An Objective Measure for Assessing Binaural Summation

Vishakha Rawool. Ph.D., CCC-A, FAA
West Virginia University
Co-investigator: Madaline Parrill, Currently 4th year AuD student at WVU
Excessive exposure to metals and solvents can have a negative impact on senses.
Sites of Effects

- Different pathogenic mechanisms may be involved that may act on
  - sensory receptors,
  - nerve fibers, and
  - the central nervous system
- (Gobba, 2003).
Brainstem abnormalities

• Abnormal auditory brainstem response has been reported in individuals exposed to
  – Solvents
    • E.g., n-Hexane
  – Mercury
  – Chlorinated hydrocarbons

• These abnormalities suggest that binaural functions may be affected since brainstem is the
  first site where neural impulses from both ears come together.
Example of structural changes in brainstem due to solvent exposure

- Before brain atrophy becomes obvious, some individuals show restricted but severe enough changes to cause neurologic symptoms in specific regions, such as
  - the brain stem
  - and/or cerebellum
- This suggests that the restricted white matter change represents an early change of diffuse white matter change
- **It will be useful to have tests that show early changes in brainstem function.**
- One function of the brainstem is to bring the information from two ears together, allowing comparison and summation
When to test for Auditory Processing Deficits?

• Is there a possibility of damage to the central auditory system?
  — Patient complaints
    • e.g Difficulty understanding speech in noise
  — H/O exposure to ototoxic substances

• Ideally, a matched control group of employees that is not exposed to solvents and/or noise should be included in evaluations.

• In evaluating individual patients, use of a normative data base is recommended.
Research Needs

• Limited research

• Further research will be useful in identifying the types of auditory processing skills that are affected due to exposure to ototoxins including solvents and metals like Mercury or lead.

• Interim recommendation
  – Use a test battery
    • for evaluating auditory processing skills in the context of occupational exposure to ototoxins
Considerations in selecting tests

- Ease of administration and interpretation in clinical settings.
- Evaluation of **brainstem** and cortical auditory pathways.
- Evaluation of
  - **binaural** and
  - temporal processing skills.
Figure 16.3. Recommended auditory processing test battery for workers exposed to ototoxins [Rawool, V. W. (2016). Auditory Processing Deficits: Assessment and Intervention. New York: Thieme].
Binaural processing can be affected even in the presence of normal or near normal hearing


- Listeners whose high frequency monaural hearing status would be classified audiometrically as being normal or “slight loss” may exhibit substantial and perceptually meaningful losses of binaural processing.
  - Results were based on a subjective procedure where listeners were expected to respond to sounds presented in noise in various configurations

- We need objective procedures to overcome fatigue, attentional or memory related factors apparent in industrial workers
Convergence of information in the auditory brainstem

- Information presented to two ears converges at the auditory brainstem level within the superior olivary complex (SOC).
Binaural summation

• One advantage of the convergence within the auditory brainstem is that the sound energy presented at two ears is summated.

• Binaural summation.

https://s-media-cache-ak0.pinimg.com/736x/83/ef/4a/83ef4a395ffdc7866f1135aa58969144.jpg
Binaural summation at threshold

• Intensity needed to just barely detect a signal tends to be lower when a person is hearing through both ears compared to when he/she can listen to the signal through only one ear under headphones.

Monaural Threshold: 10 dB SPL

Binaural Threshold: 4 dB SPL

Binaural Summation/Advantage = Monaural – Binaural Threshold
= 10 – 4 = 6 dB
Binaural summation at threshold

- The threshold advantage from listening through two ears has been referred to as binaural summation at threshold (Hirsh, 1948).
Binaural summation at supra-threshold levels

- Monaural-binaural loudness matching
- A stimulus that is presented at a given sound pressure level (SPL) tends to sound louder binaurally compared to when it is presented monaurally.

Binaural summation at supra-threshold levels

• For sound levels above 40 dB SPL, the level difference required for equal loudness (LDEL) between monaural and binaural (diotic) modes of presentation can range from 5 to 7 dB.
  • Whilby et al., 2006; Edmonds and Culling, 2006, 2009.
Binaural summation in listeners with hearing loss

• Binaural summation of loudness is also apparent in individuals with bilaterally symmetrical hearing loss
  • (Hawkins, Prosek, Walden, & Montgomery, 1987).

• However, some listeners with hearing loss show deficits in binaural summation
  • (Whilby et al.; 2006)
  • Binaural summation processing deficit can occur secondary to hearing loss
Why do we wish to measure binaural summation?

• Predict the ability of the patient to benefit from the advantages provided by binaural summation
  • (e.g., easier detection of signals in front of the listener)
Another advantage of measuring binaural summation

- Determine the functional integrity of the lower auditory brainstem areas where binaural summation occurs.
An **Objective Procedure** for Measuring Binaural Summation. **Advantages?**

- Evaluation of binaural summation skills without the effect of:
  - inattention,
  - fatigue or
  - Memory effects
  - Linguistic variables
Previous Research

- Previous pilot research (Rawool, 2014, 2016) showed that binaural summation can be assessed using **contralateral** acoustic reflex thresholds (ARTs).
- When a loud stimulus is presented to one ear the reflex is elicited in both ears
  - Ipsilateral
  - Contralateral

Adapted from Fig. 1.3. Schematic of the Acoustic reflex pathway. The right ipsilateral pathway is shown by red arrows and the left is shown by blue arrows. Crossed pathways are represented by lighter arrows. [Rawool, V. W. (2016). Auditory Processing Deficits: Assessment and Intervention. New York: Thieme].
Stimuli and Reflex Recording

- Probe tone (226 Hz) presented to contralateral ear
  - The middle ear admittance is measured using a tone of specific frequency
  - The admittance is baselined to zero
- Reflex activating stimuli (clicks presented at 100/sec rate) presented to ipsilateral ear
  - Loud stimuli are presented to activate the reflex
  - Reflex activation reduces the admittance of the middle ear
  - The reduction signifies the activation of the reflex
• In the previous study,
  • only women were included
  • and ARTs were measured only in the right contralateral condition.
Purpose of Current Investigation

• Can previously established results be generalized to men and the left contralateral condition?

• **Specific questions**
  • Are there any gender effects in binaural summation measured using acoustic reflex thresholds?
  • Are there any stimulus ear effects in binaural summation measured using acoustic reflex thresholds?
Participants

- N : 60 (30 men and 30 women)
- Age range : 19 to 32 years
- Auditory function within normal limits
  - Peripheral auditory sensitivity
  - Middle ear function
Methods

• Equipment: Tympstar II
• Commercially available
Methods

- Contralateral Acoustic reflex thresholds
- Probe tone: 226 Hz 85 dB SPL
Reflex Threshold Criterion

- The minimum level at which
- acoustic reflex (at least 0.02 ml amplitude) could be elicited
- on at least two out of three trials.
No binaural summation: Control condition

Pulsed or Alternated Configuration

- Stimulus ear: Clicks
- Contralateral Ear: Probe Tone

44 ms 53 ms 44 ms 53 ms
115 ms 115 ms
The envelope of the multiplexed stimulus is 115 ms. The total rise and fall time of the envelope is 18 ms. Within this period, clicks are presented for 44 ms and the probe is presented for 53 ms. The clicks are `off' during the presentation of the probe. Thus, the reflex is measured after the clicks are turned off for a brief period, by presenting the probe tone.
No binaural summation: Control condition

How can you measure the reflex after the clicks are turned off?

Pulsed or Alternated Configuration

Reflex “Off” latency is longer than 53 ms

Stimulus ear: Clicks

Contralateral Ear: Probe Tone

44 ms 53 ms 44 ms 53 ms

115 ms 115 ms
Binaural summation: Experimental Condition

Simultaneous Configuration: Clicks to one ear, probe tone in the other ear
Reflex Threshold Conditions

Right Contralateral Reflex activating stimuli to the right ear, reflex measuring probe in the left ear

Left Contralateral Reflex activating stimuli to the left ear, reflex measuring probe in the right ear

Experimental condition
- Simultaneous (Steady-S) Configuration
- Alternated (Pulsed-P) Configuration

Control condition
- Simultaneous (Steady-S) Configuration
- Alternated (Pulsed-P) Configuration
Example of binaural summation, right contralateral thresholds

Right contralateral Thresholds
Alternated/pulsed configuration (Contralateral Pulsed: CP) = 96
Simultaneous/steady configuration (Contralateral Steady CS) = 90
Right Clicks Binaural Summation/Advantage = 96-90 = 6 dB
Binaural summation example left contralateral thresholds

Alternated/pulsed configuration (Contralateral Pulsed: CP) = 94
Simultaneous/steady configuration (Contralateral Steady CS) = 84
Left Clicks Binaural Summation/Advantage = 94-84 = 10 dB
Another index: Binaural summation asymmetry

Right contralateral Thresholds
Alternated/pulsed configuration (Contralateral Pulsed: CP) = 96
Simultaneous/steady configuration (Contralateral Steady CS) = 90
Right Clicks Binaural Summation/Advantage = 96-90 = 6 dB

Asymmetry: 4 dB

Left contralateral Thresholds
Alternated/pulsed configuration (Contralateral Pulsed: CP) = 94
Simultaneous/steady configuration (Contralateral Steady CS) = 84
Left Clicks Binaural Summation/Advantage = 94-84 = 10 dB
Results

• MANOVA on **acoustic reflex thresholds**

• No significant gender ($p = 0.085$) or ear ($p = .736$) effects or interactions.
  • Previous results generalize to men and ear

• Thresholds significantly ($p = 0.0000$) lower/better in the simultaneous configuration compared to the alternated configuration.
  • Similar to previous findings
Previous study:
Contralateral acoustic reflex thresholds obtained from 21 women in the ‘alternated’ and ‘simultaneous’ conditions. Note better or lower thresholds in the simultaneous condition. (Figure 6.32, Rawool, 2016)
Thresholds significantly (p = 0.0000) lower/better in the simultaneous configuration compared to the alternated configuration.
## Results: Descriptive Statistics

<table>
<thead>
<tr>
<th>Stimulus Configuration</th>
<th>Mean Threshold (dB peSPL)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alternated (no summation condition)</td>
<td>99.48 dB peSPL</td>
</tr>
<tr>
<td>Simultaneous (Summation condition)</td>
<td>91.13 dB peSPL</td>
</tr>
<tr>
<td>Average Binaural Summation (Difference in the two conditions)</td>
<td>8.35 dB</td>
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</tbody>
</table>
Binaural summation: 4 dB or higher in 87% of the participants
Normative Data for Auditory Processing Evaluations

- Based on the data collected, norms suggest that the following results could indicate dysfunction within the lower auditory brainstem, specifically at the level of the superior olivary complex.

- Binaural summation of less than 4 dB
- Binaural summation asymmetries greater than 8 dB (right or left ear advantage)
Concluding Remarks

- The current study confirms an objective procedure for measuring Binaural summation using commercially available equipment (GSI Tympstar II).
- Binaural summation can be assessed in both men and women using acoustic reflex thresholds.
- This investigation has established normative data for young adults which can be used in future investigations.
**Clinical Use**

- Easy and time efficient way of measuring functional deficit
  - Binaural summation
  - Additional clinical application
    - Binaural interference
Binaural Interference?

• Some patients perform **poorly** when information is presented to both ears simultaneously
  • compared to when the information is presented to only one ear
Binaural interference can also be measured with the current procedures.
Thank You!!!

For listening