Sound – how does it happen

- Disturbance of particles in a medium.
- Particles come together (condensation) and apart (rarefaction.)
- Represented as a waveform.

Sound – how does it happen

- Frequency
  - Pitch or frequency is defined by the number of cycles per second.

Amplitude

- The height of the wave corresponds to the loudness level.
Sound Definition

- The sensation produced by the sense of hearing.

**Merriam says:**

(n). Mechanical radiant energy that is transmitted by longitudinal pressure waves in a material medium (as air) and is the objective cause of hearing.

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How do we hear?

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How do we hear?

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How do we hear?
Agenda

- Review of anatomy
- Provide an overview of common audiological procedures.
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- Overview ways to tell what sounds a child can access while aided.
- Discuss certain auditory disorders.

Evoked Potentials (EP)

- Electrodes are placed on the head.
- Earphones are placed in the ear.
- Waveforms are recorded from the electrodes.
- Early waves (<10 ms) correspond to the Auditory Brainstem Response (ABR)
- Later waves correspond to auditory structures higher in the brain and are called late potentials.

Auditory Brainstem Response (ABR)

- In order for the signal to be transmitted to the brain effectively, all of the nerve fibers need to fire at the same time. This is neural synchrony.
- ABR is a test of neural synchrony. We use the ABR to assess the auditory pathways of the brainstem.

Evoked Potentials (EP)

- The waves of the ABR correspond to different structures of the brainstem.
- Gives us an objective estimation of the audiogram.
- Stimuli used includes clicks (higher frequency bursts), and tone pips.
Auditory Brainstem Response (ABR)

ABR Video

http://www.med.unc.edu/earandhearing/pedsaud/downloads

Courtesy of Phonak, Inc.

Auditory Steady State Response (ASSR)

- Auditory Steady State Response
- Kind of like an ABR, but an ASSR looks for responses along a frequency continuum rather than a time continuum.
- Instead of an audiologist detecting peaks, a computer program uses a statistical model to detect presence or absence of a response.
- Several frequencies can be recorded at once.
- Proponents say that it is more accurate at estimating thresholds for the severe-profound population.
Cortical Tests

- Cortical Auditory Evoked Potentials assess the auditory pathway beyond the brainstem.
- Event-related potentials, meaning that we are measuring a response that is “time-locked” to an event.
- Recognition of a sound, omission of a sound
- There are several different tests measuring the function of different areas in the auditory system.

Otoacoustic Emissions (OAEs)

- A pair of tones at different frequencies (known as f1 and f2) are sent into the ear.
- If the inner ear structures are healthy, a distortion tone (equal to 2f1-f2) will be sent back and be recorded by the microphone. These sounds are generated by the cochlea.
- Does not predict threshold.
- Is not valid if there are middle ear problems.
Tympanometry

- Test of middle ear function.
- Probe is placed in the ear and pressure is changed in order to move the eardrum back and forth.
- Results from the change in pressure are recorded.

Maximum compliance of the middle ear system occurs when the pressure in the middle ear cavity is equal to the pressure in the external auditory canal.
- Compliance (static admittance) is plotted vertically. The maximum compliance is represented by the highest peak of the curve on the graph.
- Pressure is indicated on the horizontal axis of the graph, and is measured in daPa.
- Also monitors ear canal volume.

Tympanometry

A: Normal

B: "Flat" – no mobility of the tympanic membrane with an intact ear drum. Needs medical attention

C: Negative pressure – Monitor.

Word Recognition Testing – Closed Set

- Patient is presented with a word and they choose their response by pointing to a picture or selecting a corresponding toy.
- Words are presented recorded or via monitored live voice. Presented at the patients most comfortable level (MCL) when unaided or at a typical speech level when aided.
- Typically auditory only.
- Helps us assess what the child is able to hear without articulation coming into play.
### Word Recognition Testing – Closed Set

- **Common tests:**
  - WIPI (Word Intelligibility by Picture Identification)
  - ESP (Early Speech Perception Test)
  - NU-CHIPS (Northwestern University Children’s Perception of Speech)

### Word Recognition Testing – Open Set

- **Common tests:**
  - PBK-50 (Phonetically Balanced Kindergarten List – 50 words)
  - MLNT (Multisyllabic Neighborhood Test)
  - LNT (Lexical Neighborhood Test)
  - CNC (Consonant Nucleus Consonant Test)
  - CID W22 List
  - NU6 (Northwestern University Auditory Test #6)
  - HINT-C (Hearing In Noise Test – Children)

### Behavioral Audiogram

- **Air Conduction**
- **Bone Conduction**

### Audiogram

- A graph that shows us threshold compared to the average hearing person.
  - Threshold is the softest sound the child can identify reliably 50% of the time.
  - Determines:
    - Presence or absence of hearing loss
    - Type of loss
    - Degree of loss
    - Shape of loss
    - Asymmetry

### Behavioral Testing Video


Courtesy of Phonak, Inc.
Agenda

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Normal Hearing

- Is still a hearing loss!
- Children need more consonant information to learn language.
- May miss up to 40% of the speech signal in a noisy classroom.
- These are the kids who are accused of “Not paying attention.”
- 37% of children with mild or unilateral hearing loss fall at least one grade.
- ALL children with ANY type of hearing loss need assistive technology (ie an FM system).
- Classrooms are poor acoustic spaces even for children with normal hearing.

Mild Hearing Loss

- Is still a hearing loss!
- Children need more consonant information to learn language.
- May miss up to 40% of the speech signal in a noisy classroom.
- These are the kids who are accused of “Not paying attention.”
- 37% of children with mild or unilateral hearing loss fall at least one grade.
- ALL children with ANY type of hearing loss need assistive technology (ie an FM system).
- Classrooms are poor acoustic spaces even for children with normal hearing.

Mild Hearing Loss

- Often delayed in academics.
- Show gaps in that they can be age appropriate in some areas, and delayed in others.
- Reading comprehension can be poor.
- Difficulty with group discussion.
- Seem to hear everything when amplified, but can sometimes miss some information.
- Written language can suffer.
- Need an FM in school.

Moderate Hearing Loss

- Should be able to detect speech sounds when aided optimally.
- May have severe delays in speech and language.
- Reading comprehension and written language can be poor.
- Difficulty with group discussion.
- Must be aided well for spoken language.
- Need an FM in school.

Severe Hearing Loss

- Will need ongoing monitoring of speech and language progress.
- FM is essential.
- May benefit from other technologies such as CART, note taker, interpreter language facilitator...

Profound Hearing Loss

- 20% of babies identified with hearing loss have a profound loss. (agbell.org)
- These children will not be able to learn age appropriate spoken language without aggressive intervention.
- Cochlear implant is likely the best “amplification” strategy.
Profound Hearing Loss

Conductive Hearing Loss

- Occurs when sound is not conducted efficiently through the outer ear, the eardrum, and or the ossicles of the middle ear.
- Sounds is reduced but not distorted.
- Can often be medically or surgically treated.

Common Causes:
- Fluid in the middle ear
- Perforated eardrum
- Benign tumor
- Earwax (cerumen)
- Infection in the ear canal (external otitis)
- Presence of a foreign body
- Absence or malformation of the outer ear, ear canal, or middle ear

Sensorineural Hearing Loss

- Occurs when there is damage to the cochlea or to the nerve pathways from the inner ear (retrocochlear) to the brain.
- Cannot be medically or surgically corrected. It is a permanent loss.
- Not only are thresholds increased, but sounds are distorted.
- Many many causes.

Mixed Hearing Loss

- Conductive and sensorineural hearing loss occur together.
- Common Causes:
  - Middle ear infection on top of an existing sensorineural loss.
  - Malformation of the outer and inner ear.
Agenda

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Devices

- Hearing aids: Amplify sound
- Cochlear Implants: Stimulate the auditory nerve when hearing aids aren't enough.

Hearing Aids

- Behind The Ear (BTE) hearing aids for children.
  - Easy to change earmolds to account for growth of the ear canal.
  - Better microphone positioning.
  - Easier to connect to FM systems.
  - More flexibility for growing children.

Hearing Aid Troubleshooting

- If the Aid Does Not Work At All
  - Make sure the aid is turned on (don't laugh; this happens!).
  - Make sure that the T-switch is correctly positioned (not in the "T" position).
  - Check if the battery is inserted correctly (+ and in the right place). If you have to force the battery, you probably have it wrong.
  - Check to see that the battery is not dead. If in doubt, try a new one (where you have to remove the sticky paper flap off the battery surface). A dead battery is the most common reason for "dead aids".
  - Check battery contacts to be sure they are not corroded.
  - Check tubing to be sure it is not clogged with moisture (shown by water or condensation in the tube).
  - Check earmold to be sure that sound bore is not clogged with wax.

- If Sound is Weaker than Usual
  - Check battery. Replace if necessary.
  - Check tubing for cracks, fraying, moisture, etc. Replace if necessary.
  - Check that the earmold is not clogged with wax.
  - Reposition the earmold for a tighter fit; it may have been whistling (feedback) at a pitch you cannot hear.

Care and Troubleshooting!
http://www.healthyhearing.com/articles/7835-troubleshooting-your-hearing-aid
Hearing Aid Troubleshooting

- If Aid Goes On/Off or Has Scratchy Sound
  - Flick on/off switch back and forth, in case dust or lint has collected in the controls.
  - Check battery contacts.
  - Think where you have been. If in a very humid environment or have experienced excessive perspiration from vigorous activities, moisture may clog the aid and distort sounds. Use a hearing aid dehumidifier overnight and try again (see discussion above under "Moisture").
  - Check the tubing from earmold to the hearing aid and replace it if bent, cracked, frayed.

- If the Aid Whistles ("Feedback")
  - Probably an earmold problem. Remove the aid, put a finger over the earmold hole. If the whistling stops, the earmold was not properly inserted in the ear, or is not a good fit. Try it again in the ear; if the whistle continues, consult your hearing aid dispenser.
  - Sometimes feedback may occur when you have a blockage of wax in the ear canal.
  - Check volume control; it may have been turned too high.

Bone Conduction Aids

- For those with mixed or conductive hearing loss who cannot wear conventional hearing aids.
- A bone oscillator is held tightly against the head and sound is transmitted to the inner ear via bone conduction.
- Both cochlea are stimulated at the same time.

Bone Anchored Hearing Aid (BAHA)

- Permanent bone conduction option.
- A metal post is seated into the skull.
- After several months, bone growth helps “cement” the seat in place.
- The bone vibrator is snapped onto the external abutment.
Bone Anchored Hearing Aid (BAHA)

Cochlear Implants (CIs)

- A hearing aid works by amplifying sounds, making them louder.
- A cochlear implant is for patients who have levels of hearing loss in the severe to profound range or can no longer benefit from hearing aids.
- It is a "neural prosthetic device."

Cochlear Implants (CIs)

- The cochlear implant consists of two pieces
  - An internal receiver/stimulator (surgically implanted)
  - External speech processor, which is worn on the outer ear (pinna) and looks similar in appearance to a behind-the-ear hearing aid.
- Surgery is required to place the internal device.
- The external components are typically fit several weeks after surgery.

CIs and Meningitis

- Kids with CIs are at a greater risk of contracting Meningitis
- It is IMPERATIVE that they receive their meningitis vaccines.
- Children less than 2 years of age should receive Prevnar® as is recommended for all children.
- Children with cochlear implants 2 years of age and older who have completed the Prevnar series should receive one dose of Pneumovax® If they have just received Prevnar, they should wait at least two months before receiving Pneumovax (PVC13).
**Clis and Meningitis**

- Children with cochlear implants between 24 and 59 months of age who have never received either Prevnar or Pneumovax should receive 2 doses of Prevnar 2 or more months apart and then receive 1 dose of Pneumovax at least 2 months later.
- Persons 5 years of age and older with cochlear implants should receive 1 dose of Pneumovax. Revaccination is not indicated.

**FDA Candidacy Criteria**

- **General Criteria**
  - Children at least 12 months of age
  - Children with severe-to-profound hearing loss
  - Children who are healthy enough to undergo the cochlear implant surgery
  - Children whose families are motivated to use listening for communication
- **Younger children**
  - Lack of benefit from appropriately fit hearing aids that are worn consistently on a full-time basis
  - Lack of progress or a plateau in auditory development
- **Older children**
  - 30% or less word identification on standard tests when presented at a normal conversational level in the best-aided condition and without lipreading cues

**Revisions**

- **Symptoms**
  - Device stops communicating with the external processor.
  - Loss of electrodes.
  - Big regression in word recognition skills.
  - Pain/Headaches

- **Symptoms, Cont.**
  - Hearing strange percepts that can’t be “mapped” away.
    - Pain
    - Static
    - Buzzing
    - Beeping
    - Monkeys laughing
  - Intermittency with fully functional equipment, the right batteries, and mapping changes.

**Revisions**

- **Recovery**
  - On average, it takes about a year for a child to return to previous levels of performance.
  - There is no guarantee that they will do better than they did prior to revision.

**Bimodal Listening**

- Using a hearing aid in the ear opposite a cochlear implant.
- As CI criteria expands, some kids do have usable residual hearing in their non-implanted ear.
- Generally won’t have open set word recognition on its own, but does have other benefits.
  - Localization
  - Hearing in noise
  - Sound awareness
  - Music
Noise, distance, and reverberation are the main obstacles to listening.

- ANSI recommends a noise level of less than 35 dBA and a reverberation time of less than 0.6 seconds.
- A typical classroom has a noise level of 50 – 70 dBA and a reverberation time of over 1 second.

Kids NEED FM!!!!!
Evidence Based Pros and Cons

Desktop Soundfield

- **Advantages**
  - Improves signal-to-noise ratio (SNR) by 10-20 dB
  - Portable
  - Brings the signal closer to the child’s ear
  - Easy to troubleshoot

- **Disadvantages**
  - Improvements in SNR variable according to location and noise.
  - Speaker placement issues.
  - May not improve SNR to ANSI levels.

Evidence Based Pros and Cons

Neckloops

- **Advantages**
  - Often improves SNR by as much as necessary
  - SNR can meet ANSI levels
  - Portable
  - Two ears with one receiver.

- **Disadvantages**
  - Possible noise from the t-coil or interference from other sources.
  - Only one child receives improvement.
  - Processor often needs programming.
  - Troubleshooting more difficult.
  - Cannot monitor integrity of the signal from microphone through headpiece.

Evidence Based Pros and Cons

What the research says

- Meta Analysis from Erin Schafer, Ph.D.
  - Synthesized data across studies to yield cumulative results.
  - 9 studies to compare benefits of the 3 types of FM receivers for cochlear implants

<table>
<thead>
<tr>
<th>Cochlear Soundfield</th>
<th>Desktop Soundfield</th>
<th>Direct Connect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Improvement of 3.1% (+3.1)</td>
<td>Improvement of 17.1% (+8.8)</td>
<td>Improvement of 38.0% (+5.7)</td>
</tr>
<tr>
<td>No significant improvement compared to implant alone</td>
<td>Significantly poorer than direct connect</td>
<td>Significant improvement compared to implant alone</td>
</tr>
<tr>
<td>Significantly poorer than direct connect</td>
<td></td>
<td>Significantly better than classroom and desktop</td>
</tr>
</tbody>
</table>

FM

- Troubleshooting:
  - Phonak has TONS of resources!!!
  - eSchool desk
  - FM Inservice
  - Interactive Troubleshooting

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Aided Access to Sound

- Verification
- Real-ear measures
- Validation
- Functional Audiogram
- Word Recognition Testing
- Ratings Scales
Desired Sensation Level (DSL)

http://www.med.unc.edu/earandhearing/pedsauid/downloads

Programming Computer – Controls the hearing aid

Audioscan – Measures hearing aid output
Soft sounds
Average threshold for normal hearing
Average speech spectrum
Child’s Thresholds
Tolerance levels
Loud sounds
CIs – How do you know when a child needs a new map...

- Biggest clue is a change in performance.
  - Ex. The child used to detect /s/ and no longer can hear it at all.
  - They start having changes in articulation that seem to be related to what they are hearing (Ex. Used to say /f/ just fine but is suddenly substituting /b/).
  - Reduction in distance listening.
  - They are reporting strange percepts (ex. buzzing).
  - Child is playing with the controls.
  - Facial stimulation.

How you can help the audiologist

- Go to modules and be as educated as you can about auditory intervention.
- Troubleshooting: make it be the parent’s responsibility.
- Is the child wearing the device full time?
- Are parents doing carryover at home?
- What goals are you working on?
- What progress has been made?

What difficulties are you noticing?

- Are these difficulties new or recurring?
- What interventions have you tried for this particular problem?
- Is the child adding any sounds that aren’t there?
- Are they complaining about sounds that you don’t hear?
- Any intermittencies?
- Any facial stimulation?
- Is the child playing with the controls?
- If you have a gut feeling that something is off, be as descriptive as possible.

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Disorders

- Cochlear Nerve Deficiency (CND)
- Malformations
- Connexin 26
- Waardenburg
- Auditory Neuropathy Spectrum Disorder (ANS)

Cochlear Malformations

- Cochlear Nerve Deficiency
  - Small or absent cochlear nerve
- Michel Aplasia
  - Absence of inner ear structures
  - Cochlear implantation is not an option
### Cochlear Malformations

- **Mondini**
  - A true Mondini is 1.5 turns of the cochlea, with enlarged vestibule and normal semicircular canals.
  - Has become a “catch all” meaning there is an incomplete cochlea, less than 2.5 turns.
- **Common Cavity**
  - No differentiation of inner ear structures.
  - Neural survival and location are questionable.

### Connexin 26

- Genetic mutation responsible for 10% of childhood hearing loss.
- Nonsyndromic
- Recessive
- Affects potassium flow from hair cells.
- Most hearing loss is severe to profound.

### Waardenburg’s

- Wide set eyes with a broad nasal root
- Low hairline and “Unibrow”
- Autosomal dominant
- Can show some, one, all, or none of the typical features.
- Typically do well with a cochlear implant.

### Auditory Neuropathy Spectrum Disorder (ANSD)

- Auditory Neuropathy Spectrum Disorder
- Disordered auditory nerve activity due to abnormalities of the auditory nerve, inner hair cells and/or their synapses.
- Have evidence of functioning outer hair cells, while those with SNHL do not.
- Identified via ABR
  - Child does not have neural response, but does have a cochlear response known as the cochlear microphonic.
ANSD

- ABR stimulus is measured separately with positive (condensation) and negative (rarefaction) polarity stimuli.
- Response will be an inversion of the peaks of the cochlear microphonic waveform. Neural responses do not do this.

ANSD

- Many different causes.
  - Prematurity
  - Hyperbilirubinemia
  - Hypoxia
  - Metabolic disorders.
  - Genetic
- Children often have comorbid disabilities.
- Extreme variability in function.

ANSD

- Findings of the consortium.
  - Still a lot of disagreement.
  - Since there is no objective data, we need to wait for a behavioral audiogram before deciding on amplification.
  - Hearing aids should then be fit to prescribed targets.
  - Auditory based intervention is NOT contraindicated!
  - Consider cochlear implantation if there is a sufficient auditory nerve and the child does not demonstrate good progress in speech recognition and language development.
Practical Implications for the Educator and SLP: Why we should know this information

Agenda

- Discuss basic speech acoustics and relevance of hearing and learning spoken language
- Discuss use of speech acoustics to determine treatment planning
- Diagnostic Therapy planning based on audiological information

True or False

As in the past, children with cochlear implants do not hear the /s/ sound and therefore need a great deal of work to hear and say this and other high frequency sounds.

True or False

It is not necessary for speech pathologists to know a lot about speech acoustics and audiograms.

Multiple Choice

A formant is

A. Another way to say “format”
B. A bundle of sound energy
C. A small animal
D. All of the above

Sounds and Speech

- Speech does not happen independently of language
- The audiogram is an important tool for helping therapists determine a plan
- The audiogram does not provide the only necessary information
- Knowledge of basic speech acoustics and normal development is necessary to provide effective treatment
Why Know this Information

- Understanding the hearing mechanism and hearing loss is crucial to providing optimal therapeutic intervention.
- This knowledge is pertinent when explaining progress and goals to parents and families.
- Audiological knowledge is important when evaluating if amplification is appropriate for maximum success.

SPEECH ACOUSTICS: REALLY, IT'S FUN!

What is Speech Acoustics

- Scientific field that investigates the properties of speech
- Sounds measured objectively by instruments (i.e. spectrograph)
- Sounds judged subjectively
  - DURATION
  - INTENSITY
  - PITCH

From Eskridge, Henderson and Vernelson-Speech Babble Module

Speech Acoustics

Who needs working knowledge of speech acoustics?

- All hearing-related professionals
  - Audiologists
  - Speech Language Pathologists
  - Teachers of the Deaf

Speech Acoustics – Important Features

- Suprasegmentals
  - Prosody, tone, and rhythm of an utterance
- Segmentals
  - Properties of vowels & consonants
Speech Acoustics – Why do we need to know this?

- Helps us understand
  - how sounds are made and why particular speech patterns are produced when child mispronounces the sound
  - how sounds are affected by distance, background noise and reverberation

Audiograms

- Most audiograms cover the frequency range from 125 Hz-8000 Hz.
- All speech sounds have components within this range
- The Speech Banana
  - Represents where the acoustic energy for speech is concentrated
  - Frequencies at 500, 1000, and 2000 Hz are called the speech frequencies

Form-unt, Form-ant, For—What?

- FORMANTS—peaks of vocal resonance (Ling 1989)
- FORMANTS—a group of overtones (bundles of energy) corresponding to a resonating frequency of the air in the vocal tract.
  - Vowels are characterized by three formants, F1, F2, F3 (Ladefoged, 1993)
  - Harmonics: whole number multiples of the fundamental frequency

Suprasegmentals (DIP)

- Duration (time)
  - Length of sound and how it starts, changes, and finishes
  - Vowels are typically longer than consonants

Intensity (volume)—force or power of the sound
- Units are expressed in decibels
- Stress patterns

Pitch (frequency)
- Measured in Hz
- Number of waves created by the vibration from a sound which reach the ear each second
Let's Talk About Sounds

- In English -
  - 5 vowels
  - 21 consonants
  - 4 diphthongs

- In English —
  - How many vowel sounds?
  - How many consonant sounds?

Speech Acoustics Vowels and Diphthongs

- Formants - broad peaks of resonance that occur as the breath stream moves through the vocal tract
  - First two formants – F1 & F2 are the most important
    - Detection (F1) & Identification (F2)
  - Formants give vowels the acoustic characteristics that permit us to identify them as separate and distinct sounds

Fundamental Frequency

- Rate at which the vocal folds vibrate
- The rate varies depending on whether the speaker is a
  - Man 125 Hz
  - Woman 250 Hz
  - Child 325 Hz
- Why is this important information?

Speech Acoustics – Vowels and Diphthongs

- Vowels serve important functions:
  - Differentiate words that would otherwise sound alike
  - Help carry the prosody of a sentence and stress on a word
  - VOWELS ARE WHY WE HAVE ACCENTS!!!

Speech Acoustics – Vowels and Diphthongs

- Vowels
  - Duration- tense vowels have a longer duration than lax vowels (/i/ vs. /I/)
  - Intensity- back vowels have more intensity than front vowels
  - Frequency- determined by tongue height and place

Speech Acoustics

- What is a front, mid, back vowel?
- Referent vowels
  - Tongue high in the back and lips rounded: /u/
    - F1 ___ F2 ______
  - Tongue low in the middle and lips neutral: /a/
    - F1 ___ F2 ______
  - Tongue high in the front and the lips spread: /I/
    - F1 ___ F2 ______
  - All other vowels produced by adjusting tongue form these three referent vowels
Speech Acoustics – Vowels and Diphongs

Vowel Formants

- /u/ \( F_1 = 300 \text{ Hz} \), \( F_2 = 800 \text{ Hz} \)
- /o/ \( F_1 = 700 \text{ Hz} \), \( F_2 = 1,250 \text{ Hz} \)
- /i/ \( F_1 = 300 \text{ Hz} \), \( F_2 = 2,400 \text{ Hz} \)

Based on Dan Ling’s production p. 33 of Foundations of Spoken Language.

Vowels

Produced by changing the resonance of airflow through the oral cavity by altering the position of tongue and lips.

Tense/lax:
- Tongue Height
- Tongue Place
- Lip Rounding

Speech Acoustics – Vowels and Diphongs

Vowel Sentence:

“Who Would Know Ought (Of) Art Must Again Learn
And Then Take His Ease”

“hu wʊd no ɔt (of) art mʊst əɡən lɜrm ænd
ən tɛik hɪz ɪz”

More Vowels

Speech Acoustics - Consonants

- Release, stop, or interrupt vowels in running speech
- Classified by their manner, place, and voicing
Manner – how sounds are produced
- Plosives or stops
- Nasals
- Fricatives
- Liquids/laterals
- Semi-vowels
- Affricates

Place – where a sound is produced
- Bilabial
- Labio-dental
- Lingua-dental
- Alveolar
- Lingua-palatal
- Velar
- Glottal

Voicing
- Voiced sounds
- Voiceless sounds

What about formants for consonants????
- Vowels influence the production of adjacent consonants
- Co-articulation affects the frequency of consonants
- Therefore……….

It is impossible to chart the exact location of a consonant on a graph like an audiogram.
Each consonant would occupy a range rather than a location
However…

We feel it is important to know the possible ranges and
We are providing you with a handout that shows ranges of consonant formants.
/s/ example
Definitions

- **Threshold**: the softest level at which a child hears a sound 50% of the time
  - Thresholds are measured in decibels (dB)
  - Thresholds are tested at frequencies (Hz) between 125 Hz and 8000 Hz
- **Pure Tone Average (PTA)**: The average of hearing ability measured at 500, 1000, and 2000 Hz
  - Degree of hearing loss is based on PTA for each ear
  - PTA does not accurately estimate the effect of the hearing loss on speech recognition

**SPEECH ACOUSTICS FOR THERAPY**

**WHAT?!?! – IT’S RELEVANT?**

- **Definitions**
  - **INTENSITY**-perceived loudness (dB)-specified on the vertical axis of the audiogram
  - **FREQUENCY**-perceived pitch (Hz)- on horizontal axis of the audiogram
  - Acoustic building blocks of speech:
    - Frequency
    - Intensity
    - Time (duration)

- **DETECTION**-the ability to respond to presence or absence of sound
  - Requires aided hearing to F1 of the sound
  - “I hear that!”
  - Example: Raising hand or looking when sound is present
Looking at an audiogram, what might a therapy activity be for detection?
What if you did not have an audiogram to reference?

Practical Thinking

What might be an appropriate activity to assess/diagnostically evaluate discrimination?

Practical Applications

DISCRIMINATION-the ability to perceive similarities and differences among two or more speech stimuli
- Same or different
- Example: “Hop-hop-hop” versus “moo” or “elephant” versus “pig.”

Levels of Auditory Skill Development

IDENTIFICATION-the ability to reproduce a speech stimulus by naming or identifying through pointing to a picture or repeating the speech heard
- Requires aided hearing to F1 AND F2 of a particular sound
- Example: Imitating the Ling 6 sounds

What other activities might be used to evaluate/address this level of auditory skill development?

Practical Application

COMPREHENSION-the ability to understand the meaning of speech by answering questions, following instructions, paraphrasing, or participating in a conversation

Levels of Auditory Skill Development
Practical Application

What about comprehension? How is knowledge of audiological information helpful?

Speech Information Across the Frequencies (Ling, 1989)

- Important to be familiar with this information if child is not detecting or identifying a certain sound
- We can determine the problem
- We know where the child may require more work

250 Hz, plus or minus ½ Octave

- 1st formant of vowels /u/ and /i/
- Fundamental frequency of female and children’s voices
- Nasal murmur of /m/, /n/, /ng/
- Male voice harmonics
- Voicing cues
- Suprasegmental patterns (stress, rate, inflection, intonation

500 Hz, plus or minus ½ Octave

- 1st formants of most vowels
- Harmonics of all voices (male, female, child)
- Voicing cues
- Nasality cues
- Suprasegmentals
- Some plosive bursts associated with /b/ and /d/

1000 Hz, plus or minus ½ Octave

- 2nd formants of back and central vowels
- Important CV and VC transition information
- Nasality cues
- Suprasegmentals
- Some plosive bursts
- Cues for manner or articulation
THIS IS THE KEY FREQUENCY FOR INTELLIGIBILITY OF SPEECH!
- CV and VC transition information
- acoustic information for the liquids /r/ and /l/
- plosive bursts
- fricative turbulence

2000 Hz, plus or minus ½ Octave

4000 Hz, plus or minus ½ Octave
- Key frequency for /s/ and /z/ morpheme audibility
- /s/ and /z/ are critical for language learning because they signal plurals, idioms, 3rd person, copulas, etc.

Acoustic cues for PLACE of articulation
- 2nd and 3rd formant information for vowels
- liquids /r/ and /l/
- plosive bursts
- fricative turbulence

Multiple Choice
The Ling 6 sound test is
- A language test
- A speech/articulation task
- A listening check
- Auditory-Verbal Therapy

Multiple Choice
If a child is able to imitate all 6 of the Ling sounds, he/she is
- An excellent cochlear implant performer
- Really smart
- Able to hear and identify sounds in the speech spectrum
- Able to sing

True or False
The Ling 6 sound check should be the main focus of therapy to help the young child with the cochlear implant learn to listen and speak.

Ling 6 Sound Check

- ah
- m
- oo
- ee
- sh
- s
Ling 6 Sound Check

- Not a speech task
- Designed to determine if child is able to detect and/or identify the sounds at the speech frequencies
- Sounds representing the frequencies of speech
- Used to assess levels of auditory skill development

For the Therapist

- Is the child able to detect the Ling 6 sounds?
- What are the vowel and consonant errors or delays?
- What hearing factors may contribute to the child's abilities or lack of?

For the Therapist

- The audiogram is not the ultimate representation of a child's spoken language potential
- If the child is amplified appropriately, the audiogram can be used as a guide to determine goals
- If the child's skills do not match the audiogram, diagnostic therapy can help determine possible reasons why

For the Therapist

- Speech "babble" = an entire workshop
- Important to understand the progression and why it matters
- Important to note how and when a child progresses through stages of babble
- Necessary to note how this relates to a child's audiogram and/or device(s) used to access hearing
- What do you do if a child is unable to progress through appropriate stages of babble?

The Facts

- A cochlear implant is very different from a hearing aid
  - Sensorineural hearing loss is caused by deficient or absent hair cells in the inner ear
  - Hearing aids amplify sounds so they may be detected by damaged ears
  - Hearing aids rely on the responsiveness of the hair cells to stimulate the auditory nerve
  - Many of these hair cells are damaged or missing
The Facts

- Cochlear implants bypass damaged portions of the ear and directly stimulate the auditory nerve.
- Signals generated by the implant are sent by way of the auditory nerve to the brain, which recognizes the signals as sound.

The Facts

- Cochlear implants, coupled with intensive postimplantation therapy, can help young children to acquire speech, and social skills.
- Most children who receive implants are between two and six years old.
- Early implantation provides exposure to sounds that can be helpful during the critical period when children learn speech and language skills, prior to age 2.
- Critical period for speech and language development.
- Current FDA criteria is 12 months or older.

Source: www.nidcd.nih.gov/health/hearing

The Audiogram

- **Frequency**: Low Pitch to High Pitch
- **Loudness**: Soft to Loud

- **Age**: 12 months to 24 months - profound sensorineural hearing loss in both ears
- **Age**: 25 months or greater - severe to profound sensorineural hearing loss bilaterally
- Minimal benefit from appropriate hearing aids
- No medical or radiological contraindications
- High motivation and appropriate expectations from the family
- Hearing aid trial 3-6 months (*special consideration for post meningitis patients*)

(Summarized from Advanced Bionics 90K Package Insert)

Candidacy: Children

- Although newer candidacy guidelines have allowed for greater numbers of cochlear implants, and for younger children to receive cochlear implants...
From the Educator’s Perspective

- Minimal?
- Appropriate?
- Motivation?
- Progress?

These ambiguous terms often make determining candidacy difficult!

Determining Candidacy

- Educators are now faced with new ideas surrounding progress, achievement, and success with the cochlear implant.

Determining Candidacy

- The therapist or teacher may be more instrumental in suggesting a cochlear implant than even the audiologist or physician.

WHY?

Responsibilities of the Educator & Therapist

- Know expectations for progress
- Be familiar with recent research and case studies
- Knowledge of outcomes with the cochlear implant and hearing aids
- When in doubt about amplification, candidacy, hearing changes…

ASK FOR ASSISTANCE!!!
THINK ABOUT A REFERRAL.

EXAMPLE CASE 1

Age: 10 months

- Preschool Language Scale-4
  - Auditory Comprehension
    - Standard Score 67
    - Age Equivalent 5 months
  - Expressive Communication
    - Standard Score 54
    - Age Equivalent 1 month

Summary: Language delayed
Age: 10 months

- Rossetti Infant-Toddler Language Scale
- Language Comprehension- 3 months
- Language Expression- 3 months
- Play- 9 months

Aided Soundfield Audiogram Age: 11 mos

Referring audiologist unwilling to refit with other hearing aids.

Plan

- Audiologically NOT a candidate
- Plan: Enroll child in weekly Auditory-Verbal Therapy to closely monitor spoken language progress
- Excellent family follow-through

Auditory-Verbal Therapy

- “Learning to Listen” sounds introduced (Estabrooks, 2006)
- Teaching conditioned play response to sounds and to Ling 6 sounds
- Teaching response to environmental sounds of varying intensities
- Evaluating babble and imitations during each session

Results of Auditory-Verbal Therapy

18 Sessions (1 hour each)

- Detection of all 6 Ling sounds using a conditioned response
- Imitates “oo” for “ee”
  - Does not have access to 2nd formant of /i/.
  - Imitates durational quality of Learning to Listen sounds (hop-hop-hop, quack-quack, ahhhh, woof-woof)
- Imitation of words significantly improved with new hearing aids, but feedback is a chronic problem (hearing aids turned down as a result)
- Spontaneously says: out, open, bye-bye, hi, hella, up, no, mama, help, moo, hop-hop, yeah
Age 16 months

- Due to feedback, hearing aids were turned down and aided detection decreased
- Child stopped responding to /s/ and /sh/ with Ling sound check
- Child did not learn any new words for 2 months
- Still unable to imitate /i/
  - Poor access to 2nd formant of the sound
  - Consistently substituted /a/ and /u/ for /i/

Summary

- Child deemed an implant candidate, in spite of the audiogram
- Without intense therapy this would not have been identified
  - Use of speech acoustics
  - Use of normal developmental milestones
- In the past this child would have been “doing well” with her hearing aids
- “Doing well” has new meaning now with new technology

Case Study
Borderline CI Candidate

Child: Silas

- C.A. 3yrs 10 months
- H.A. 3yrs 7 months
- C.I.A 2yrs 1 month
- A.V.A. 2yrs 7 months

History

- Failed newborn hearing screening
- Failed ABR at 1 month of age: suspected profound hearing loss. (referred to pediatric audiologist)
- Failed ABR at 2 months of age: confirmed severe-to-profound Sensorineural hearing loss
- Etiology unknown (a few birth complications)
- Hearing aids fit at 3 months of age:
  - Phonak Power Maxx 411 BTE
- Strong family unit, stay home mom previous school teacher, father works out of the home w flexible hours.
Speech Language Results
Age: 10 months

- Preschool Language Scale-4
  - Auditory Comprehension:
    - Standard Score 76
    - Age Equivalent 7 months
  - Expressive Communication:
    - Standard Score 98
    - Age Equivalent 9 months
  - Total Communication:
    - Standard Score 86
    - Age Equivalent 8 months

Summary: Borderline Language Delay

Speech/Language Results
Age: 16 months

- Rossetti Infant-Toddler Language Scale
  - Language Comprehension- 9-12 months
  - Language Expression- 6-9 months
  - Play- 15-18 months
  - Gesture- 12-15 months
  - Pragmatics-12-15 months
  - Interaction- 15-18 months

Therapy in Early Intervention

- Hearing Aides are accessing speech
- Aided audiogram looks promising
- Child is in weekly Auditory-Oral therapy to assess spoken language progress
- Excellent attendance
- Excellent follow through and “homework”
- Family consistently unsure of CI due to:
  - audiological recommendations
  - access to sound
  - possible loss of residual hearing

Progress

Auditory-Oral Therapy
- Learning to Listen Sounds
- Ling 6 sounds using conditioned play
- Environmental sounds of varying intensities
- Documenting babble and all imitations/reactions to sounds and therapy.
- Songs and Nursery Rhymes
- Reading and Literacy expectations.

During EI while bi-laterally aided....
- Silas was very consistent with auditory detection at 3-6 feet
  - He would lose this at 12 feet but this is typical of a new listener.
  - /s/ and /sh/ proving the most problematic during ling sounds.
- Silas was making consistent progress but not appropriate progress based on peers.
  - Good sound detection
  - Auditory comprehension of common phrases and nursery rhymes w motions were consistent
  - He would answer questions with gestures or head nod.
Silas would detect sound but had trouble discriminating it.
Silas made similar sounds for several of the LTLS. He grouped them by suprasegmentals.
- pulsed sounds sounded the same (quack quack and beep beep)
- long sounds sounded similar as well
  - He could pick 2 critical elements if very diff but he would not get them correct if they were similar (step 3 word level on ALQ)
  - He made a lot of “common mistakes” with speech but could not get the appropriate discrimination through hearing to correct this.
    - Sub m for n
    - Sub f for k (could be considered age appropriate at that time)
    - Silas would correctly imitate vowels and alternated vowels inconsistently during speech babble producing /ue/ for /ee/ and /ee/ or /ah/ for /i/
    - Silas would not imitate consonants varying in manner (not all age appropriate consonants were mastered).
    - Silas was using age appropriate vowels with the exception of /i/ and /ee/

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### Progress
- Silas was using age appropriate vowels with the exception of /i/ and /ee/

### Yes or No
Is this child making appropriate progress at 10-16 months of age when compared to peers with normal hearing?

### Summary
- Knowledge of audiological procedures and tests is important for therapists and teachers working with families of children who have hearing loss
- Basic speech acoustics application is essential to provide comprehensive therapy for children with hearing loss
- Understanding of changing cochlear implant candidacy guidelines is crucial
  - When in doubt, ask questions!
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