Comprehensive Evaluation of Auditory Processing Disorders in TBI

Catherine A. Fabian, AuD

Scripps Memorial Hospital-Encinitas

Rehabilitation Services
- Physical Therapy
- Occupational Therapy
- Speech-language Therapy
- Audiology
- Psychology
- Social Work
- Neurology

Scripps Memorial Hospital-Encinitas

Central Auditory Processing Disorder and Traumatic Brain Injury
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7th Annual Brain Injury Rehabilitation Conference 2012

Brain Injury Day Treatment Program
Ecologically valid therapy settings
- Physical
- Cognitive
- Intensive clinical therapy settings

Audiology and Cognitive Rehabilitation
- Rule out hearing loss secondary to head trauma or acoustic trauma
- Assess auditory processing

Patient complaints
Anecdotal therapist observations
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“We hear with our brains, not our ears.”

-Nina Kraus, Ph.D., Northwestern University

Central Auditory Processing
Beyond Sensation

The neurological underpinnings for
• Sound localization
• Sound recognition
• Verbal communication

Intact Sensory Pathway and Organ

• No hearing loss but difficulty hearing
• Complaints
  – Background noise
  – Rapid speech
  – Awareness
  – Music appreciation

Auditory Processing: The Basics

http://hyperphysics.phy-astr.gsu.edu/hbase/sound/anerv.html

Tonotopic organization in the central auditory pathway.
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The Brain and Brainstem

What's going on in that head of yours?

The Central Auditory Pathway

Corpus Callosum – Your Brain’s Transfer Station

Trauma and the Auditory Mechanism

- Anatomy of the peripheral sensory pathway and organ of hearing
- Head trauma: disarticulation, temporal lobe fracture
- Acoustic trauma: temporary threshold shift, tympanic membrane rupture, basilar membrane rupture, hair cell shearing
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Trauma and the Auditory Nervous System

- Coup/Counter-Coup
- Hematoma/Contusion/Hemorrhage

Vulnerability of the CANS

- Torsional Shearing
- Diffuse Axonal Injury
Sound Processing

Characteristics of Running Speech
- Amplitude modulated speech envelope—syllabic structure
- Spectral peaks and valleys—Fundamental frequency and formants
- Periodicity of vowels and voiced consonants
- Fine spectral structure of fricatives and stopped consonants

Speech Perception
- Frequency/Pitch: V formants, nasal formants, spectral energy of Cs
- Intensity: Segmental perception, syllabic, prosodic
- Onset: Stops, affricates
- Periodicity: Vs, fricatives, temporal syllabic envelope

Speech in Noise: Cocktail Party
- Stream separation
  - Frequency-following F0 in voice of interest
  - Listening for the gaps
  - Monitoring steady-state noise

Detection/Sensation
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Processing Sound through the ANS VIIIth Nerve
- Faithful transduction/representation of acoustic signal

Specialization
Auditory nerve fibers (those are in the auditory periphery, not the CNS) show very little specialization; i.e., they’re nearly interchangeable with one another, with one exception: Some have low thresholds (and high spontaneous rates), some have high thresholds (and low spontaneous rates). That’s about it for specialization. Neurons in central auditory system, on the other hand, are specialized.

Four Different cell types in the cochlear nucleus
- A
- B
- C
- D

Structurally, the cells look different. They also respond differently to input from other neurons.

Processing Sound through the ANS Cochlear Nucleus

Tomotopic organization in the central auditory pathway.

Characteristic frequencies

Processing Sound through the ANS Superior Olivary Complex
Contralateral Input
- Lateral Superior Olive - Detects interaural level differences
- Medial Superior Olive - Detects interaural time differences.
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Processing Sound through the ANS

Inferior Colliculus

• Integrates input from the SOC and the CN
• Crucial for localization

Thalamus

• Medial Geniculate Body
• Multi-sensory Integration

The Hemispheres

• Right Hemisphere Specialization
• Left Hemisphere Specialization
• Corpus Callosum Transfer

Key Points about the Central Auditory System

Summarized below are the concepts that are most important to know about the central auditory system:

1. Endpoints of the Auditory Pathway. The pathway begins in the cochlear nucleus of the medulla and ends with the auditory radiations, which run from the thalamus to auditory cortex.

2. General Architectural Features

(a) decussation (crossing over)
(b) tonotopic organization
(c) specialization
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Behavioral Sound Processing

Auditory Processes Defined

- sound localization and lateralization (binaural interaction)
- auditory discrimination
- auditory pattern recognition
- temporal aspects of audition, including temporal discrimination/resolution and temporal ordering
- auditory performance in competing acoustic signals, including dichotic listening (binaural integration and separation)
- auditory performance with degraded acoustic signals (monaural auditory figure ground, auditory closure)

Sound Localization and Lateralization

Where does sound come from?
The brain uses both time differences and intensity differences to figure out where sound comes from.

Auditory Discrimination

The ability to use acoustic cues to differentiate similar sounding words:

- fish vs. dish
- Deaf vs. death
- Peach vs. teeth

Auditory Pattern Recognition

The capacity to perceive intensity, duration, and frequency patterns. Recognition and sequencing of these patterns requires interhemispheric interaction.


Temporal Processing: It’s about Time
Temporal processing refers to the processing of acoustic stimuli over time. Temporal processing is very important for us to be able to understand speech in quiet and in background noise, since speech stimuli and other background sounds vary over time.

• Integration - the ability of the auditory system to add up information over time or over duration
• Discrimination (Gap Detection) – standstill or stand still, can you hear the difference?
• Ordering – which sound comes first

Auditory Performance in Competing and/or Degraded Acoustic Signals
• Dichotic listening
  – Binaural Integration
  – Binaural Separation
• Figure Ground
  – Understanding in noisy environments
• Closure
  – Inferring speech from degraded input

Symptoms of Auditory Processing Disorders
Common symptoms of CAPD are:
• inordinate difficulty hearing in noisy or reverberant environments;
• difficulty following conversation on the phone
• difficulty following multi-step directions
• difficulty following long conversations
• difficulty taking notes
• difficulty with social situations—difficulty “reading” others / pragmatic communication issues
• difficulty with spelling, reading and writing
• lack of music appreciation
• difficulty directing, sustaining, or dividing attention

CAPD Testing
Behavioral Tests
• Filtered Words: Degraded Speech, auditory closure
• Time Compressed Speech: Degraded Speech, temporal processing
• QuickSIN: Auditory Figure Ground – Speech in Noise
• Staggered Spondaic Words– Binaural Integration
• Competing Sentences – Binaural Separation

Behavioral Tests

- **Gap Detection**: Temporal Discrimination (standstill vs. stand still)
- **Pitch Pattern Sequence**: Temporal Ordering stimulus
- **Masking Level Difference**: Binaural Interaction (lateralization, signal in noise detection)

**CAPD Profiles**

<table>
<thead>
<tr>
<th>Processes Affected</th>
<th>General Site of Lesion (bottleneck)</th>
<th>Behavioral Difficulties</th>
</tr>
</thead>
<tbody>
<tr>
<td>Integration</td>
<td>Temporal Patterning</td>
<td>Corpus</td>
</tr>
<tr>
<td></td>
<td>Binaural Separation/Integration</td>
<td>Callosum</td>
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<tr>
<td></td>
<td></td>
<td>Interhemispheric Transfer</td>
</tr>
<tr>
<td></td>
<td>Decoding</td>
<td>Left Hemisphere</td>
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<tr>
<td></td>
<td>Auditory Closure</td>
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</table>

**What does it sound like? (cont.)**

**Auditory Decoding Difficulties**
Imagine not being able to distinguish whether you hear a /p/ or a /t/ or a /k/ and you hear a person say, “Do you have the car keys?” You may hear that sounding like “Do you have the tar teys?” or “Do you have the par peas?” Discrimination difficulties might look like this:

Twhnkke, tvinje kitsle rtaq.
Hov I wnnddr wgt wou zre.
tp aaovd thd woqd sn hifh,
lhke z dizmnd im thd skx.
Twhnkke, tvinje kitsle rtaq.
Hov I wnnddr wgt wou zre.

How hard would you have to work to decode this message?

**What does it sound like?**

While we can’t actually simulate what it sounds like, we can draw a parallel to what it looks like.

**Auditory Integration Difficulties**
Problems with auditory closure, binaural integration, or auditory synthesis. In essence, integration relates to how a person takes pieces of messages and puts them together to form the whole.

In order to simulate auditory integration difficulties, only pieces of the message will be presented and it will be your task to figure out the entire message. Strategies such as familiarity, knowing the topic, and linguistic knowledge will help you as they can help someone with auditory integration deficits.

Hey the cat cow
The little to see sight
And the ran away
What does it sound like? (cont.)

Prosody Difficulties
Imagine tone deafness to the extent that you cannot distinguish the rise and fall of pitch or the that you cannot detect the intensity or duration markers of stress in a person’s voice.

“You have the car keys?”
“You have the car keys.”
“You have the car keys.”

How easy would it be to miss a person’s intent?

Mary Had a Little Lamb
First Stanzas

Physiologic Testing

- CT Scan
- MRI/fMRI
- PET
- MEG
- Event Related Potentials

Electrophysiologic Testing

- Practical
- Time Domain
- Online

Electrophysiologic Tests

- ABR – Auditory Brainstem Response test
- Requires subject to: Lay quietly while listening to clicks presented through insert earphones.
- Occurs at approximately: 1.5 – 6.5 ms in the EEG
- Assesses: 8th nerve & Low brainstem function.
- Probable site of lesion by peak of waveform:
  - Waves I – II: 8th nerve
  - Wave III: Cochlear Nucleus
  - IV: Superior Olivary Complex
  - Wave V: Lateral Lemniscus and caudal auditory track
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Electrophysiologic Tests

- **MLR – Middle Latency Response**
  - Requires subject to: Lay quietly while listening to clicks presented through insert earphones. Can be recorded simultaneously with ABR.
  - Occurs at approximately: 10 – 100 ms.
  - Assesses: Low brainstem through auditory cortex and corpus callosum, primarily the projections into the auditory cortex.

P300 – The “Cognitive” Potential

- Tests: Attentional function
- Integrative function
- Discriminative function
- Requires subject to: attend to infrequent tone, and count them, while ignoring other tones.
- Occurs at approximately 250-500 ms.
- Assesses: Low brainstem, corpus callosum, frontal lobe, auditory cortex and cognitive processes. This is inferred based on scalp recordings. Primarily cortical functions.
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### Evoked Potential Testing

<table>
<thead>
<tr>
<th>Test</th>
<th>What It Measures</th>
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<tbody>
<tr>
<td>Auditory Brainstem Response (I, II, III, IV, V)</td>
<td>ABR details the transmission of the auditory signal from the ear through the brainstem</td>
</tr>
<tr>
<td>Middle Latency Response (Na, Pa, Nb, Pb)</td>
<td>MLR measures responses from the thalamocortical region.</td>
</tr>
<tr>
<td>P300 Event-Related Potential (N1, P2, N2, P3)</td>
<td>P300 measures reflect primary auditory cortex and cognitive processes. These structures involve attentional, integrative and discriminative function.</td>
</tr>
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### P300 Waveform

![P300 Waveform Diagram]