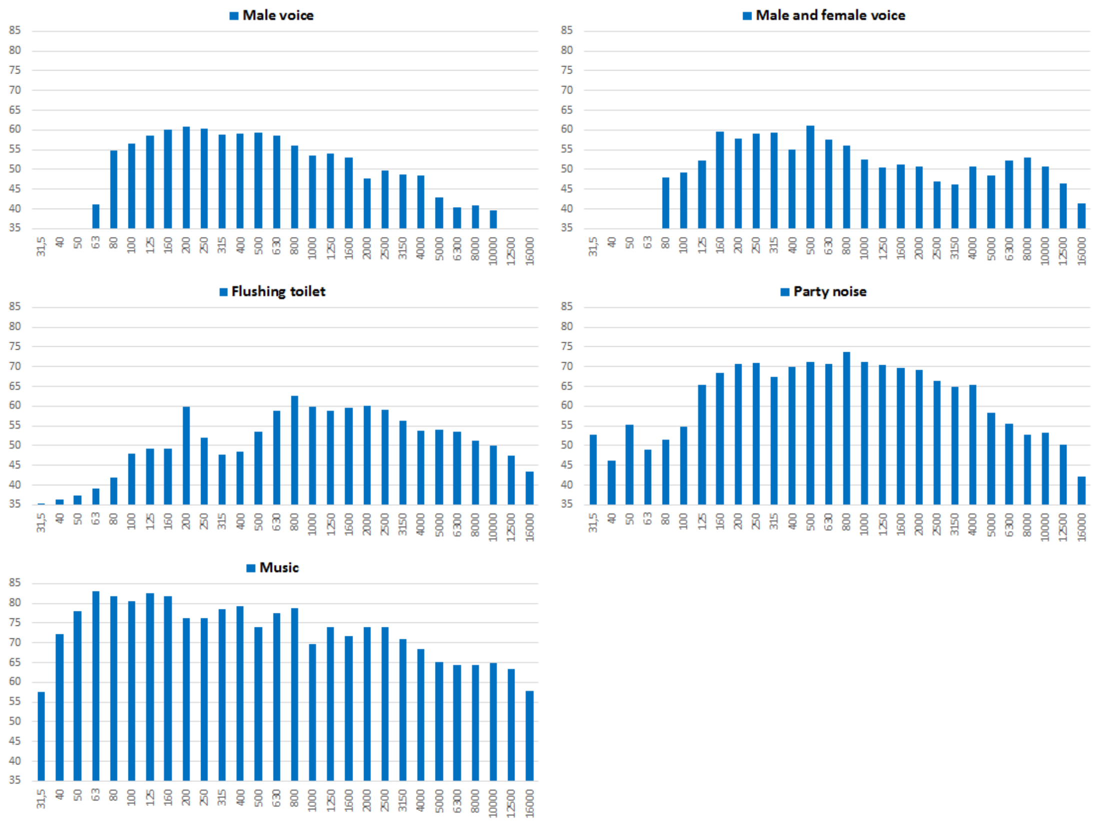

Figure 4

Graphs of L_{eq} of the 1/3 octave band spectra for the sound samples on the sending side.

Hz	31.5	40	50	63	80	100	125	160	200	250	315	400	500	630	800	1000
Male voice	35	31	31	41	55	57	59	60	61	60	59	59	59	58	56	53
Male and female voice	28	22	24	35	48	49	52	60	58	59	59	55	61	58	56	53
Flushing toilet	35	36	37	39	42	48	49	49	60	52	48	48	54	59	63	60
Party noise	53	46	55	49	52	55	65	68	71	71	68	70	71	71	74	71
Music	58	72	78	83	82	81	83	82	76	76	79	79	74	77	79	70

Hz	1250	1600	2000	2500	3150	4000	5000	6300	8000	10000	12500	16000
Male voice	54	53	48	50	49	49	43	40	41	40	35	30
Male and female voice	51	51	51	47	46	51	48	52	53	51	46	41
Flushing toilet	59	60	60	59	56	54	54	53	51	50	48	43
Party noise	70	70	69	66	65	65	58	56	53	53	50	42
Music	74	72	74	74	71	68	65	64	64	65	63	58

Table 2
The 1/3 octave band linear sound pressure levels (L_{eq}) of the sound samples on the sending side.

14.3 Traffic noise

Traffic noise is usually perceived through windows and other facade elements. Therefore, the sound of the traffic outside the windows will be the most relevant sound source for listening test for the sound insulations of facades. Types of traffic noise to be considered as standard noise types are:

- Constant noise from a motorway with light and heavy vehicles in several lanes
- Noise from urban roads with free-flowing traffic
- Vehicles passing by in a street
- Noise from traffic starting after a red traffic light.

Specific types of traffic noise may be relevant, e.g. the low frequency sound of a diesel bus starting from a bus stop outside a window, see reference [5].

Reference and anchor sounds (see clause 5.1) may be relevant. The simplified outdoor background (traffic) noise defined in Appendix 4, clause 17 may be used for that purpose e.g. with A-weighted sound pressure levels of 55, 65 and 75 dB outside the façade.

15. Appendix 2 – Application for impact sound from neighbours

15.1 General

This appendix describes which impact sources to use and how to perform recordings of these.

15.2 Instrumentation

The recording equipment should be chosen according to the intended reproduction method, as described in section 5.1. To be able to describe the sound level in the receiving room, a microphone as specified in ISO 16283-2:2015 must be used. Alternatively, the signal from the binaural recordings could be used by correcting for the diffuse field response of the binaural device.

The frequency range of the recording shall be 10-20000 Hz.

In addition to the recording of the stimuli, measurements of the impact sound according to ISO 16283-2:2015 should be made for reference. The measurements should be carried out for both the tapping machine and the rubber ball, in the frequency range 50-5000 Hz.

15.3 Impact sources

The impact sources to be recorded in the test shall both cover standardized sources and well defined non-standardized sources. The non-standardized sources shall represent daily life sources or other specific sources to test.

The sources can be categorized as either single point impact or continuously moving. The single point impact sources are sources with fixed impact positions, and the continuously moving sources are sources that moves along a line (e.g. walking along a line).

Tapping machine and rubber ball

Mandatory sources to include in the tests are the tapping machine and the massive rubber ball, as described in ISO 16283-2:2015.

The tapping machine shall be recorded in minimum 20 seconds for each position. Before presentation to listeners the sound pressure level should be attenuated 10 dB to be more in line with the levels of everyday impact sounds.

The rubber ball shall be recorded with the ball is dropped from 1 m height and jumping with multiple impacts until it stops. This shall be repeated three times for each impact position. Before presentation to listeners the sound pressure level should be attenuated 10 dB, to better simulate a normal ball or a jumping child. Pauses between the drops should be shortened so the total duration of the stimuli with the three drops are 15 seconds.

Single point impact sources

Examples of single point impact sources are everyday items which are dropped or deliberately thrown at the floor, as e.g. a remote control or children's toys.

To represent toys which are deliberately dropped on the floor DUPLO bricks are chosen. The bricks shall be dropped from a height of 1m, from a box. The box shall be mounted on a stand, where a weight can ensure a repeatable drop, see Figure 5.

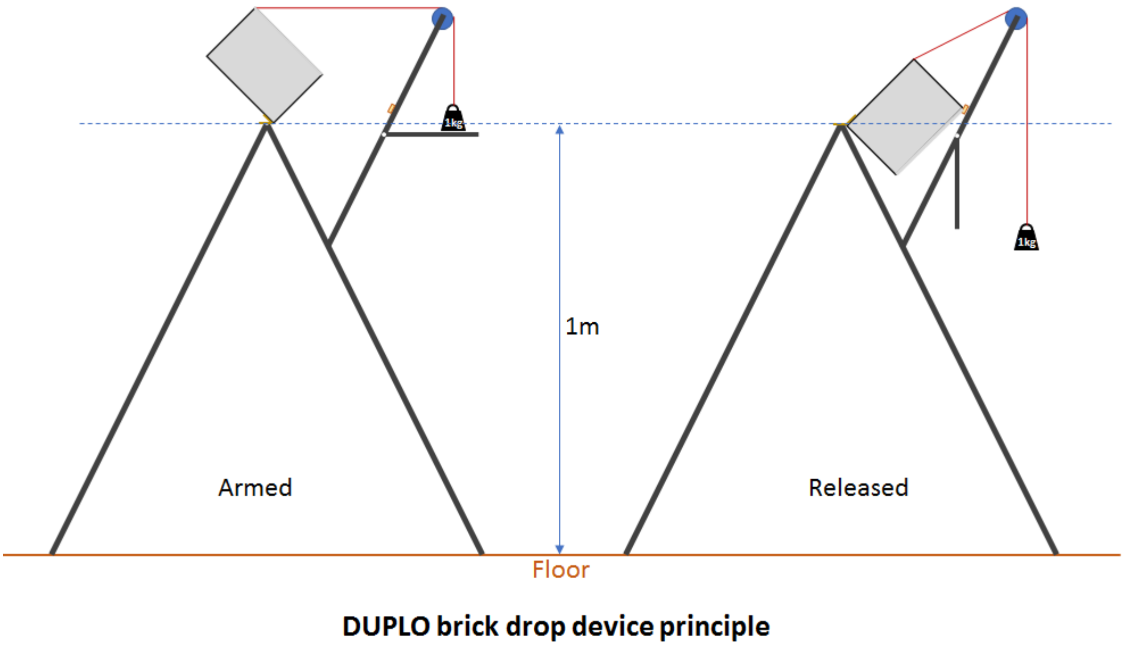

Figure 5: Setup for releasing toys
The Duplo bricks are placed in the grey plastic box with hard smooth internal surfaces (approximate size H: 16 cm W: 32 cm D: 22 cm). The device is activated by momentarily releasing suspension of the 1 kg weight, which by a string (horizontal in the starting position) and a pulley, will tip the plastic box with the bricks in a well-defined way. The starting and ending slope of the box is 45 degrees. The box rotation is stopped by a piece of soft material.

The DUPLO bricks shall be traditional shaped 2x4 bricks, and the amount shall be of a total weight of 1 kg.

To represent things that are dropped by accident, a football can be dropped by the same procedure as the standardized rubber ball. The football shall be a "IMS International Matchball Standard" size 5. The ball shall be inflated to 0.8 bar.

The sources shall be described by a product item description, a visual documentation (photo or drawing), by weight and by number of sources.

Continuously moving sources - Human footsteps

Examples of continuously moving sources are everyday items with multiple or long-time impacts with the floor, such as human footsteps with different footwear or a vacuum cleaner.

Human footsteps are the most obvious source to use, but the poor reproducibility shall be taken into consideration if used. In the tests reported in **Error! Reference source not found.**, it was found that even with the same person, walking the same route in the same pace and carefully walking in the same manner, significant level differences occurred between successive recordings in the same apartment. Furthermore, the source strength is low which may cause poor signal to noise ratios in the receiving room and barely audible signals for floors with good impact insulation.

So natural walking/steps is not a reproducible impact source, but the other sources mentioned in this Appendix were found to have high correlation with the assessment of annoyance potential for steps.

If human footsteps are used, the following guidelines apply:

- The person walking shall train the route and manner of walking before the recordings are made.
- The person shall be categorized as of Normal weight according to Body mass index classification.
- The footsteps shall be performed in a tempo of 100 impacts per minute. To ensure the tempo, the person walking shall have an indicator nor disturbing the sound recordings e.g. headphones with a click/metronome signal of 100 bpm. The duration of the walking shall be at least 20 seconds.
- Different footwear can be used to represent different types of impact. Examples of footwear can be hard soles shoes (leather or hard rubber), soft rubber soles (e.g. Converse All Star) and bare foots.
- The person shall be described by height, weight and shoe size. The footwear shall be described by product item description (shoe brand and model), a categorization of the sole (soft, medium or hard) and a visual documentation (photo or drawing).

15.4 Impact source positions for single point impact

The impact source positions for single point impact shall be chosen according to ISO 16283-2:2015 Annex E and F.

15.5 Impact source positions for continuously moving impact

Impact source position for continuously moving sources shall be routes between the single impact point positions. The routes shall be possible to perform multiple times in a row, without discontinuations. The routes shall be possible to follow without atypical behaviour of the type of impact sources, e.g. no sharp turns for a person walking or routes where the person shall wind around objects which causes unnatural behaviour.

15.6 Microphone positions in receiving room

The microphone positions in the receiving room shall be chosen as obvious places for a resident to be placed, such as sitting nearby a table, a sofa or standing in the room. The distance from an absorbing or reflecting surface shall minimum be 50 cm. Recording shall be performed for one position representing a human standing position and one position of a human sitting. Standing position shall be in a height of 1.5 m and sitting position shall be in a height of 1.1 m.

15.7 Background noise

Background noise (including inherent noise in microphones and amplifiers) shall be measured in the receiving room, to ensure that the recorded sound in the receiving room is not affected by the background noise.

The background noise shall be minimized during measurements to give as high signal to noise ratio. Therefore, shall noisy electrical equipment in the receiving room be unplugged or turned off, and ventilation shall likewise be turned off, shut down or covered if necessary. Windows and doors to the receiving room shall be closed.

Microphones with low inherent noise should be used and the amplification in the first stages of the signal chain should be maximized as much as possible without overload, to avoid noise in later stages. It should be noted, that while a signal to noise ratio of 6-10 dB is enough for measuring purposes, a significant larger signal to noise ratio is needed for recordings to listening tests. Ideally the background noise should be below the hearing threshold, when the recordings are used in the listening test.

15.8 Measurement of sound insulation between measurement rooms

To describe the sound insulation between the source and receiver room, where the recordings has been performed, the airborne sound insulation shall be measured according to ISO 16283-1: 2014 and the impact sound insulation with the tapping machine according to ISO 16283-2:2015.

15.9 Reverberation time

The reverberation time of the receiving room shall be within 0.5 to 1 seconds.

The reverberation time shall be measured as described in ISO 16283-2:2015.

16. Appendix 3 – Scale labels for noise annoyance in other languages

Verbal scale labels for the annoyance scale is shown in Table 3 (from reference [2], see clause 13). The precise wording of the annoyance question in the languages in the table can be found in the same reference.

	1	2	3	4	5
English	**not at all**	**slightly**	**moderately**	**very**	**extremely**
Dutch	**helemaal niet**	**een beetje**	**tamelijk**	**erg**	**extreem**
French	**pas du tout**	**légèrement**	**moyennement**	**beaucoup**	**extrémement**
German	**überhaupt nicht**	**etwas**	**mittelmässig**	**stark**	**äusserst**
Hungarian	**eqyáltalánnem**	**kissé**	**közepesen**	**naqyon**	**rettenetetesen**
Japanese	**mattakunai**	**sorehodonai**	**tashô**	**daibu**	**hijôni**
Norwegian	**ikke**	**litt**	**ganske**	**mye**	**voldsomt**
Spanish	**absolutamente nada**	**ligeramente**	**medianamente**	**muy**	**extremadamente**
Turkish	**hiç değil**	**hafifçe**	**orta derecede**	**çok**	**şekilde**
Polish	**wcale nie**	**mało**	**średnio**	**bardzo**	**skrajnie**
Danish	**slet ikke**	**lettere**	**moderat**	**kraftigt**	**ekstermt**
Portuguese - Brazilian	**nada**	**algo**	**medianamente**	**muito**	**extremamente**
Romanian	**absolut deloc**	**putin**	**nici mult, nici putin**	**mult**	**extrem**
Chinese **Simplified** **Traditional**	**yi dian ye bu** 一点也不 一點也不	**yi dian dian** 一点点 一點點	**zhong deng** 中等 中等	**fei chang** 非常 非常	**ji du** 极度 極度
Korean	**junhyia**	**jogum**	**jebupp**	**meu**	**umchungnage**
Vietnamese	**hoan toan khong on**	**on mot phan nao**	**khong qua on**	**on nhieu**	**cuc on**
Thai	ไม่รบกวน/ ไม่ทำให้รำคาญเลย	รบกวนเล็กน้อย/ ทำให้รำคาญเล็กน้อย	รบกวนพอสมควร/ ทำให้รำคาญพอสมควร	รบกวนอย่างมาก/ ทำให้รำคาญอย่างมาก	รบกวนอย่างมากที่สุด/ ทำให้รำคาญอย่างมากที่สุด

Table 3
Verbal scale labels for the annoyance scale in different languages.

17. Appendix 4 – Simplified background noise

17.1 Simplified outdoor background noise

The simplified background noise is developed from several outdoor background noise spectra where the background noise is caused by road traffic, see reference [8]. The simplified background noise is also used in reference [4] for testing purposes. This broadband noise reduces the issues associated with fluctuations or peaks. The standardized noise is an advantage for repeatability.

Figure 6 shows the frequency weighting that can be applied to a pink noise signal to obtain the simplified background noise for testing purposes.

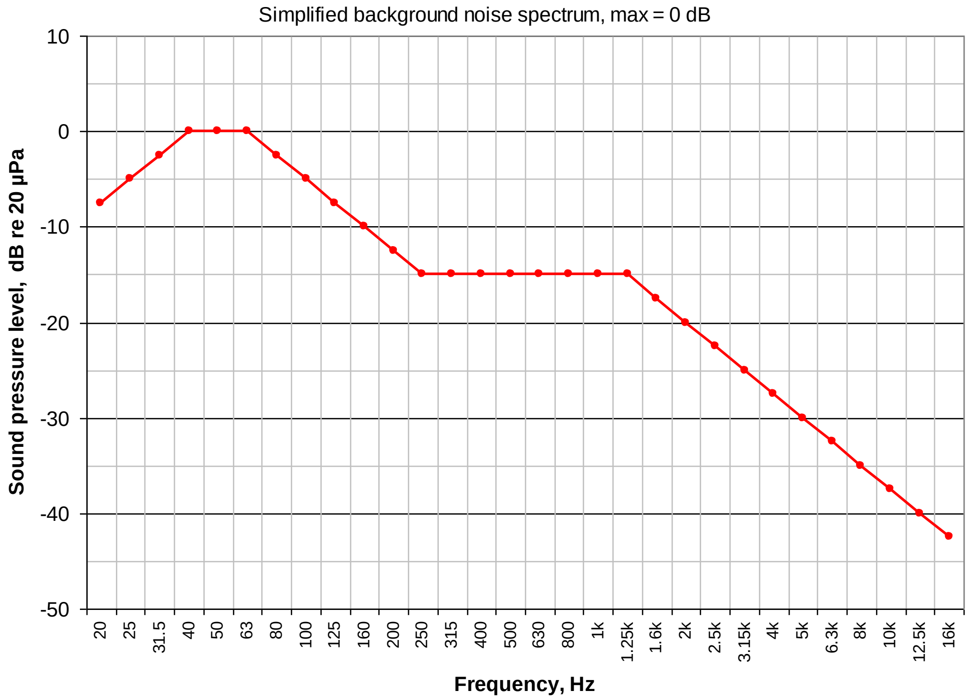

Figure 6
The graph showing the 1/3 octave band frequency weighting that can be applied to a pink noise signal to obtain a simplified background noise for testing purposes.

The values of the weighting curve are given in Table 4.

Hz	dB	Hz	dB	Hz	dB
20	-7.5	200	-12.5	2k	-20
25	-5	250	-15	2.5k	-22.5
31.5	-2.5	315	-15	3.15k	-25
40	0	400	-15	4k	-27.5
50	0	500	-15	5k	-30
63	0	630	-15	6.3k	-32.5
80	-2.5	800	-15	8k	-35
100	-5	1k	-15	10k	-37.5
125	-7.5	1.25k	-15	12.5k	-40
160	-10	1.6k	-17.5	16k	-42.5

Table 4
Attenuation values for generation of the simplified outdoor background noise from pink noise (same attenuations as shown in Figure 6).

The simplified background noise may be used as reference or anchor sound in listening tests. It may serve as a reference sound for comparison with other types of noise in listening tests e.g. with noise from wind turbines.

Listening tests for indoor situations, e.g. testing sound insulation, see clause 14.3, This outdoor noise should be attenuated (frequency dependent) according to an average sound insulation for traffic noise.

17.2 Simplified indoor traffic noise

When the noise from the traffic is heard indoor, a frequency dependant attenuation is caused by the faceade. The simplified indoor trafiic noise is obtained by subtracting the attenuation, A, given in equation 1 from the simplified background noise spectrum described in clause 17.1.

$$\boldsymbol{A = 7 \cdot log(f) + a} \quad [\boldsymbol{dB}] \quad \textit{Equation 1}$$

where f is the frequency in Hz and a is an adjustment term to obtain the wanted overall level.

The resulting simplified indoor noise from traffic is shown in Figure 7 and Table 5.

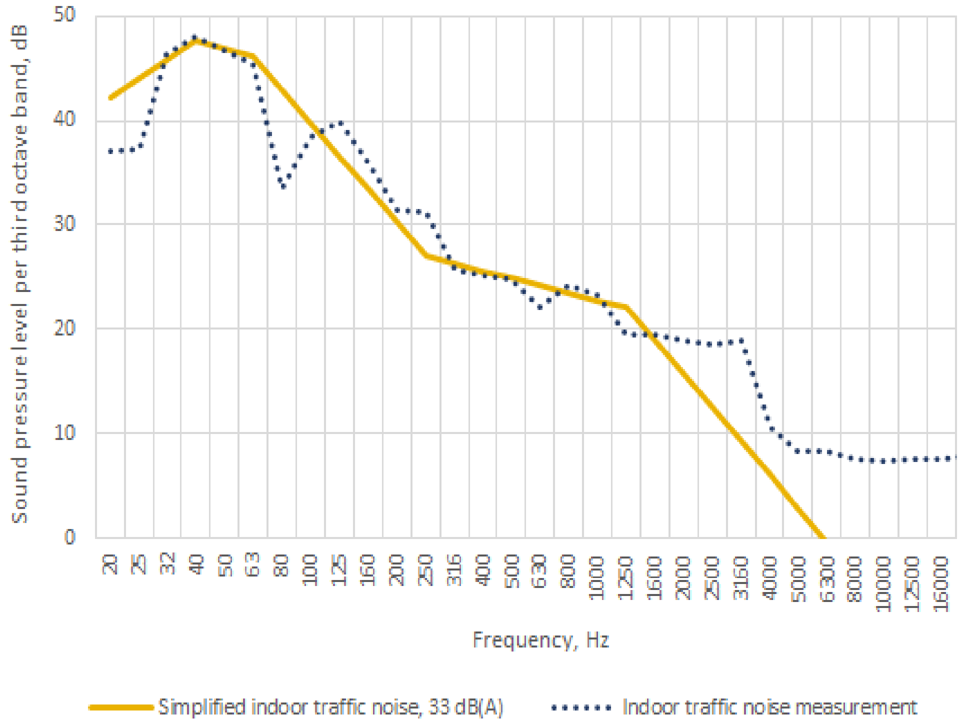

Figure 7
The third octave band spectrum of the simplified indoor traffic noise shown together with the result from measurement in an apartment in a city close to a road.

Hz	dB	Hz	dB	Hz	dB
20	-5.4	200	-17.4	2k	-31.9
25	-3.6	250	-20.6	2.5k	-35.1
31.5	-1.8	315	-21.3	3.15k	-38.3
40	0	400	-22	4k	-41.5
50	-0.7	500	-22.7	5k	-44.7
63	-1.4	630	-23.4	6.3k	-47.9
80	-4.6	800	-24.1	8k	-51.1
100	-7.8	1k	-24.8	10k	-54.3
125	-11	1.25k	-25.5	12.5k	-57.5
160	-14.2	1.6k	-28.7	16k	-60.7

Table 5
Attenuation values for generation of the simplified indoor traffic noise from pink noise.