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Acoustics — Loudness scaling by means of categories

Acoustique — Mesurage de la sonie par échelles de catégories

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

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ISO 16832 was prepared by Technical Committee ISO/TC 43, *Acoustics*.

Introduction

The assessment of loudness function based on category loudness scaling is used when the evaluation of hearing is not only necessary at the boundaries of the auditory sensation area (threshold of hearing, uncomfortable level), but for a knowledge over the entire individual auditory sensation area.

Important fields of use are diagnostic evaluations, especially the evaluation of recruitment and fitting of hearing instruments.

Since the results of loudness scaling can markedly depend on the exact procedure used, this International Standard sets the conditions for reliable measurement methods.

Acoustics — Loudness scaling by means of categories

1 Scope

This International Standard specifies basic methods for scaling loudness into categories for audiological applications.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 8253-1:1989, *Acoustics — Audiometric test methods — Part 1: Basic pure tone air and bone conduction threshold audiometry*

ISO 8253-2:1992, *Acoustics — Audiometric test methods — Part 2: Sound field audiometry with pure tone and narrow-band test signals*

IEC 60645-1:2001, *Electroacoustsics — Audiological equipment — Part 1: Pure-tone audiometers*

3 Terms and definitions

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

3.1
loudness
auditory sensation in terms of which sounds can be ordered on a scale extending from soft to loud

NOTE Loudness depends primarily upon the sound pressure of the stimulus, but also depends upon its frequency, bandwidth, waveform and duration; see IEC 60050[4].

3.2
category
one of an exhaustive set of classes among which loudness sensations can be distributed

3.3
category scale
ordering of a loudness sensation by means of categories

NOTE 1 The scale should contain a middle category and an equal number of categories above and below the middle category.

NOTE 2 Perceptively equidistant categories should be used (for an example, see Annex A).

3.4
category loudness scaling
method whereby the test subject judges the loudness of a presented stimulus on a category scale

NOTE Verbal categories only describe loudness (for an example, see Annex A).

3.5

response alternatives

choices available to the test subject in the rating scale

NOTE 1 The number of response alternatives may be larger than the number of categories on the category scale.

NOTE 2 If verbal categories are used, the number of response alternatives should be larger than the number of categories.

3.6

presentation level

sound pressure level at which the signal is presented

NOTE The number of presentation levels can be different from the number of categories and the number of response alternatives.

3.7

dynamic range of hearing

difference between the highest stimulus level that is judged by the category “not heard” and the lowest stimulus level that is judged by the category “extremely loud” for a specific auditory stimulus

3.8

auditory sensation field

region defined by the dynamic range of hearing across the audible frequency range

NOTE Because the auditory sensation area, according to IEC 60050[4], is enclosed by the threshold of pain, the necessity for the additional definition of the auditory sensation field was seen in order to define the actual measurement range.

3.9

loudness function

function describing the relation between the signal level and the corresponding loudness

3.10

familiarization

process of orienting the subject with the range of possible loudness magnitudes, the response alternatives and the procedure

NOTE Within this range, stimuli are perceived absolutely with respect to their magnitude, i.e. without any perceived relation, e.g. very loud or soft. The state of being familiarized may have its origin by past experience or actual presentation of the range of loudness magnitudes.

4 Category loudness scaling procedure

4.1 General

The purpose of the category loudness scaling is to evaluate the loudness function of a test subject. Therefore, signals with different levels are presented to the test subject who shall judge the loudness on a category scale. The description of the scale can be verbal, numerical or symbolic. When verbal descriptions are used, preferably, the name of the middle category is “medium”, the names of the boundary categories are “not heard” and “extremely loud”. These categories can be transformed to a scale ranging, for example, from 0 to 50. In this case, “0” on the scale corresponds to “not heard”, “25” corresponds to “medium” and “50” corresponds to “extremely loud” (see Annex A).

4.2 Procedure for assessment

4.2.1 Preparation and instruction of test subject

In the preparation and instruction of test subjects the requirements given in ISO 8253-1:1989, 5.1 and 5.2 apply. For other conditions for the audiometric tests, follow the procedures given in ISO 8253-1:1989, Clause 4, as applicable.

NOTE An example of the instruction is: “During the following examination you will hear signals (e.g. sounds, tones) that differ in loudness (and pitch). Following each presentation, please indicate how loud the signal (the sound, the tone) is.”

In addition, the loudness categories shall be explained. The rating scale consisting of the response alternatives shall be presented to the test subject during the test. The response alternatives shall contain at least all used verbal or numerical categories. It should have provisions to make finer judgements between verbal categories. Statistical analysis has shown that a minimum of 11 response alternatives is recommended.

4.2.2 Training and familiarization

The preparation and instruction is followed by a training and familiarization phase, in which the test subject should hear levels over the whole dynamic range. This phase trains the subject and confirms the expectations induced by the scale (between “not heard” and “extremely loud”). This phase avoids biases caused by the first trials that do not cover the whole dynamic range. The phase ends when the test subject is judged to be ready for a valid test.

4.2.3 Test

During the test, signals are presented to the test subject at all presentation levels. The range of presentation levels should cover the individual dynamic range of hearing. An estimation of the dynamic range can be derived from the results of the training phase (for an example, see Annex A).

After the presentation of a stimulus, the test subject shall indicate the loudness of the signal.

Each test signal shall be presented at at least five levels. These presentation levels shall be distinguishable and should cover the whole dynamic range.

NOTE 1 In reasonable cases, exceptions can be made. Examples are tests with children or with test subjects with extremely narrow residual dynamic range.

The presentation levels should be sequenced in a non-systematic way (pseudo-randomized). To avoid obtaining judgements biased by the previous signal, two subsequent signals should be clearly different. These signals should be as different as possible without confusing the test subjects (e.g. by variation of presentation level and/or frequency). To ensure that the test subject stays familiarized during the whole test, the dynamic range of hearing should be covered fully during short groups of subsequent presentations.

When the whole auditory sensation field is to be tested with narrow band signals, tests at at least four different centre frequencies are required.

NOTE 2 Preferred standard centre frequencies are 500 Hz, 1 kHz, 2 kHz and 4 kHz.

4.3 Test signal characteristics

The duration of the test signals shall be at least 1 s. However, the signal may be switched off immediately if the response of the test subject is “extremely loud”. The rise and fall times of the signal must comply with IEC 60645-1:2001, 8.6.3.

In loudness scaling, narrow band signals shall be used. This includes filtered noise and warble tones. The bandwidth of the signals shall not exceed one-third octave. To measure frequency-dependent effects, the filter slope of the narrow band signals shall exceed 36 dB per octave. The filter slope of the test signals limits the

application of the method. For subjects with steeply sloping hearing losses, a filter slope of at least 80 dB per octave is recommended.

Whenever other signals are used, e.g. in cochlear-implant patients, they shall be specified in detail.

4.4 Test room and equipment

4.4.1 Transducers

Signal presentation may be via a loudspeaker, an earphone or, if neccessary, a cochlear implant.

4.4.2 Test room

For sound field audiometry, the ambient noise levels in the test room must comply with ISO 8253-2:1992, Clause 6.

Sound field conditions shall be in accordance with ISO 8253-2:1992, Clause 5.

If pure tones are used in a free sound field, that sound field shall be in accordance with the specifications given in ISO 8253-2:1992, 5.1.

For signal presentation via earphone, the test room shall comply with the requirements given in ISO 8253-1:1989, 4.6.

4.4.3 Equipment

The test equipment shall comply with the general requirements given in IEC 60645-1:2001, Clause 5.

5 Evaluation of the category loudness scaling

5.1 Determination of reference values

To estimate a reference loudness function for each method, loudness scaling tests must be performed for a sufficiently large group of normal hearing subjects (number of subjects $>$ 20). For each response alternative, median values of the corresponding levels shall be calculated. These points reflect the form of the loudness function. Then a loudness function is fitted to these points giving a reference loudness function (for an example, see Clause A.6). The interquartile range of the levels used to calculate the median value is given as the reference range. The reproducibility of the test method may be checked by conducting the tests at least two times with a time gap of at least one week with a control group of normal hearing test subjects (number of subjects $>$ 20).

5.2 Numerical and graphical presentation of the results

The rating scale should be transformed into a numerical scale by an appropriate monotonically increasing function. A 51-point scale is recommended. The relation between the scales should be given.

To provide a comparable aspect ratio in the graphical presentation of the results, the full loudness scale should be the same length as that of a 50 dB-range on the level axis (for examples, see Clause A.6).

The function related to loudness should be approximated with a straight line, lines or a curve that best fits the measured data points in order to interpret the results.

For the interpretation of the function related to loudness, all data points should be given. Levels should be given as sound pressure levels in decibels. Alternatively, the results of the loudness scaling can be presented as equal loudness level contours.

6 Test report

The test report shall contain identifying information including date of birth of the tested subject, sex, date of the test, identification of the examiner, information about the test signals and the number and manner of presentations, and a description of the scale.

The test report shall contain the location of the test, the type of test room, and a list of the presented signal sequence containing information about the presentation level and the responses of the test subject to the respective signal.

Graphical presentations should comply with 5.2.