A FRESH approach to pediatric audiometry; Should we stop using NBN now?

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What this is about

Average Left Ear HTLs as a Function of Stimuli

- Pure tone
- Frequency modulated tone
- Narrowband noise
- FRESH

Frequency (kHz): 0.5, 1, 2, 3, 4
Hearing Level (dB): -10, 0, 10, 20, 30, 40, 50, 60, 70, 80, 90, 100, 110, 120

Frequency
- Pure tone
- Frequency modulated tone
- Narrowband noise
- FRESH

Hearing Level (dB)
- -10
- 0
- 10
- 20
- 30
- 40
- 50
- 60
- 70
- 80
- 90
- 100
- 110
- 120
Masking Noise

Dr Robert Bárány, MD, Vienna (1876 to 1936)

“The Barany Box is inserted in the hearing ear and creates a loud buzzing sound while the examiner shouts in the deaf ear to determine if the patient can hear anything. If the patient cannot hear the words shouted, then the ear is considered "Barany Deaf."

(Source: www.hearingaidmuseum.com)

“It is scarcely necessary to enumerate the many objections to the use in audiometry of such masking devices as the Bárány noise box and jets of air or water. They are unpredictable in effect and awkward in use.”

(Denes & Naunton, 1952)

The sound level produced by this Barany Box measured a whopping 110 dB, so if you weren´t Barany Deaf before...
NBN Masking

- 1950’s: The advantage of NBN over Wide Band Noise was recognized
  - **Masking Efficiency**: the relation between a sound's ability to mask and its loudness. A sound with high masking efficiency is one with good masking ability but minimal loudness.
  - 1/3 octave Narrow Band Noise
Effective Masking Level Corrections

Critical Ratio: SNR at threshold when shifted by the noise

Since the NBN masking noise is wider than the critical band, some energy that is "wasted" outside must be accounted for in the calibration.

Amounts in Decibels (dB) to be Added to the Reference Equivalent Threshold Sound Pressure Level (RETSPL) to achieve Effective Masking (dB EM) for One-Third Octave Band Masking Noises

<table>
<thead>
<tr>
<th>Frequency (Hz)</th>
<th>125</th>
<th>250</th>
<th>500</th>
<th>750</th>
<th>1000</th>
<th>1500</th>
<th>2000</th>
<th>3000</th>
<th>4000</th>
<th>6000</th>
<th>8000</th>
</tr>
</thead>
<tbody>
<tr>
<td>For one-third octave-band noise</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>6</td>
<td>6</td>
<td>6</td>
<td>5</td>
<td>5</td>
</tr>
</tbody>
</table>

(Extract from ANSI S3.6-2004 American National Standard Specifications for Audiometers)
Standing Waves in Sound Field

- Pure tones (sine waves) gives rise to standing waves at certain frequencies
- What are the available options that may also be of interest for a hard-to-impress toddler?
- Warble and Narrow Band Noise have been used extensively for many years as sound field stimuli for pediatric audiometry
- These popular stimuli also made their way into pediatric audiometry under headphones and inserts
Standing Waves in Sound Field

H. Dillon and G. Walker, Stimuli for audiometric testing.

FIG. 1. Microphone mounted on a cable-drawn trolley used to determine sound field distribution within the test room.

FIG. 2. Sound intensity variations within the test room at a frequency of 1200 Hz. The loudspeaker is located 0.1 m to the left of the center of the left-hand side “wall.”
Comparison of stimuli used in sound field audiometric testing

Harvey Dillon and Gary Walker

National Acoustic Laboratories, 5 Hill Road
(Received 20 November 1980; accepted 7 August 1981)

The problems associated with performance in sound fields are illustrated with the use of a test booth. A microphone mounted on the subject's head provides a comprehensive comparison is the sound field situation of the test stimulus train, and narrow bands of noise used to determine the bandwidth of the stimulus is the same. The most appropriate stimulus for the subject is found by determining the constraints of obtaining a threshold with complex stimuli to those stimuli with narrow bands of noise appearing in the sound field.

A disadvantage of widening bandwidth, to reduce errors arising from field variability, is that the hearing loss at a specific frequency will be underestimated to some degree unless the threshold is flat across frequency. This occurs because the thresholds, varying with frequency, vary with frequency. Stimuli suitable for most purposes have bandwidths ranging from about 30% at 0.25 kHz to about 10% at 4 kHz. Stimuli having narrower or broader bandwidths are desirable for some special purposes. The test room should be as nonreverberant as possible and the subject should be seated on an adjustable height chair with headrest. The control microphone method of calibration is preferred but a method is also presented for carrying out the traditional precalibration procedure. The SPL of the complex stimulus should be taken as the peak deflections on a sound level meter set to "RMS-FAST." A conversion table is presented which allows thresholds obtained in the sound field to be expressed as dB HTL. With the materials and methods described here it is possible to achieve the same reliability for sound field testing as for audiometry under earphones.

In addition to questions concerning the choice of stimuli, there is a lack of consensus about other aspects of sound field testing, such as the subject's position relative to the loudspeaker and the calibration techniques to be used. Sound field audiometry, with frequency specific stimuli, is used extensively in the National Acoustic Laboratories (NAL) for assessing the hearing of infants, and as an integral part of our hearing aid selection procedure. This fact, coupled with the existence of many unresolved issues concerning sound field audiometric techniques, prompted a series of studies with the aim of formulating a comprehensive set of clinical recommendations. In this article we...
Comparison of stimuli used in sound field audiometric testing

Harvey Dillon and Gary Walker

National Acoustic Laboratories, Sydney, Australia

(Received 20 November 1980; accepted 1 December 1980)

The problems associated with performance in sound field audiometric testing are illustrated with the use of simple and complex stimuli. A microphone mounted on an adjustable headrest provides a more comprehensive comparison if the stimulus is presented on a sound level meter or other equipment, and narrow bands of noise are used. The bandwidth of the stimulus is the most appropriate stimulus for hearing assessment. When the constraints of obtaining a complex stimulus are considered, a narrow band of noise appears to be the most appropriate stimulus.

The relative accuracy of testing procedures is discussed.

Sound Field Audiometry: Recommended Stimuli and Procedures

Gary Walker, Harvey Dillon, and Denis Byrne

National Acoustic Laboratories, Sydney, Australia

The error produced can be substantial. To minimize this error, it is desirable that the bandwidth of the stimulus be kept as small as possible (consistent with other considerations), and that the energy outside the band be minimized across frequency. Although many authors have provided the only alternative, the performance of the audiometric test equipment must be taken into consideration. Sound field audiometry, with frequency specific stimuli, is used extensively in the National Acoustic Laboratories (NAL) for assessing the hearing of infants, and as an integral part of our hearing aid selection procedure. This fact, coupled with the existence of many unresolved issues concerning sound field audiometric techniques, prompted a series of studies with the aim of formulating a comprehensive set of clinical recommendations. In this article we
More concerns about NBN filter slopes

• Orchik and Mosher (1975)
  – “…realize that the noise parameters, especially bandwidth and filter slope, can result in a significant overestimate of threshold sensitivity in patients with sloping audiometric configurations.”

• Orchik and Rintelmann (1978)
  – ”...for subjects with sharply sloping high frequency sensorineural hearing losses...narrow band noise may substantially overestimate pure tone threshold sensitivity.”

• Stephens and Rintelmann (1978)

![Average difference from normalized pure tone thresholds per stimulus type for sharp configurations](image)
Principle illustrated using the OTOsuite Hearing Loss Simulator

Pure tone stimulus

Test frequency
Principle illustrated using the OTOsuite Hearing Loss Simulator

FRESH noise stimulus

Test frequency
If we present a Narrow Band masking noise as stimulus at the same level, the patient will respond to the circled area where the narrow band noise spills over into the audible range. Hence we will continue decreasing the stimulus level until the patient stops responding...

Principle illustrated using the OTOsuite Hearing Loss Simulator

Assumed test frequency

NBN as stimulus
Assumed test frequency

Principle illustrated using the OTOsuite Hearing Loss Simulator

The patient stops responding and we mark the assumed threshold and thus underestimate the hearing loss

NBN as stimulus

Assumed test frequency
Principle illustrated using the OTOsuite Hearing Loss Simulator

NBN as stimulus

This picture illustrates why there is no evident problem when the hearing loss is relatively flat. The stimulus remains within the inaudible range across all frequencies.
FREquency Specific Hearing noise

• The “recipe” used for FRESH noise in the Madsen Astera Audiometer (GN Otometrics) from Walker, Dillon and Byrne (1984)

<table>
<thead>
<tr>
<th>Center Frequency (kHz)</th>
<th>Narrow Deviation (% of center frequency)</th>
<th>Narrow Bandwidth (Hz)</th>
<th>Standard Deviation (% of center frequency)</th>
<th>Standard Bandwidth (Hz)</th>
<th>Wide Deviation (% of center frequency)</th>
<th>Wide Bandwidth (Hz)</th>
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<tbody>
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<td>0.25</td>
<td>9.7</td>
<td>24</td>
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<td>72</td>
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<td>145</td>
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<tr>
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<td>5.7</td>
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<td>17</td>
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<td>34</td>
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<tr>
<td>1.5</td>
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<tr>
<td>2</td>
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<td>220</td>
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<tr>
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<td>90</td>
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<tr>
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<td>16</td>
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<tr>
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<td>8</td>
<td>480</td>
<td>16</td>
<td>960</td>
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<tr>
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<td>2.7</td>
<td>216</td>
<td>8</td>
<td>740</td>
<td>16</td>
<td>1280</td>
</tr>
</tbody>
</table>
Sloping Audiograms

(Walker, Dillon and Byrne, 1984)

<table>
<thead>
<tr>
<th>Frequency (kHz)</th>
<th>Maximum Slope (dB/octave)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.25</td>
<td>11</td>
</tr>
<tr>
<td>0.5</td>
<td>13</td>
</tr>
<tr>
<td>1.0</td>
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<tr>
<td>1.5</td>
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<td>6</td>
<td>34</td>
</tr>
<tr>
<td>8</td>
<td>34</td>
</tr>
</tbody>
</table>
FRESH Noise in Astera control panels

Classic mode

Sunshine mode
Sound Examples

NBN 500 Hz  FRESH 500 Hz  NBN 1000 Hz  FRESH 1000 Hz
Pilot study
Subject #1
MATLAB Modelling

b. Dead region: 1-4 kHz

Frequency (kHz)

Threshold (dB HL)

tone
NBN
FRESH
First subject at ISVR

Average Left Ear HTLs as a Function of Stimuli

- Pure tone
- Frequency modulated tone
- Narrowband noise
- FRESH
Consequence of NBN

- What consequence may the underestimated hearing loss have clinically?

![Graph of Underestimated hearing loss (NBN) and True hearing loss](www.otometrics.com)
DSL 5 Aided Response Target

Underestimated hearing loss (NBN)

True hearing loss
References

American National Standards Institute. ANSI S 3.6-2004, American national standard specification for audiometers”


