Comprehensive Evaluation of Auditory Processing Disorders in TBI

Catherine A. Fabian, AuD

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Brain Injury Rehabilitation
Conference
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Central Auditory Processing Disorder and Traumatic Brain Injury

Dr. Catherine A. Fabian, Au.D.
Scripps Memorial Hospital-Encinitas
Brain Injury Day Treatment Program
fabian.catherine@scrippshealth.org

Scripps Memorial Hospital-Encinitas

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

Scripps Memorial Hospital-Encinitas

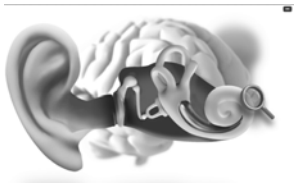
Brain Injury Day Treatment Program

Ecologically valid therapy settings

- Physical
- Cognitive
- Intensive clinical therapy settings

Audiology and Cognitive Rehabilitation

- Patient complaints
- Anecdotal therapist observations
- Rule out hearing loss secondary to head trauma or acoustic trauma
- Assess auditory processing



"We hear with our brains, not our ears."

-Nina Kraus, Ph.D., Northwestern University

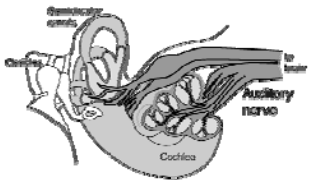
Central Auditory Processing
Beyond Sensation

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

Intact Sensory Pathway and Organ

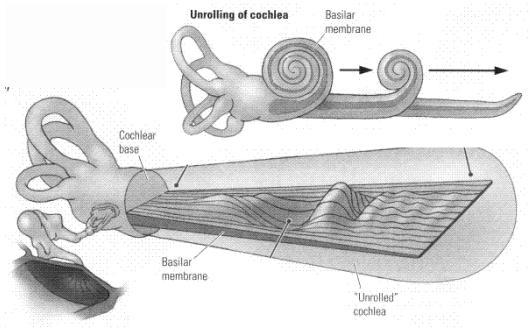
- No hearing loss but difficulty hearing
- Complaints
  - Background noise
  - Rapid speech
  - Awareness
  - Music appreciation

Auditory Processing: The Basics

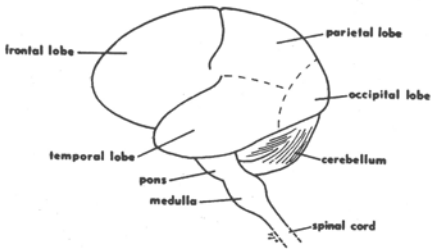


http://hyperphysics.phy-astr.gsu.edu/hbase/sound/anerv.html

Tonotopic organization in the central auditory pathway.

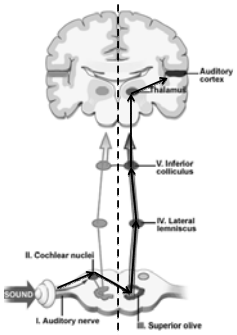


The Brain and Brainstem



http://homepages.wmich.edu/~hillenbr/206.html

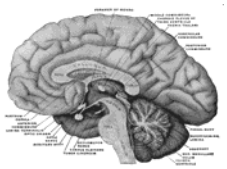
What's going on in that head of yours?



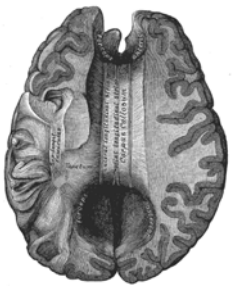
OR

The Central Auditory Pathway

Corpus Callosum – Your Brain's Transfer Station



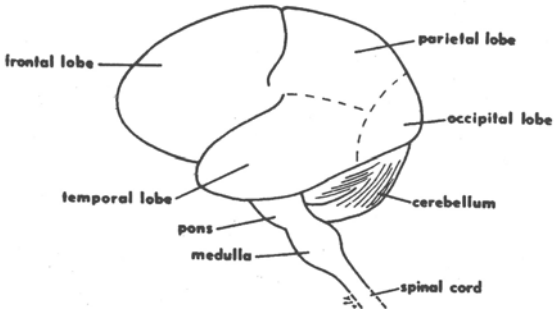
Fibers run through the Corpus Callosum, transferring information between the two hemispheres.



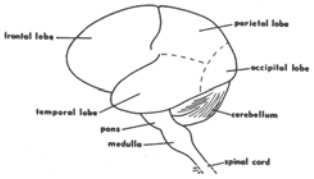
Trauma and the Auditory Mechanism

- 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

Trauma and the Auditory Nervous System

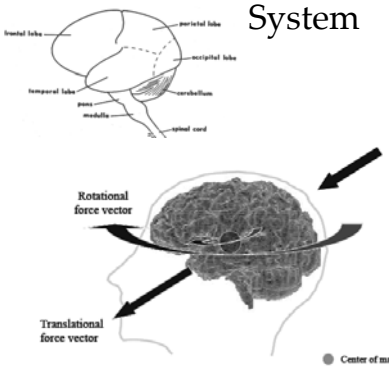


Trauma and the Auditory Nervous System



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

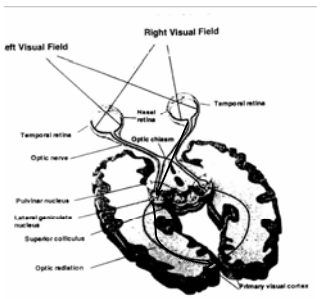
Trauma and the Auditory Nervous System

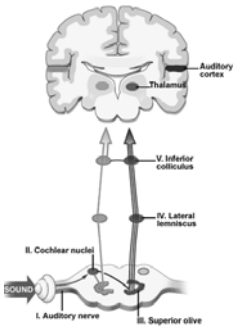


(Figure adapted from Arciniegas & Beresford 2001)

- Torsional Shearing
- Diffuse Axonal Injury

Vulnerability of the CANS

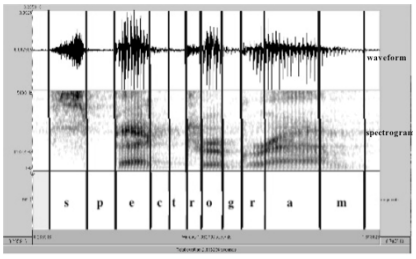




Sound Processing

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



Sound Processing

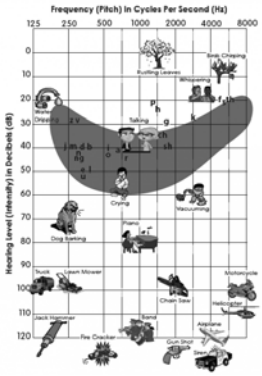
Speech Perception

- 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

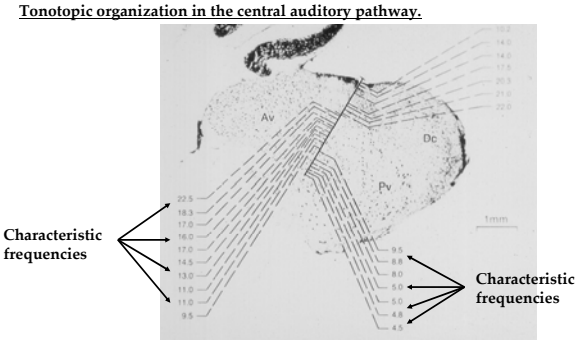


Processing Sound through the ANS VIIIth Nerve

- Faithful transduction/representation of acoustic signal

Processing Sound through the ANS Cochlear Nucleus

Tonotopic organization in the central auditory pathway.



Specialization

Auditory nerve fibers (*these 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

Structurally, the cells look different.

They also respond differently to input from other neurons.

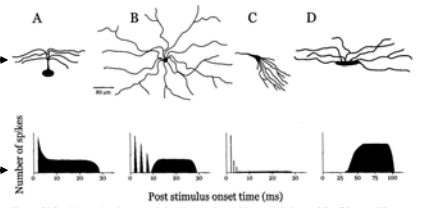


Figure 26-1. Upper drawings are stylized impressions of the morphology of 4 cell types of the cochlear nucleus, prompted by the descriptions of Oertel et al[21] and Rhode.[20] Lower panels are schematic, stylized impressions of the poststimulus time histograms of the responses to CF tones that might be expected from the neurons depicted (prompted by those presented by Rhode and Greenberg[18]).

Processing Sound through the ANS Superior Olivary Complex

Contralateral Input

- **Lateral Superior Olive -** Detects interaural level differences
- **Medial Superior Olive -** Detects interaural time differences.

Processing Sound through the ANS Inferior Colliculus

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

Processing Sound through the ANS Thalamus

- Medial Geniculate Body
- Multi-sensory Integration

Processing Sound through the ANS 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

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)

American Speech-Language-Hearing Association. (2005). *(Central) Auditory Processing Disorders—The Role of the Audiologist* [Position Statement]. Available from www.asha.org/policy.

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.

Pinheiro, M. (1976). Auditory pattern perception in patients with left and right hemisphere lesions. *Ohio Journal of Speech and Hearing, 12,* 9–20.

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

Rawool, V. W. (2006). The effects of hearing loss on temporal processing. **Part 2**: Looking beyond simple audition. Hearing Review 13(6): 30,32,34.

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

Processes Affected	General Site of Lesion (bottleneck)	Behavioral Difficulties
Integration		
Temporal Patterning Binaural Separation/Integration	Corpus Callosum/Interhemispheric Transfer	+Understanding in noise +Linking content with intent +Tracking noise source across midline +Music appreciation +Taking notes
Decoding		
Auditory Closure Temporal Processing Discrimination Binaural Separation/Integration	Left Hemisphere	+Understanding in noise +Understanding soft/distant speech +Frequent requests for repetition +Auditory Fatigue
Prosodic		
Temporal Patterning Discrimination of vowels and non-speech stimuli Binaural Separation/Integration	Right Hemisphere	+Understanding intent +Music appreciation +Recognizing humor

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, tvinjle kitsle rtaq.
Hov I wnnddr wgat wou zre.
tp aaovd thd woqd sn hifh,
lhke z dizmomd im thd skx.
Twhnkke, tvinjle kitsle rtaq.
Hov I wnnddr wgat 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

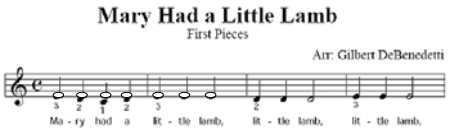
What does it sound like? (cont.)

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?



Physiologic Testing

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

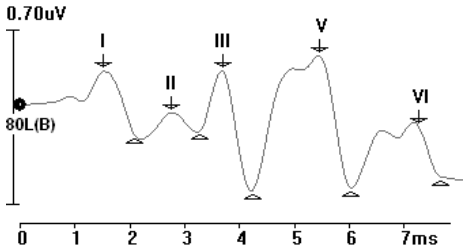
Electrophysiologic Testing

- 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 Leminscus and caudal auditory track

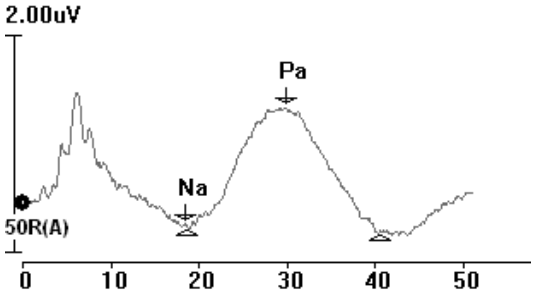
ABR Waveform



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

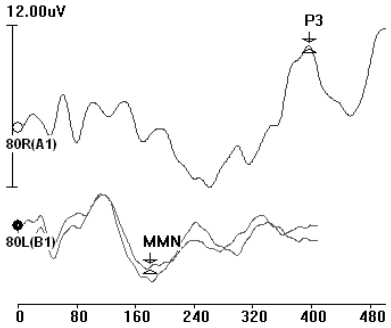
Middle Latency Response Waveform



Electrophysiologic Tests

- **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.

P300 Waveform



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