The new ISO 16832 „Acoustics – Loudness scaling by means of categories“

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Introduction: Why a standard for loudness scaling?

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 over the entire individual auditory sensation area. Important fields of use are diagnostic evaluations, especially the evaluation of recruitment and fitting of hearing instruments. However, the results of loudness scaling are significantly influenced by details of the measurement procedure used. One example is the range of presentation levels. If this range is too small, subjects tend to “spread” the used scale and use more or less the whole scale for the small level range. Another example is the sequence of presentation levels. Monotonous rising or falling level sequences lead to “hysteresis” effects. Also of great influence are the names of the categories, especially the middle category: words like “comfortable” or “OK” not only denote level perceptions, but have a variety of connotations influencing the ratings. The category names must be absolute instead of relative (“extremely loud” instead of “too loud”).

Not least have these pitfalls impeded a widespread use of loudness scaling in audiometry and hearing aid fitting, although a variety of methods have been introduced.

In order to overcome these obstacles, the new ISO 16832 sets the conditions for reliable measurement methods and specifies basic methods for scaling loudness using categories for audiological applications. Furthermore, an exemplary method is given in detail in an informative annex.

Key contents of the standard

Terms and definitions

In the terms and definitions section, among others, definitions are given for the “dynamic range of hearing”, which is defined as 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. This definition takes into account that there might be several presentation levels judged as “not heard” (e.g., for hearing impaired subjects). Only the highest of these levels is taken as the lower boundary for the dynamic range of hearing. A similar argument holds for the upper boundary. The “auditory sensation field” is defined as the region given by the dynamic range of hearing across the audible frequency range. In IEC 60050, the “auditory sensation area” is given. However, since the auditory sensation area 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, which (of course) does not include the threshold of pain.

Category loudness scaling procedure

In this section, general requirements for loudness scaling procedures are given. The scales for the loudness perception can be given verbally, numerically, or symbolically. If verbal scales are used, the middle category preferably shall be named „medium“, and the boundary categories shall be named „not heard“ and „extremely loud“. It is important that the scale names must only describe loudness to avoid any connotations that might influence the rating. Numeral scales can be, e.g., from 0 to 50. Mapping then should be „not heard“ – 0, „medium“ – 25, „extremely loud“ – 50. These scales and this mapping are in most widespread use. The symbolical scales allow, e.g., the use of pictures for loudness scaling with young children. For the instruction and preparation of the test subject, ISO 18632 refers to ISO 8253, in which other audiometric test methods are specified. As an example instruction is given: „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.“ It is important to instruct subjects to absolutely rate the presented sound and not to compare them to any previously presented sounds.

Prior to the measurement, a training and familiarization phase is recommended. This phase could be skipped if the subject already has sufficient experience with the method.

The presentation levels should cover the entire individual dynamic range to avoid the range effects described in the introduction, and each test signal should be presented at least five different levels. These levels should be sequenced in a non-systematic way to avoid the “hysteresis” effects caused by monotonous rising or falling sequences and to facilitate absolute ratings. Preferred centre frequencies are 500 Hz, 1 kHz, 2 kHz, 4 kHz, which are aligned to standard audiometry frequencies. If required, other frequencies can be used. For the assessment of a steeply sloping hearing loss, it might be appropriate to choose centre frequencies that are more closely spaced around the cut-off frequency of the hearing loss.

The duration of the test signals shall be at least 1 second to make sure that the loudness perception is fully developed even in hearing impaired subjects. However, if the signal is rated “extremely loud”, the presentation might be aborted. To take frequency-dependent effects into account, narrow band signals (not exceeding 1/3 octave) shall be used. The filter slopes of the signals limit the application for sloping hearing losses. If the filter slopes are too shallow, significant off-frequency listening could occur in steeply sloping losses.

To determine reference values for a specific measurement method, tests must be performed with a sufficient large group of normal hearing subjects (n>20). For each response alternative, median values shall be calculated. A loudness curve is fitted to these points. The interquartile ranges should be given as an indicator for the measurement accuracy. The reproducibility of the method can be checked by conducting the test at least two times with the same normal hearing control group (n>20).

For the numerical and graphical presentation of the results, a 51-point numerical scale (0-50) is recommended as reference. For verbal scales, the mapping given above shall be used. For a constant aspect ratio, the length of the 51-point loudness scale should correspond to the length of 50 dB on the level axis. Following this, even the slopes of different loudness curves can be compared across different graph sizes. Along with the loudness curve, all data points should be given to facilitate interpretation of the results.

The reference method

In an informative annex, an example for a reference method is given. The method is a two-phase method. In phase I, the dynamic range of the subject is estimated by presenting two alternating level sequences starting at 65 dB and spreading out the dynamic range until the ratings “not heard” and “extremely loud” have been achieved. As a side effect, this phase can be seen as the training and familiarization phase recommended in the standard. If the dynamic range is known from previous tests and the subject is already familiar with the method, this phase might be skipped.

In the second phase, five levels are equally spread over the actual estimation of the dynamic range and presented in a pseudo-randomized sequence to avoid “hysteresis” effects. Based on the yielded ratings, the estimated dynamic range is recalculated and a new set of five levels is calculated and presented. These loops are repeated until sufficient measurement accuracy is reached. During this phase, the boundary categories must be re-checked from time to time to make sure that the whole dynamic range is covered. Figure 1 show typical results yielded with this method for 22 normal-hearing listeners (aged 16-42 years, median 25 years). Both ears of each subject were tested monaurally. Signals were one third octave noises centered around 125 Hz, 250 Hz, 500 Hz, 1 kHz, 1.5 kHz, 2 kHz, 3 kHz, 4 kHz, 6 kHz, 8 kHz, and 10 kHz, respectively. Signals had a duration of 1000 ms and were presented monaurally via Sennheiser HDA 200 headphones.

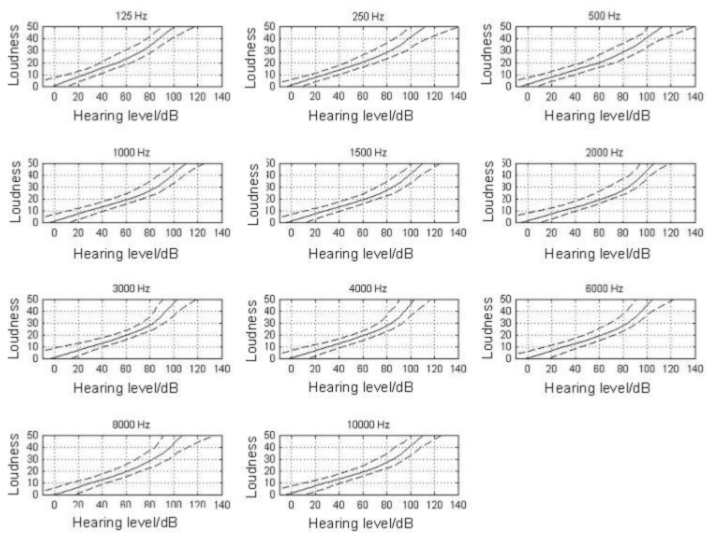

Figure 1: typical loudness functions yielded with the measurement method given in Annex A of ISO 16832. Shown are the mean levels (solid lines) as well as 5%- and 95%-percentiles (dashed lines).

Benefits of loudness scaling

For diagnostic evaluations, the main benefit of loudness scaling procedures is the assessment of not only the boundaries (hearing threshold and UCL), but the entire dynamic range thus especially evaluating recruitment.

In the context of hearing aid fittings, individual gain targets (both frequency- and level-dependent) can be derived from the comparison of the loudness function of a hearing impaired individual with reference curves yielded with normal hearing subjects. These individual gain targets enable a first fitting taking individual data into account instead of using (statistical) first fitting rules.

Summary

The assessment of loudness growth function based on category loudness scaling is used, where the evaluation of hearing is not only necessary at the boundaries of the auditory sensation area (threshold of hearing, uncomfortable level) but where also knowledge over the entire individual auditory sensation area seems to be necessary. 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 standard sets the conditions for reliable measurement method.

References (taken from ISO 16832)

ISO 266, Acoustics - Preferred frequencies

IEC 60645-2, Audiometers - Part 2: Equipment for speech audiometry

IEC 61260, Electroacoustics - Octave-band and fractional-octave-band filters

IEC 50801:1995, International Electrotechnical Vocabulary - Chapter 801: Acoustics and electroacoustics

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