NORMATIVE THRESHOLD LEVELS FOR A CALIBRATED, COMPUTER-ASSISTED VERSION OF THE LING SIX-SOUND TEST

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1. Introduction

Traditionally, the Ling Six-Sound test has been used as an informal test of hearing ability (Ling, 1989). Consisting of the phonemes /m/, /i/, /a/, /u/, /sh/ and /s/, this test was designed to assess hearing across the speech frequencies (Ling, 1989). However, although convenient, the use of the Ling Six-Sound task in clinical practice is limited by its lack of a calibrated method of delivery, or normative data on detection thresholds.

When testing detection levels in sound field, wide band stimuli such as speech, warble tones, and random noise are commonly used (Arlinger & Jerlvall, 1987). Wide band signals are purported to be more reliable, as they generate a more uniform sound pressure level in the subject's region of sound field (Walker, Dillon & Byrne, 1984).

The present study combined the traditional Ling Six-Sound test with principles of sound field audiometry. The first aim of the study was to design and implement a calibrated, computer-assisted version of the Ling Six-Sound test in order to establish normative data on ten normal-hearing adults. In addition, test-retest reliability of phonemic thresholds was completed.

2. Method

The Ling Six phonemic stimuli were used to test auditory detection levels. The phonemes were recorded by a female speaker in a sound-treated booth, and were edited using Goldwave software to be of equal duration and peak level. Calibration on all stimuli was completed using concatenated sound files played at 70 dB HL through one speaker of a five-speaker array. Sound pressure at 0 degrees azimuth was analyzed using a B & K Signal Analyzer Unit type 2035. The resulting SPL values yielded the frequency distribution of each phoneme, as well as overall a-weighted levels in dB SPL.

2.1 Participants

Participants in this study were 10 normal hearing adults (3 male, 7 female) between the ages of 21 and 35. Auditory health was verified using tympanometry, otoacoustic emissions, case history questionnaires, and full inter-octave audiograms between 250 and 8000 Hz.

2.2 Procedure

Phonemic stimuli were inputted into a computer-assisted threshold bracketing procedure. Subjects were seated in sound field, and responded to sound presentations by selecting "heard it" or "didn't hear it" options on a computer screen. Based on these responses, attenuation levels were altered until threshold was bracketed. Subjects completed two full trials of this procedure for each phoneme. Thresholds were determined by subtracting attenuation levels at threshold from the a-weighted stimulus levels.

3. Results

Table 1 displays the mean, standard deviation, and 95% confidence intervals across phonemes. Values ranged from 1.9 to 5.5 dB SPL. Although there is wide variation in obtained values, it is important to note that threshold values of the stimuli /u/ and /sh/ were influenced by one subject who had threshold differences of over 10 dB between trials.

Phoneme	Mean Threshold (dB SPL)	SD	95% C.I. Upper Cutoff (dB SPL)
/m/	21.8	2.2	26.1
/u/	7.9	5.3	18.4
/i/	5.9	5.5	16.6
/a/	0.0	2.5	5.0
/sh/	-3.1	2.3	1.4
/s/	16.7	1.9	20.5

Table 1: Mean thresholds, standard deviation values, and upper cutoff threshold levels for the Ling Six phonemes.

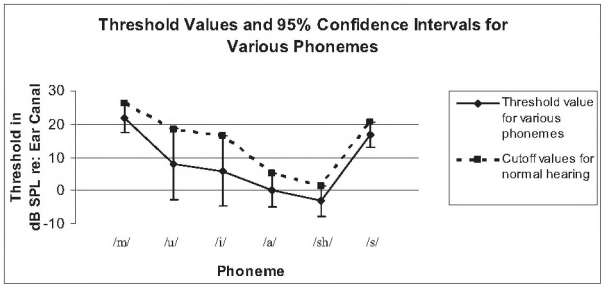

Figure 1: Normal-hearing threshold values and 95% confidence intervals for the Ling Six phonemes.

Using 95% confidence intervals, cutoff values for detection thresholds of the Ling Six phonemes were also established. These values are displayed in Figure 1. All cutoff thresholds were below 26 dB SPL, with some values as low as 1.4 dB SPL

The test-retest reliability of each phonemic stimulus was determined using Intraclass Correlation Coefficients (ICCs) and is shown in Table 2. Results from this analysis revealed a wide range of reliability coefficients with no effect of stimulus bandwidth.

Phoneme	ICC Values	Reliability*
/u/	0.92	Good
/m/	0.81	Good
/sh/	0.73	Moderate
/s/	0.70	Moderate
/i/	0.63	Moderate
/a/	0.47	Poor-Moderate
GRAND AVG	**0.71**	**Moderate-Good**

Table 2: Test-retest reliability ICC values for each phoneme.
* from Portney & Watkins (2000)

Finally, in order to assess the use of the Ling Six phonemes in hearing impaired subjects, an adult with a high-frequency sloping hearing loss was tested with the calibrated Ling Six-Sound test while aided. Figure 2 compares the aided hearing impaired thresholds with normal hearing averages. Results revealed thresholds above normal hearing limits on only the two highest-frequency phonemes, /sh/ and /s/.

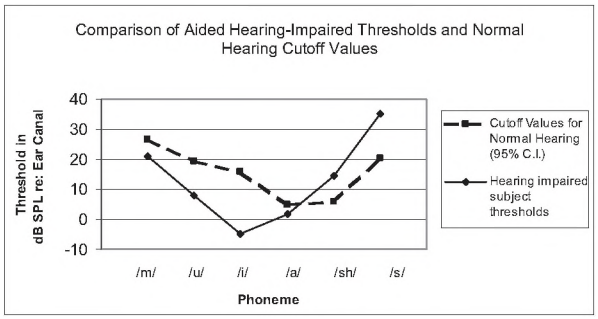

Figure 2: Comparison of aided hearing-impaired thresholds and normal-hearing cutoff values across the Ling Six phonemes.

4. Discussion

While test-retest reliability analyses revealed variability in ICC values between stimuli, ratings of moderate to good for five of six stimuli suggest acceptable reliability for the Ling Six-Sound test. According to Portney and Watkins (2000), ICC values of 0.75 and over are considered to have good test –retest reliability. As the current ICC average value was 0.71, the Ling Six-Sound test appears to fall between moderate and good test-retest reliability.

Comparisons of 95% Confidence Intervals of the Ling Six phonemes and warble tones also indicated acceptable test-retest reliability. The current study found overall averaged 95% Confidence Interval for all phonemes to be +/- 7.1 dB, compared to +/- 15.1 dB for warble tones averaged across the frequency span (Hawkins, Montgomery, Prosek, & Walden, 1987). Thus, it appears that phonemes in sound field may be more reliable than traditional warble tone stimuli for detection tasks.

Furthermore, although the results of a single hearing-impaired subject cannot be generalized to a larger population, this preliminary assessment suggests that the Ling Six-Sound test may be sensitive to the effects of hearing loss, as thresholds were only outside normal limits for the high frequency phonemes in this subject with high frequency loss. Obviously, this requires further study.

Future development of the calibrated, computer-assisted Ling Six-Sound test may involve comparison of audiometric and Ling Six thresholds. Eventual clinical use of a calibrated Ling Six-Sound test may be warranted, as it is a fast and reliable method of testing phoneme detection in sound field.

6. References

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