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COMPARATIVE RELIABILITY OF WARBLE TONE THRESHOLDS UNDER EARPHONES AND IN SOUND FIELD

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ABSTRACT

Hearing thresholds of 10 subjects were measured under sound field and earphone conditions using warble tones of frequencies 0.25 kHz, 0.5 kHz, 1 kHz, 1.5 kHz, 2 kHz, 3 kHz, 4 kHz and 6 kHz. Measurements were made on two successive days for each condition at each frequency. The test-retest reliability was found to be equivalent for the two conditions. It was concluded that sound field threshold measurements for frequency specific stimuli are just as reliable as measurements under earphones provided an approriate technique is used.

Introduction

Sound field testing has an important, and apparently increasing, role in audiometry. Traditionally, the main applications have been sound field speech audiometry and the testing of young children with frequency-specific stimuli. Recently, there has also been considerable interest in the use of frequency-specific stimuli for sound field testing of adults, as well as children, as part of the process of hearing aid selection and evaluation. This is associated with increasing interest in the use of prescriptive procedures for selecting hearing aids, and the recognition that any such procedure should include the measurement of real-ear gain by aided threshold testing or an equivalent technique (Byrne and Walker, 1978).

It has long been recognised that the traditional frequency-specific audiometric stimulus, namely the pure tone, is not suitable for sound field testing. Except in anechoic conditions, there are standing waves which produce a non-uniform field which may result in considerable variations in threshold arising from small degrees of head movement or frequency drift. A detailed examination has been made of the stimuli which have been suggested as alternatives to the pure tone (Walker and Dillon, 1980). This has resulted in recommending, as the preferred type of stimulus, warble tones having certain specified parameter values. In other studies in this laboratory, various aspects of sound field testing technique have been examined by Walker (1979) and a method has been developed for calibrating warble tones, or other stimuli, to yield thresholds which would correspond to ones obtained with pure tones (Dillon and Walker, 1980).

From the above cited studies, we would predict, on theoretical grounds, that sound field tests should have comparable reliability to tests performed under earphones, provided that suitable stimuli and procedures are used. However, several clinical audiologists have reported to us that the sound field tests used in hearing aid selection and evaluation, are **not** adequately reliable and that repeated tests often show variations as large as 15 or 20 dB at some frequencies. We decided, therefore, to compare the reliability of sound field and earphone audiometry by examining some data which had been collected for another purpose.

Method

The data of this study are measurements which were taken to derive a particular type of transfer function. Thresholds were measured with warble tones under earphone and sound field conditions with two measurements for each condition at each of 8 frequencies. The test procedure was identical for both conditions, except that stimuli were presented through an earphone, for one and through a loudspeaker for the other. Thus, it was possible to compare the test-retest reliability for earphone versus sound field testing.

Subjects

10 adult subjects (9 male, 1 female, ages 25-65 years) participated. Only one ear was tested, this being the better ear, if there was any difference, or otherwise chosen arbitrarily. Seven subjects had normal hearing in the test ear and the other three had sensori

neural hearing impairments of moderate severity.

Stimuli

The frequency deviations and centre frequencies of the 8 warble tone stimuli were: ± 40 Hz at 0.25 kHz; ±63 Hz at 0.5 kHz; ±100 Hz at 1 kHz and 1.5 kHz; ±160 Hz at 2 kHz and 3 kHz; ±250 Hz at 4 kHz and 6 kHz. The modulation rate for all stimuli was 16 Hz.

Procedure

All testing was conducted in an 1AC model 404A test booth with the equipment located externally. The stimuli were presented through either an earphone (TDH49/MX41AR cushion) or a loudspeaker (JBL 4331A). They were generated by a beat frequency oscillator (B&K type 1022) and passed through an amplifying system incorporating a recording attenuator (G.S. type E3262A). Frequency and output voltage were monitored on a frequency counter and multimeter, respectively. The subject tracked thresholds for about 1½ minutes for each stimulus using a Bekesy type switch which controlled the recording attenuator. The mean of the mid points of the trace excursions, for the final one minute of each trace, was taken as the threshold value.

For the sound field measurements, the subject was positioned carefully to face the loudspeaker. He was seated on a chair with a headrest which was adjustable in height and horizontal position. The position of the chair was marked on the floor and a small weight was suspended from the roof to indicate a position slightly above the centre of the subject's head. The subject's test ear was positioned 117 cm from the floor. This was achieved by adjusting the height of the headrest and, when necessary, by seating the subject on a cushion. The subject was instructed to be careful to sit in the correct position for each sound field test. The non-test ear was occluded with an earplug. System calibration was performed with the measurement microphone located at the position normally occupied by the centre of the subject's head. For earphone testing, the subject was instructed to be careful in positioning the headset, which contained a pair of earphones, so that the test earphone covered the test ear.

The tests were performed so that the sound field test at any given frequency always followed the earphone test at that frequency for one test session and preceded it for the other session. In each session half the frequencies were tested first by sound field. The frequencies were tested in a quasi-random order. The test session consisted of one measurement for each condition for each frequency. The retest was conducted on the following day and was identical to the test session except that the testing order was reversed.

Results

The test-retest differences were calculated for each subject. The mean differences, and the standard deviations of the differences, are shown in Table I. Averaged across frequencies, the mean differences between test and retest are only 0.1 and 0.2 dB for sound field and earphone conditions respectively. This confirms that there was no systematic charge in threshold between test and retest. The standard deviations, also averaged across frequencies, are 4.6 and 4.1 dB. Although this shows that the sound field thresholds were slightly more variable, the difference between these two values is small and is not significant.

Taking a mean figure for the standard deviation of test-retest differences of 4.3 dB, differences exceeding 10dB can be exceeding to occur only 2% of the time, provided thresholds are determined using a technique of accuracy comparable to that used in this

Tabla I. The mean and standard deviation of the differences between test and retest thresholds.

	Sound Field		Earphone	
Frequency (kHz)	Mean (dB)	Stand. Dev. (dB)	Mean (dB)	Stand. Dev. (dB)
0.25	0.1	5.2	0.5	3.9
0.5	−1.3	3.6	−1.8	4.1
1.0	1.9	4.3	0.2	2.8
1.5	1.8	6.0	3.5	3.2
2.0	−2.8	3.8	−2.9	4.8
3.0	0.7	4.1	−0.3	4.7
4.0	0	5.6	1.0	3.9
6.0	−1.2	4.3	1.5	5.5
Averages	0.1	4.6	0.2	4.1

study. It is possible, of course, that some people who are tested in the audiology clinic may be less reliable than the subjects used in this study. If so, the variability of both earphone and sound field testing would be increased to a similar extent. However, we did not attempt to select especially reliable subjects.

Conclusion and Discussion

For the techniques used in this study, sound field and earphone audiometry have comparable reliability. It is somewhat surprising that this was found for all frequencies since there are acoustic factors (e.g. earphone leakage) applying to only one condition which are highly frequency dependent. Possibly the testing of a larger sample might reveal statistically significant differences at some frequencies but obviously any such differences would be too small to be of clinical importance.

We have no data concerning the reliability of sound field tests performed in hearing clinics. However, it may well be poorer than that found in this study considering that clinical testing arrangements do not always include a chair with a headrest or any other head restraint. We recommend that such a restraint be used for all sound field tests and that the test position be marked by measures such as those used in this study. Preferably, the height of the chair should be adjustable. Otherwise it is necessary to adopt some make-shift measure (e.g. a cushion was used in this study) to ensure that the test ear is at the correct height. The type of warble tones (ramp modulated) used in this study is not the type which we would now recommend but we doubt that this would affect the reliability issue.

In summary, provided that appropriate techniques are used for sound field testing, the thresholds obtained with warble tones should be just as reliable as thresholds tested under earphones for all frequencies from 0.25 kHz to 6 kHz.

References

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