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Sørensen, Michael Friis; Frandsen, Peder Christian; Lydolf, Morten; Møller, Henrik

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COMPARISON OF EIGHT PSYCHOMETRIC METHODS FOR MEASURING THRESHOLD OF HEARING

**Michael Friis Sørensen, Morten Lydolf,
Peder Chr. Frandsen, Henrik Møller**
Acoustics Laboratory, Aalborg University, Aalborg Ø, Denmark

SUMMARY

The aim of this investigation was to examine the significance of the psychometric method used for measuring thresholds of hearing. Eight psychometric methods were studied, of which six were adaptive. The group of adaptive methods consisted of the method of adjustment, the PEST method, and four methods of limits, including the ascending and bracketing methods as described in ISO 8253-1, a descending method, and a fixed-frequency Békésy method. Two non-adaptive methods, methods of constant stimuli, were included in the investigation, one in the classical form with direct detection, and one implemented as a 2-AFC procedure.
24 otologically normal persons participated, and hearing thresholds were determined in a free field for pure tones at the frequencies 500, 1000 and 2000 Hz. Three repetitions were made. The results remain to be analyzed at the time of submission.

INTRODUCTION

ISO 226 [1] contains reference data for the binaural hearing threshold of pure tones in a free field. Even in the latest version from 1987, the free field data are exclusively based on investigations made by Robinson and Dadson in 1956 [2]. In 1988 ISO Working Group TC 43/WG 1 "Threshold of hearing" decided to revise the reference threshold data, and new values based on data from ISO 226 and from 6 recent studies were issued in 1994 as ISO 389-7 [3]. However, the differences between threshold data from different studies are so large that they cannot be explained from statistical variation. One possible reason for discrepancies is the psychometric method. The aim of the present investigation was to examine the significance of the psychometric method used for measuring hearing thresholds.

METHOD

Eight psychometric methods were included, of which six were adaptive. For each subject, the threshold was determined at the frequencies 500 Hz, 1000 Hz and 2000 Hz, using the six adaptive methods. Following this, the two non-adaptive methods were used to determine the threshold at 1000 Hz. These methods need a fair estimate of the threshold as input, and for this purpose the individual mean of the thresholds obtained in the adaptive methods was used. The order of the adaptive methods was balanced in a latin square design, while the order of the two non-adaptive methods was randomized. Threshold determination with the whole range of methods was carried out three times, two times at one day and one time a few days after. New latin squares for the adaptive methods and new random choices of the order of the non-adaptive methods were used for the repetitions.

Some of the methods looked identical to the subjects, as their task was the same. Each time a method with a new task was used with a subject, a *task familiarization* was carried out comprising a complete threshold determination at 1000 Hz. The result of this was not used. In all methods each threshold determination commenced with a *tone familiarization*, implemented by starting the presentations 35 dB above the threshold of ISO 226. Data from the tone familiarization provided adequate inputs to start some of the adaptive methods. In general, the methods were implemented in rather long versions, probably longer than needed for a satisfactory threshold determination. This was done to facilitate a study of various ways of threshold estimation, including maximum likelihood estimation. Examples of the course of the methods are given in Figure 1.

Bracketing method. The tone familiarization included a decent and an ascent, both having a step-size of 10 dB. The ascent started 7,5 dB below the first level in the descent, at which the subject did not respond. The bracketing method itself comprised 6 sets ascents and descents, both having a step-size of 5 dB. Ascents started 5 dB below the first level in the preceding descent, at which the subject did not respond, and descents started 7,5 dB above the first level in the preceding ascent, at which the subject responded.

Ascending method. The tone familiarization was as in the bracketing method. The ascending method itself comprised 12 ascents with a step-size of 5 dB. Each ascent started 7,5 dB below the level, at which the first response occurred in the preceding ascent.

Descending method. The tone familiarization was as in the bracketing method. The descending method itself comprised 12 descents with a step-size of 5 dB. The descents started 7,5 dB above the first level, at which no response occurred in the preceding descent.

The bracketing and ascending methods were implemented nearly as described in ISO 8253-1 [4]. However, a step-size at or below 2,5 dB was specified in preferred test conditions given by WG 1 [5]. Preliminary experiments showed, though, that the resulting low rate of change in level might appear undesirable for the subject. As it was believed that the low step-size was specified by WG 1 as a means of obtaining a high accuracy, it was decided to use a step-size of 5 dB, but to maintain presentations with 2,5 dB intervals by interlacing the ascents and descent by using the "odd" steps of 7,5 dB after a descent or an ascent.

Parameter Estimation by Sequential Testing (PEST). The method was originally described by Taylor and Creelman [6], but a modified version was used as described by Findlay [7]. The step-size commenced at 10 dB, then repeatedly halved down to 0,3 dB. With the step-size of 10 dB, W was 0,5 to obtain the tone familiarization, thereafter W was increased to 1.

Method of constant stimuli with direct detection. The tone familiarization consisted of a descent with four stimuli and a step-size of 10 dB. 91 levels were equally distributed in the interval ±12,5 dB around the threshold estimate. The selected levels were randomized before presentation.

In the five methods described above the subjects were instructed to press a button, each time they heard a tone. The duration of the tone was 1 s, and the response accept period was from tone start to 0,5 s after tone stop. The delay between presentations was randomized in the interval 0,75-4 s, if response occurred commencing after the response or at the termination of the tone, whichever was the latest, or if no response was given commencing at the termination of the accept period. However, in the ascents of the bracketing and the ascending methods, and in the ascents of the tone familiarization of the descending method, presentations were only delayed 0,25 s, since the unheard tones were believed to be perceived by the subjects as a delay.

Method of constant stimuli with two alternative forced choice (2-AFC) detection. The tone familiarization was as in the method with direct detection. 61 levels were equally distributed in the interval ±12,5 dB around the threshold estimate. Levels below the threshold estimate were duplicated, resulting in a total of 91 levels. The selected levels were randomized before presentation. Tones with a duration of 1 s were presented during either a red or a green period, indicated by lights and separated by a pause of 0,5 s. The order of the lights was fixed. 0,25 s after the green period, both lights turned on, and the subjects was to answer.

Békésy method. The method was implemented as a fixed-frequency method in accordance with ISO 8253-1 [4]. The tone familiarization consisted of a descent with a step-size of 2,5 dB. The method itself consisted of 8 ascents and descents with a step-size of 1,25 dB. The tone duration was 250 ms, followed by a pause of 250 ms. The corresponding rates of level change were 5 dB/s and 2,5 dB/s. The subjects were instructed to keep the answer-button pressed, when the tones were audible.

Method of adjustment. In this method the tone was continuous. The subjects were instructed to use a volume control (a multi-turn dial) and turn down the level below audibility, then up and down to encircle their threshold and mark by pressing a button, when the tone was just audible. The procedure was carried out six times.

The tones were presented in an anechoic room with the subjects facing a loudspeaker placed behind a curtain. The sound field, harmonic distortion, frequency stability etc. were in accordance with the preferred test conditions [5]. 10 female and 14 male subjects participated. The age range was 19 to 25 years with an average of 23,4 years. Questionnaires were answered by all subjects to ensure that none had a history that would suggest an impaired hearing. Standard audiometry was made for documentation. The subjects were asked not to be exposed to noise the last two days before the experiments were made. All subjects were found otologically normal in a medical examination with otoscopy and tympanometry on the days of experimentation. The subjects were paid for their participation.

The results remain to be analyzed at the time of submission.

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3. ISO/DIS 389-7 Acoustics - Reference zero for the calibration of audiometric equipment - Part 7: Reference threshold of hearing under free-field and diffuse-field listening conditions, 1993 (accepted as a final standard with editorial corrections, May 1994).

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

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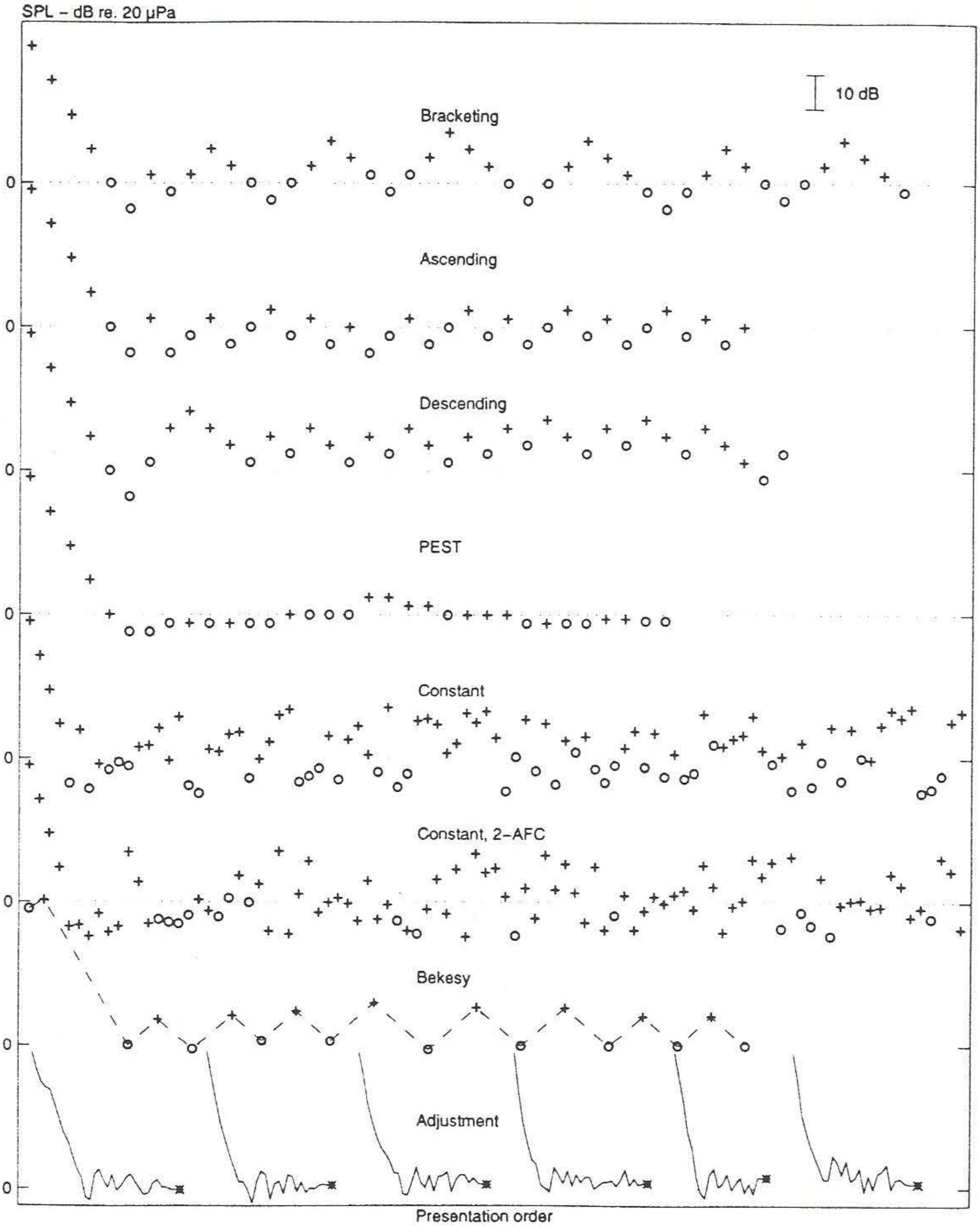

Figure 1. The course of the 8 psychometric methods, shown for one subject, first repetition at 1000 Hz. For the first 5 methods '+' indicates a response and 'o' indicates no response. In the 2-AFC method '+' indicates a correct response and 'o' symbolizes a wrong response. In the Békésy method '+' indicates, when the subject presses the button, and 'o' indicates, when he releases it. An asterisk in the adjustment method symbolizes the subject's threshold mark. The scale of the abscissa is not the same for all methods.