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Test person operated 2-Alternative Forced Choice Audiometry compared to traditional audiometry

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Introduction
Measurement of correct and reliable hearing thresholds is dependent on correct measurement techniques conducted by trained technicians and patient compliance. Hearing thresholds can be estimated with a system operated by the test persons themselves. This technique is based on the 2 Alternative Forced Choice (2AFC) paradigm known from the psychoacoustic research theory. Psychoacoustic adaptive procedures are reliable but time consuming and they have not played a major role in clinical audiometry. Thresholds are measured with the 2AFC paradigm and an adaptive method and compared to ordinary clinical hearing thresholds conducted by a trained technician.

Methods
Population: 30 male and female aged 20-69 years naive listeners recruited from ordinary patient examination at a department of audiology.
Material: For 2AFC audiometry Tucker-Davis Technologies RM-2 processors under control from a personal computer were used. The system was calibrated to use Sennheiser HDA-200 headphones.
Procedure: Traditional audiometry was conducted following known standards (ISO 8253-1)².
The 2AFC audiometry procedure can be described with the following taxonomy:
Paradigm: 2 Alternative Forced Choice with no feedback
Starting rule: At 40 dB HL or 60 dB HL if known or suspected hearing loss is present.
Progression rules: An adaptive procedure using modifications of the well known 2 down 1 up procedures and the maximum-likelihood techniques with a build in controls of false alarms (See figure 1).
Stopping rule: After at least 6 correct consecutive responses corresponding to or close to the upper limit of the most probable psychometric function combined with at least 2 errors at the lower limit of the expected psychometric function (See figure 1). The number of trials is at least 30 trials.
Datum definition: Arbitrarily set to 95% correct responses.

Results
2AFC audiometry gives thresholds 1-2 dB lower compared to traditional audiometry. Standard deviations between the two test methods are below 4.5 dB for frequencies from (250-4000 Hz) and up to 6.7 dB for frequencies above 4000 Hz (figure 2 and table 1).

Test-retest studies of 2AFC audiometry show standard deviation below 3 dB at most frequencies (table 2).

Table 1
<table>
<thead>
<tr>
<th>Frequency (dB HL)</th>
<th>Difference (dB)</th>
<th>Std.dev.</th>
<th>95% limits of agreement</th>
</tr>
</thead>
<tbody>
<tr>
<td>250 Hz</td>
<td>-4.933</td>
<td>4.491</td>
<td>-13.735 - 3.868</td>
</tr>
<tr>
<td>500 Hz</td>
<td>-2.550</td>
<td>3.629</td>
<td>-9.662 - 4.562</td>
</tr>
<tr>
<td>1000 Hz</td>
<td>-0.933</td>
<td>3.248</td>
<td>-7.298 - 5.432</td>
</tr>
<tr>
<td>2000 Hz</td>
<td>-1.883</td>
<td>3.619</td>
<td>-8.976 - 5.210</td>
</tr>
<tr>
<td>3000 Hz</td>
<td>-0.545</td>
<td>4.251</td>
<td>-8.877 - 7.788</td>
</tr>
<tr>
<td>4000 Hz</td>
<td>-1.058</td>
<td>4.076</td>
<td>-9.046 - 6.930</td>
</tr>
<tr>
<td>6000 Hz</td>
<td>-3.737</td>
<td>6.365</td>
<td>-15.848 - 9.102</td>
</tr>
<tr>
<td>8000 Hz</td>
<td>-0.585</td>
<td>6.686</td>
<td>-13.689 - 12.519</td>
</tr>
</tbody>
</table>

Standard deviations and 95% confidence intervals of differences between the two methods using the Bland Altman method.

Table 2

<table>
<thead>
<tr>
<th>Frequency (dB HL)</th>
<th>no. ears</th>
<th>Mean Std.dev. (dB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>250 Hz</td>
<td>26</td>
<td>2.42</td>
</tr>
<tr>
<td>500 Hz</td>
<td>26</td>
<td>2.96</td>
</tr>
<tr>
<td>1000 Hz</td>
<td>26</td>
<td>2.26</td>
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<tr>
<td>2000 Hz</td>
<td>26</td>
<td>2.48</td>
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<tr>
<td>3000 Hz</td>
<td>10</td>
<td>1.41</td>
</tr>
<tr>
<td>4000 Hz</td>
<td>26</td>
<td>1.88</td>
</tr>
<tr>
<td>6000 Hz</td>
<td>10</td>
<td>2.47</td>
</tr>
<tr>
<td>8000 Hz</td>
<td>26</td>
<td>3.02</td>
</tr>
</tbody>
</table>

Test-retest results with the 2AFC procedure.

References

Conclusion
2 AFC audiometry is a reliable alternative to traditional audiometry. Hearing thresholds are close to or slightly below hearing threshold obtained with traditional audiometry. Test-retest studies indicate an acceptable reproducibility.

Figure 1

2AFC Audiometry
Traditional audiometry
16 dB SPL corresponds to 13.5 dBHL at 3000 Hz when Sennheiser HDA200 headphones are used.

Figure 2

Bland and Altman plot illustrating mean differences between the traditional audiometry and the test person operated 2 AFC Audimetry. Yellow line: Perfect agreement. Light blue line: Observed agreement. Red lines: 95% confidence intervals of the differences between the two test methods (See also table 1).

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