



# Cognitive Issues with Hearing Aids or *Why the Brain Matters*

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# Outline

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- ◆ Background: Hearing Loss and Hearing Aids
- ◆ Cognitive Ability
  - ⇒ Age and hearing loss
  - ⇒ Visual Correlates
- ◆ Measures of Attention and Effort
  - ⇒ UC Berkeley Project
- ◆ Auditory Scene Analysis

# Outline

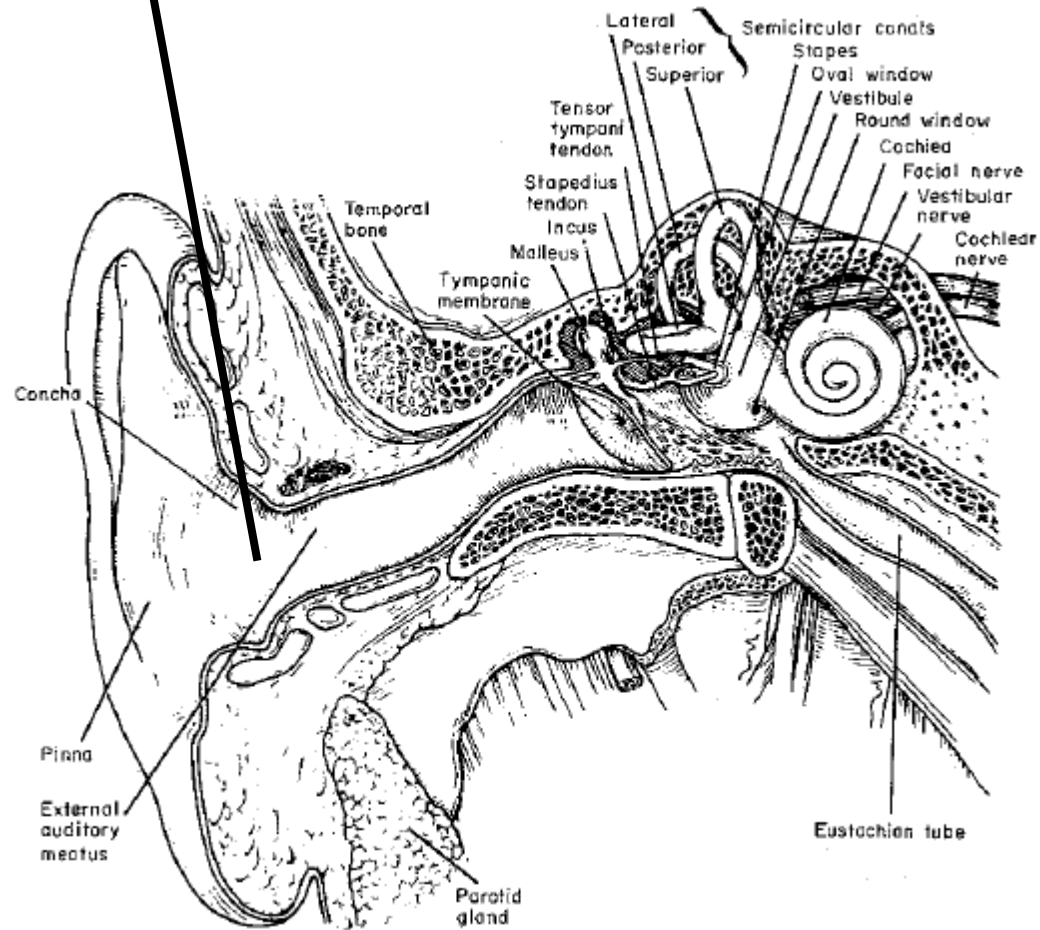
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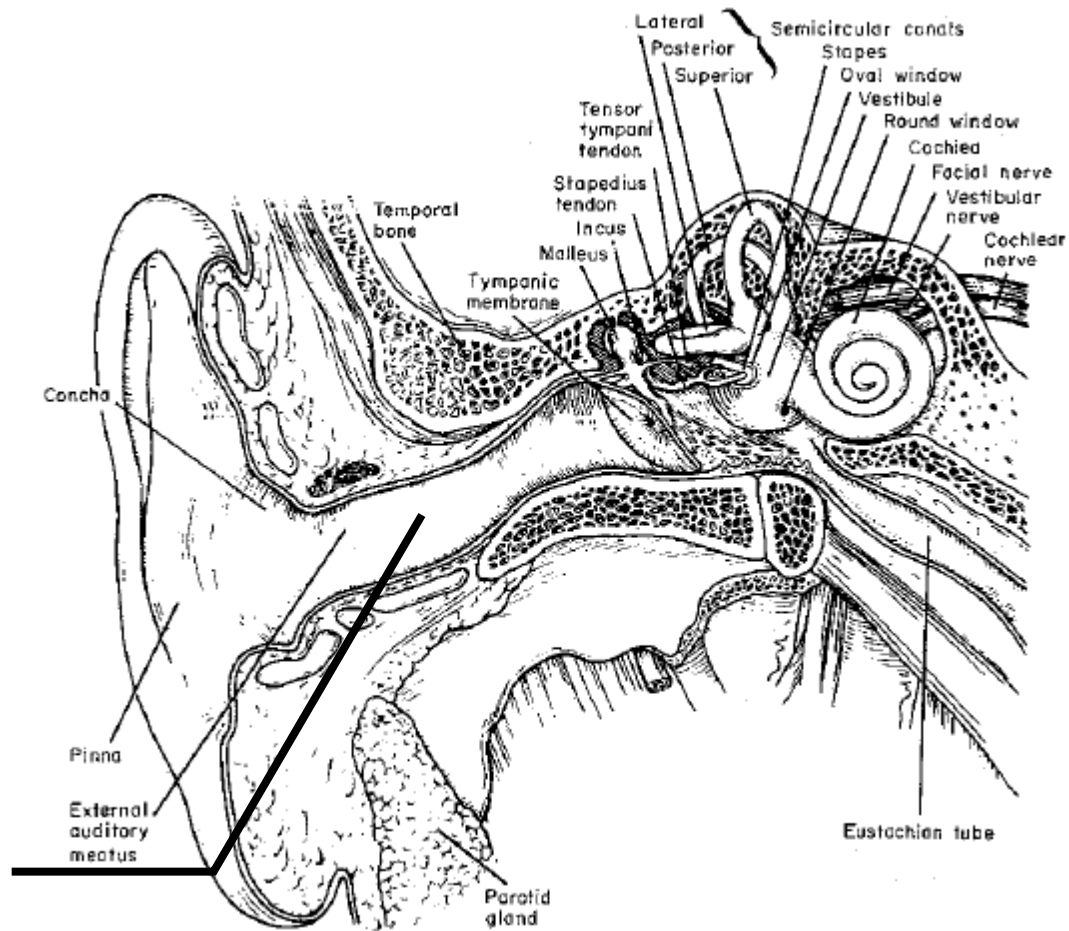
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How do *companies* think about  
Hearing impairment?

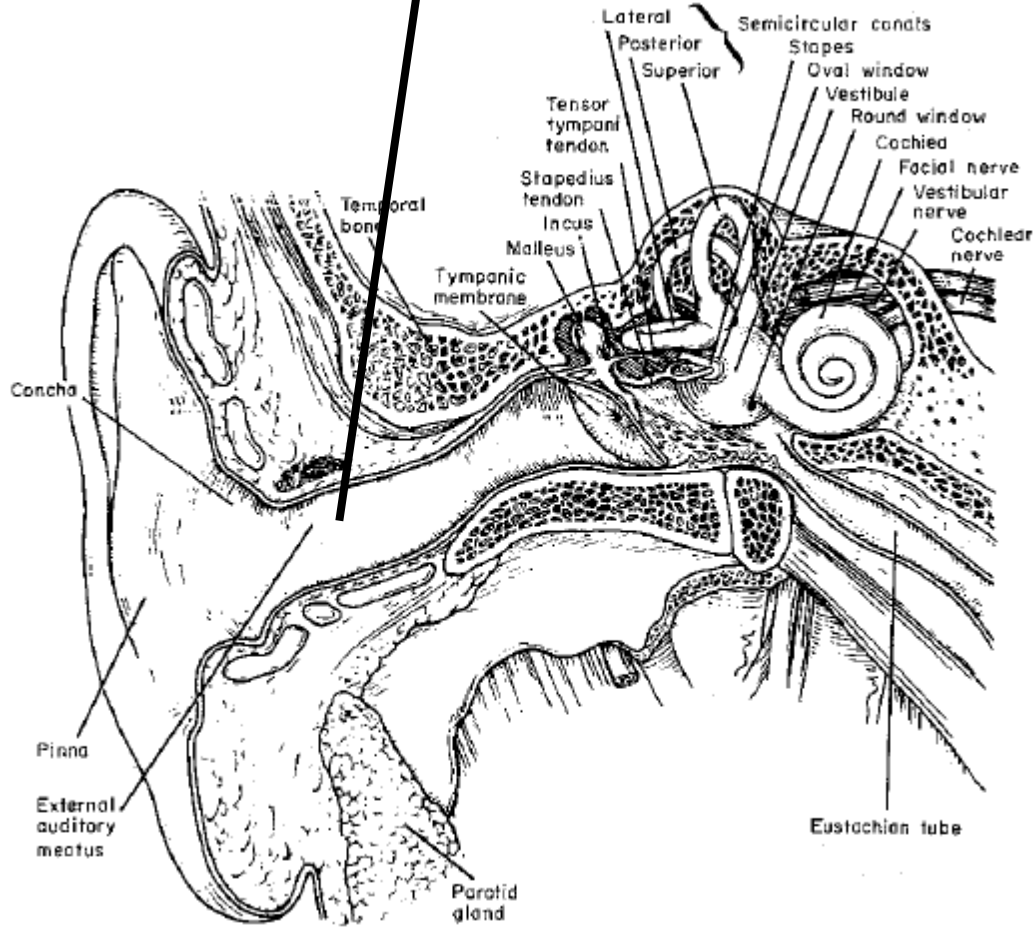
Improved  
speech signal:  
Directionality,  
Noise Reduction

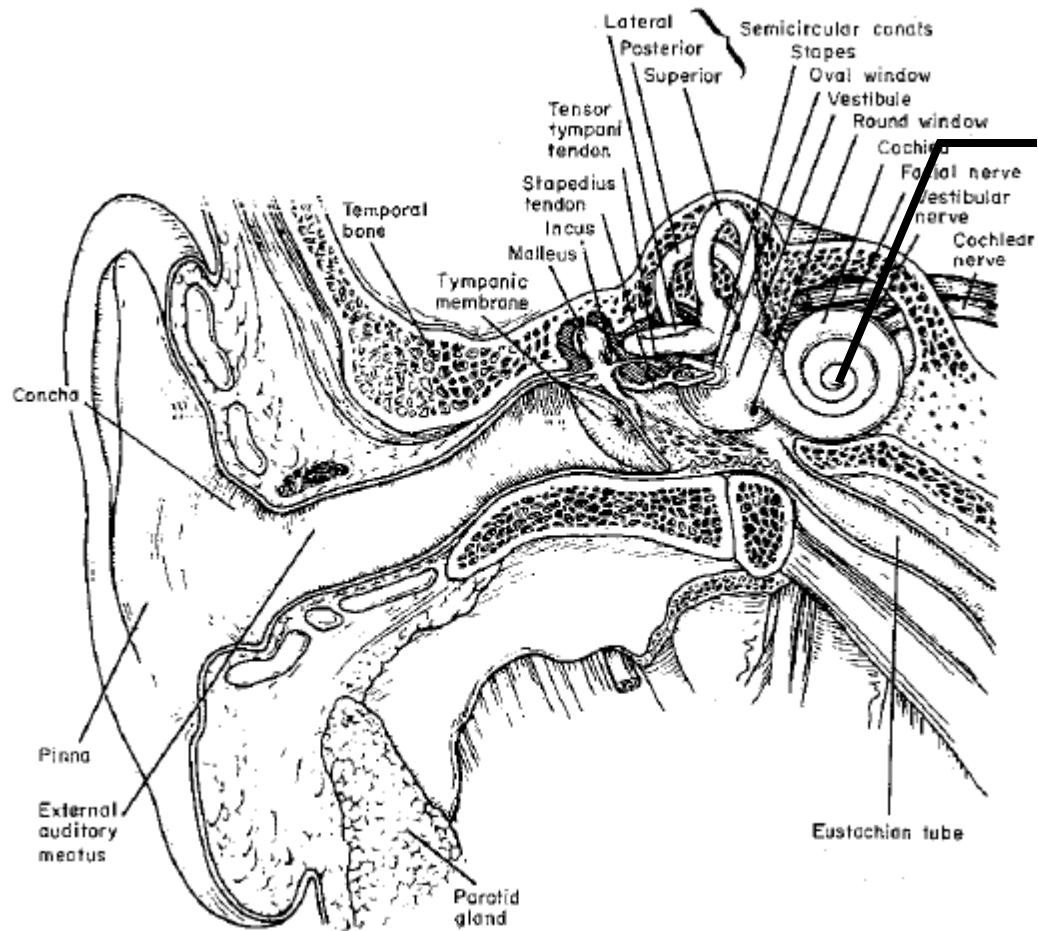




Acoustics:  
 Feedback,  
 CORFIG, receiver  
 coupling

Fit:  
Feedback,  
comfort





Sensorineural  
damage:  
Compression

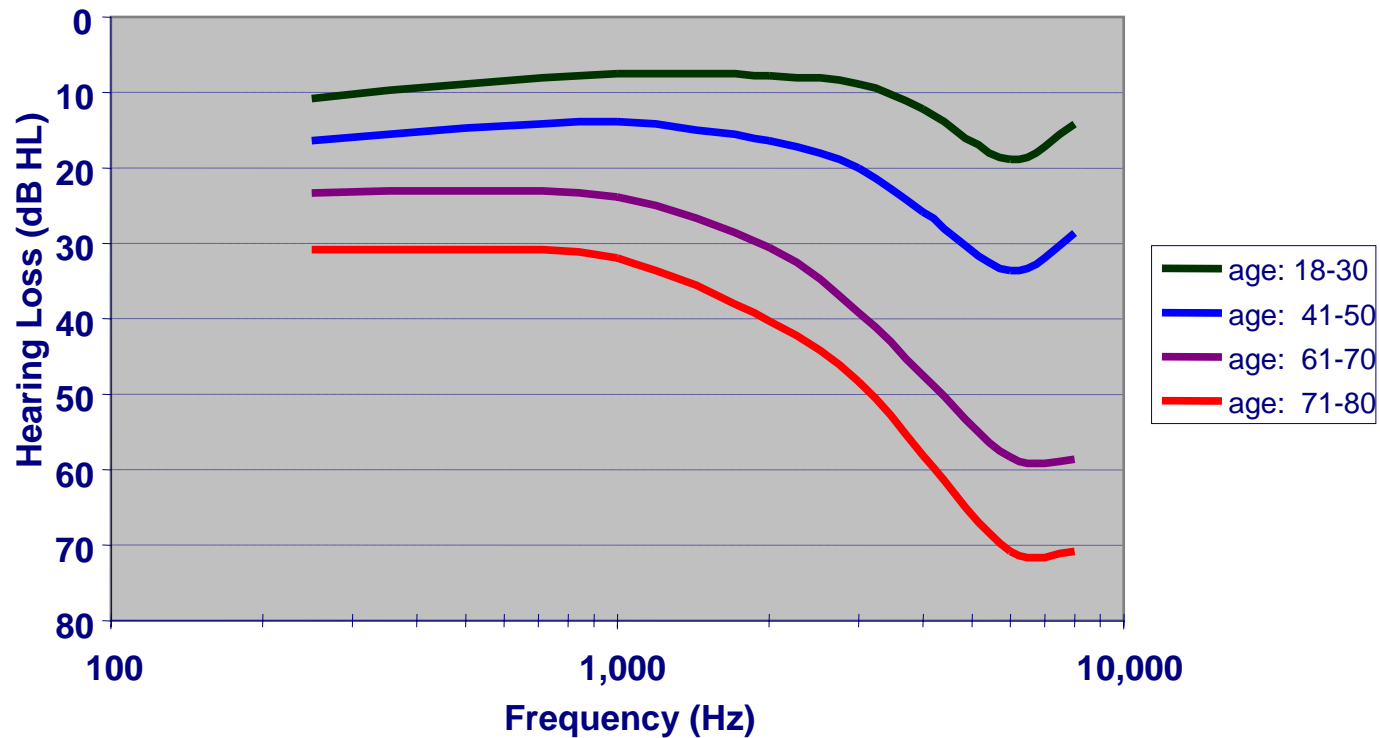
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How do *you* think about  
Hearing impairment?

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♦ Main characteristics of hearing impairment

⇒ Elevated thresholds

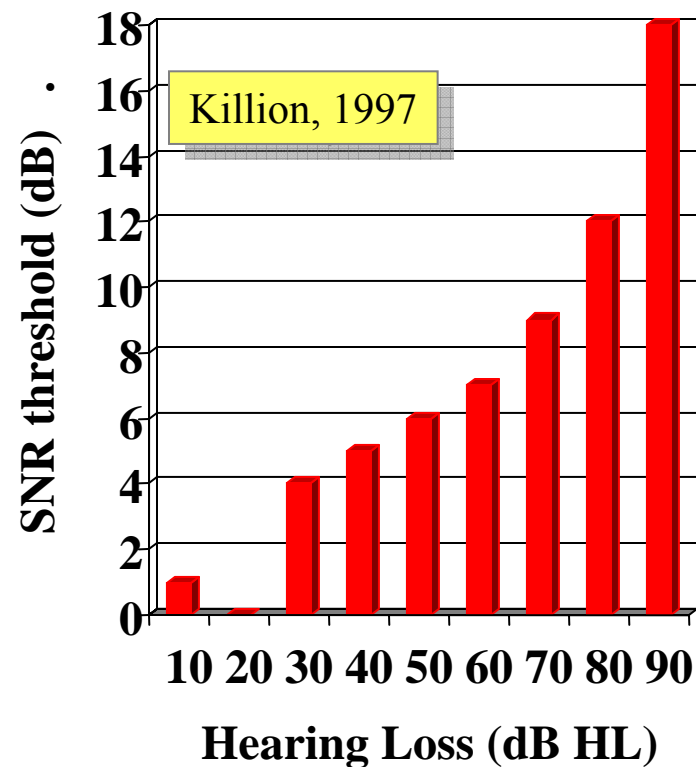


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- ◆ Main characteristics of hearing impairment

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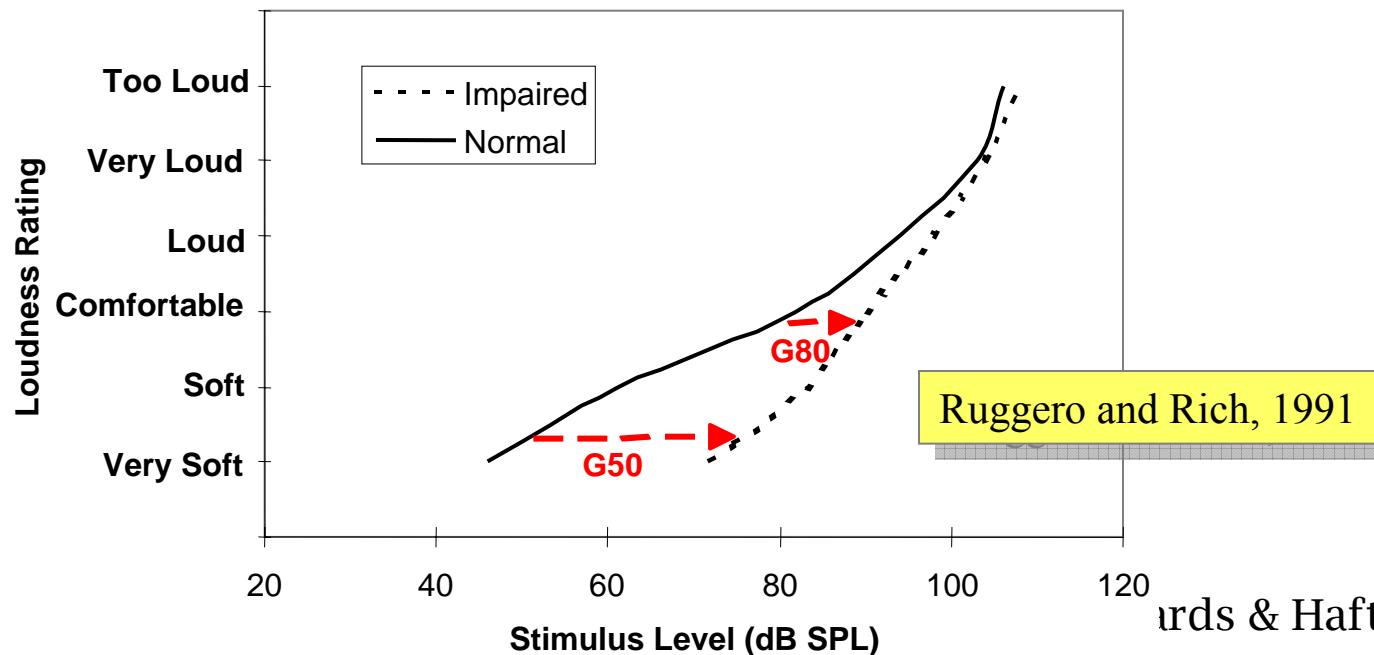
- ⇒ Poor ability to understand speech in noise

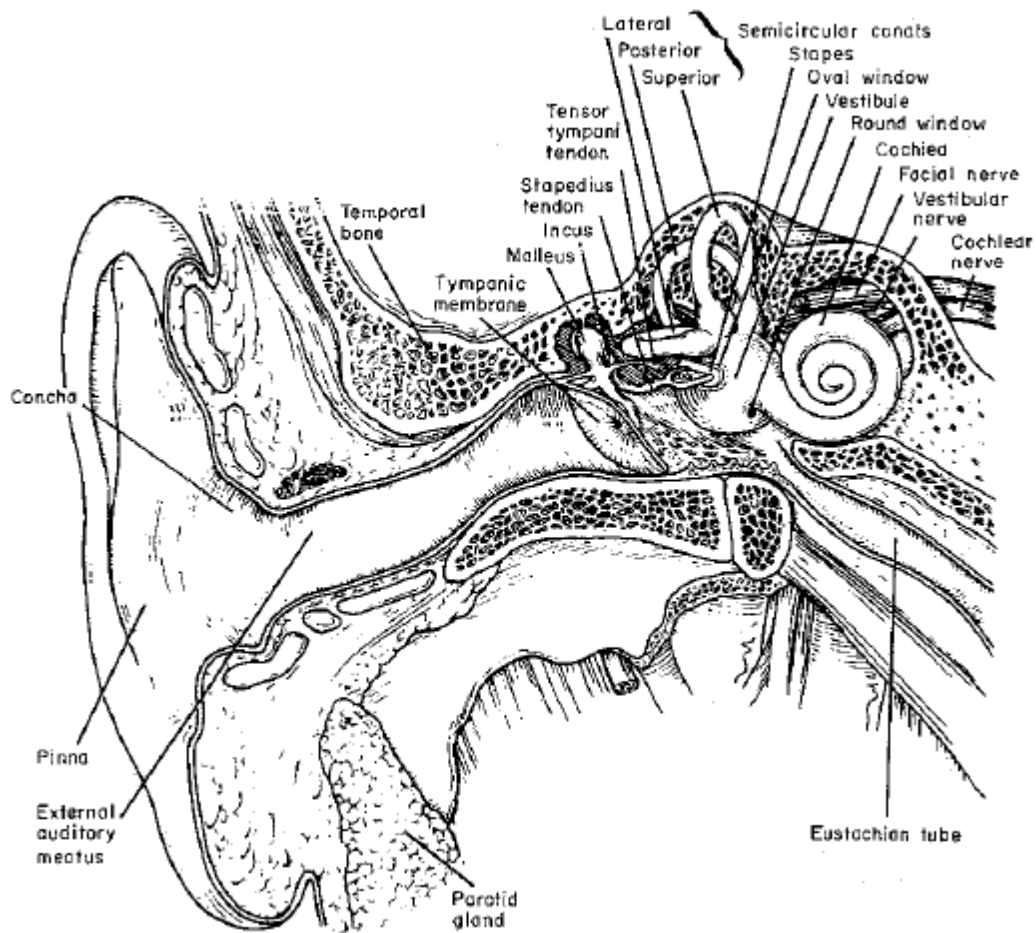


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◆ Main characteristics of hearing impairment

- ⇒ Elevated thresholds
- ⇒ Poor ability to understand speech in noise
- ⇒ Abnormal growth of loudness





# Hearing Aid Features

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- ◆ Current digital features include:
  - ⇒ Multiband compression
  - ⇒ Feedback cancellation
  - ⇒ Noise reduction
  - ⇒ Directionality
  - ⇒ Adaptive capabilities
  - ⇒ Wireless connectivity

# Hearing Aid Validation

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- ◆ Current assessments of hearing aid performance (Arlinger, 1998):
  - ⇒ electroacoustic verification of hearing aid performance on real ear
  - ⇒ speech reception in noise
  - ⇒ patient-perceived hearing aid benefit

# Hearing Aid Validation

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  - ⇒ speech reception in noise
  - ⇒ patient-perceived hearing aid benefit
- ◆ Not sensitive enough to differentiate between compressors with current technology

Subjective  $\neq$  Objective

# Disability from Impairment

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- ◆ Gatehouse characterizes hearing disability as being embodied by poorer:
  - ⇒ Speech communication
  - ⇒ Access to environmental and other non-speech sounds
  - ⇒ Spatial hearing
  - ⇒ Selective attention

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# Definition

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- ◆ Cognitive:
  - ⇒ Relating to thinking, reasoning, intellectual activity
- ◆ So what is cognitive hearing?
  - ⇒ Understanding what you hear using complex brain activity



# Cognitive Issues

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- ◆ Hearing impaired suffer from listening fatigue

- *Loss of environmental awareness leads to stress and anxiety.*
- *Listening is not passive.*
- *Relaxing is hard to do.*

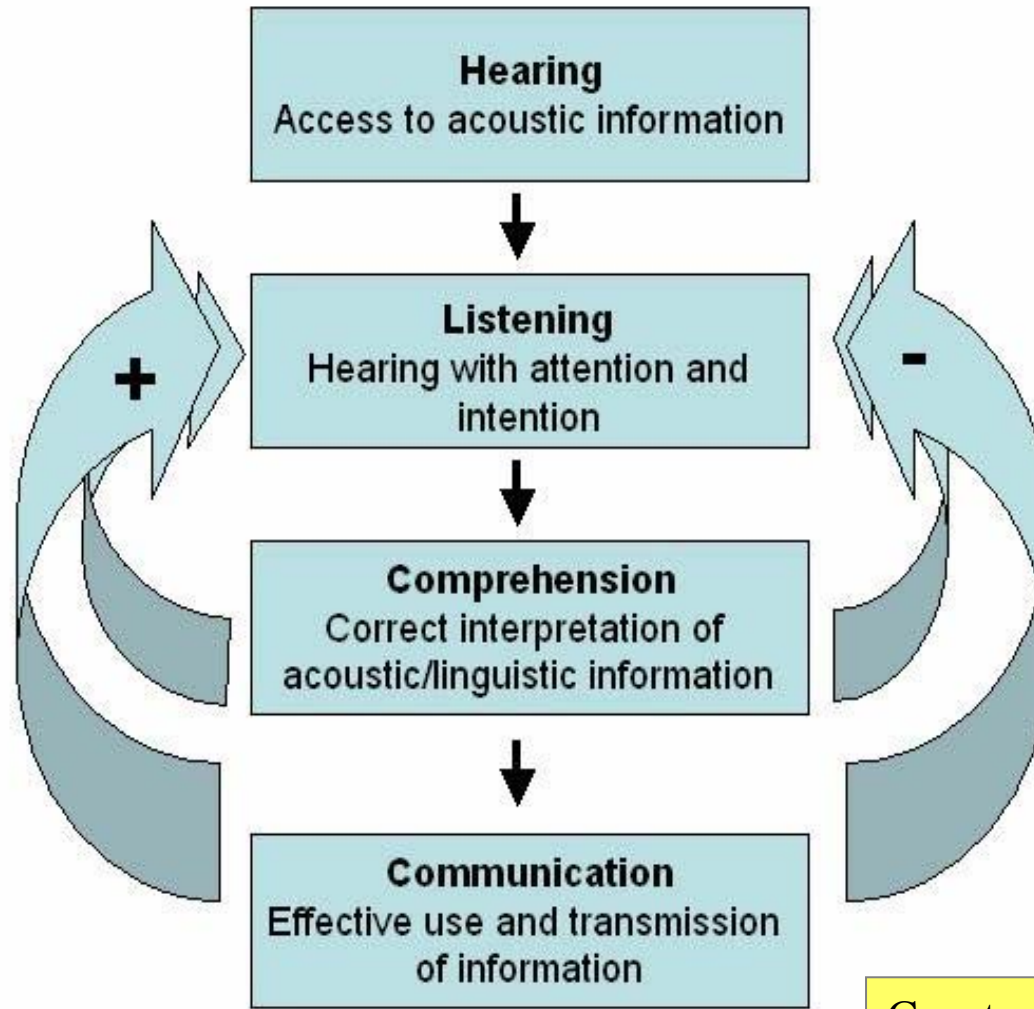
Portis, 2005

- ◆ Increased effort in listening to speech in noise could affect rehearsal, encoding and deep processing
  - ⇒ Working memory (Pichora-Fuller et al., 1995) and digit span (Cleary, 1997) tasks poorer with impairment

Cognitive processing  
affects how we hear

# Elements of Communication

(Kiessling, et al, 2003; Sweetow and Henderson-Sabes, 2004)



Courtesy of Robert Sweetow

Can patients adapt over time  
to hear better with their new hearing aids?

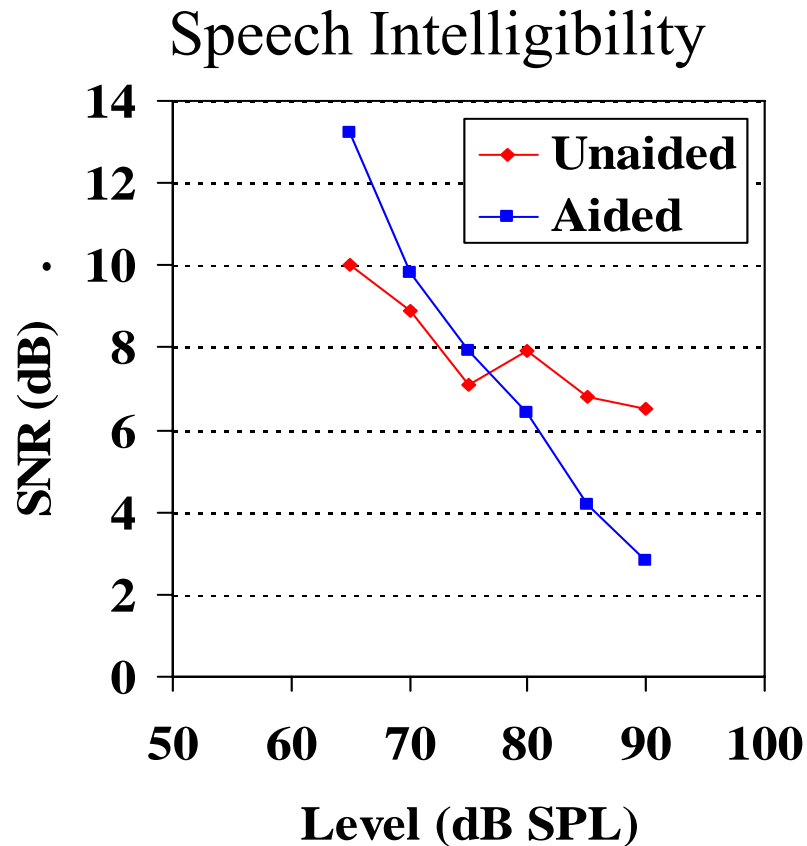
# Cognitive Issues and Hearing Aids

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- ◆ Previous experience affects quality scales
  - ⇒ New users prefer milder gain
  - ⇒ Linear wearers prefer excess gain
  - ⇒ Habituates over time

# Acclimatization with Monaural Hearing Aid Wearers

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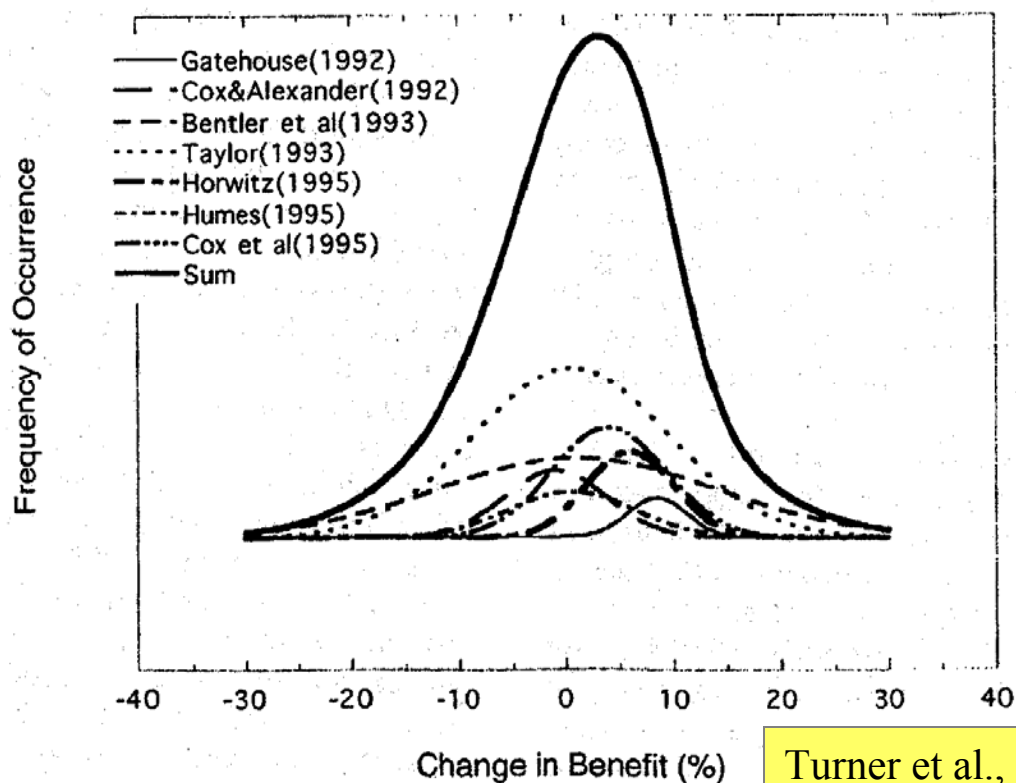


(Gatehouse, 1989)

# Changes to Speech Recognition

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- ◆ In general, improvements to speech understanding are very small



Turner et al., 1996

Edwards & Hafter, AAA 2006

Can patients *be trained*  
to hear better with their new hearing aids?

# Cognitive Issues and Hearing Aids

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- ◆ Previous experience affects quality scales
  - ⇒ New users prefer milder gain
  - ⇒ Linear wearers prefer excess gain
  - ⇒ Habituates over time
- ◆ Cognitive ability interacts with ability to use advanced processing (Gatehouse et al., 2003)
  - ⇒ Greater cog. ability → better use of nonlinear processing

# What is Listening and Communication Enhancement (LACE)?

- ♦ An interactive, adaptive, computerized training program designed to strengthen listening and cognitive skills

Courtesy of Robert Sweetow

# LACE Objectives

- ◆ Get the patient involved
- ◆ Make the patient recognize difference between hearing and listening
- ◆ Build patient confidence
- ◆ Provide the patient with communication strategies
- ◆ Reduce RFC
- ◆ Reduce unnecessary patient visits

Courtesy of Robert Sweetow

# LACE

## (Listening and Auditory Communication Enhancement)

- ◆ Cognitive
  - ⇒ Auditory Working Memory
  - ⇒ Speed of Processing
- ◆ Degraded and competing speech
  - ⇒ Background noise
  - ⇒ Compressed speech
  - ⇒ Competing speaker
- ◆ Context / Linguistics
- ◆ Interactive communication

*All of the above are designed to enhance listening and communication skills and improve confidence levels*

Courtesy of Robert Sweetow

# Cognitive Issues and Hearing Aids

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- ◆ Previous experience affects quality scales
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- ◆ Cognitive ability interacts with ability to use advanced processing (Gatehouse et al., 2003)
  - ⇒ Greater cog. ability → better use of nonlinear processing
- ◆ Hearing aid users are abnormally bothered by background sounds
  - ⇒ Fans, refrigerators, air conditioners



Edwards & Hafter, AAA 2006

- 
- ◆ We are hardwired to pay attention to change
    - ⇒ “change detectors”
  - ◆ We ignore unchanging sounds
    - ⇒ Unconsciously decide they are not worth our attention
  - ◆ Inability to notice gradual change
    - ⇒ *Switch to Inattentional Blindness demo*

# Change Blindness

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- ◆ Failure to identify changes/information when it occurs along with other changes
  - ⇒ *Next Slide is Flicker Demo (lunch)*

# Implications for Hearing Aids

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- ◆ Processing should not introduce artificial changes to sound
  - ⇒ Sounds should be “natural”
    - Preserve ability to ignore unattended sounds
    - Preserve ability to detect/identify changes to sounds
      - Ability to hear waiter when listening to spouse at table

# Aided Perception

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- ◆ We know little about cognitive ability while wearing a hearing aid
- ◆ Would like to be able to measure cognitive ability with different hearing aids

# Outline

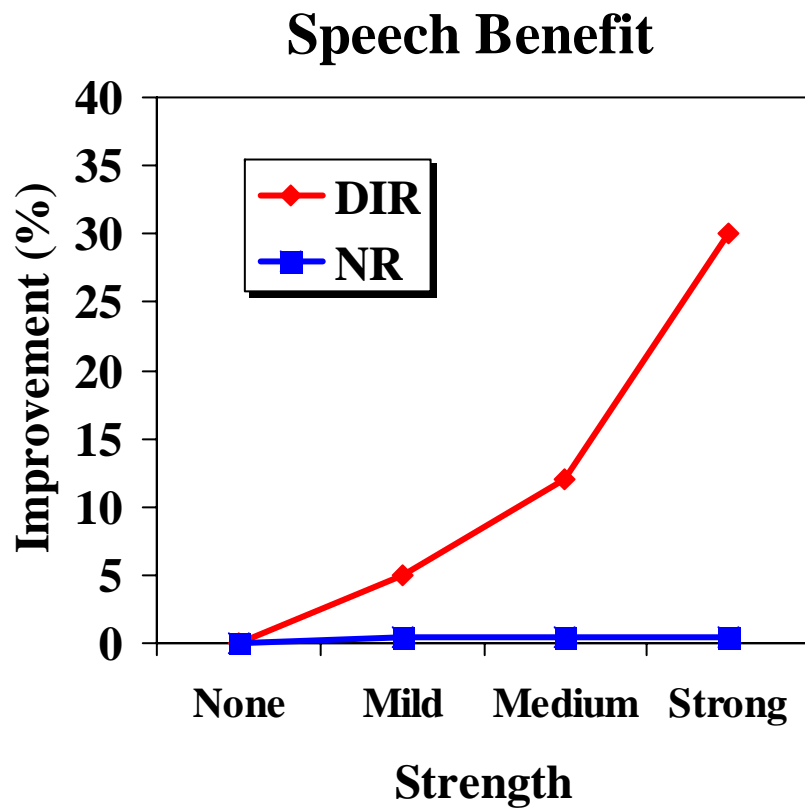
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  - ⇒ UC Berkeley Project
- ◆ Auditory Scene Analysis

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- ◆ *Switch to Berkeley Presentation*

# Measured Patient Benefit

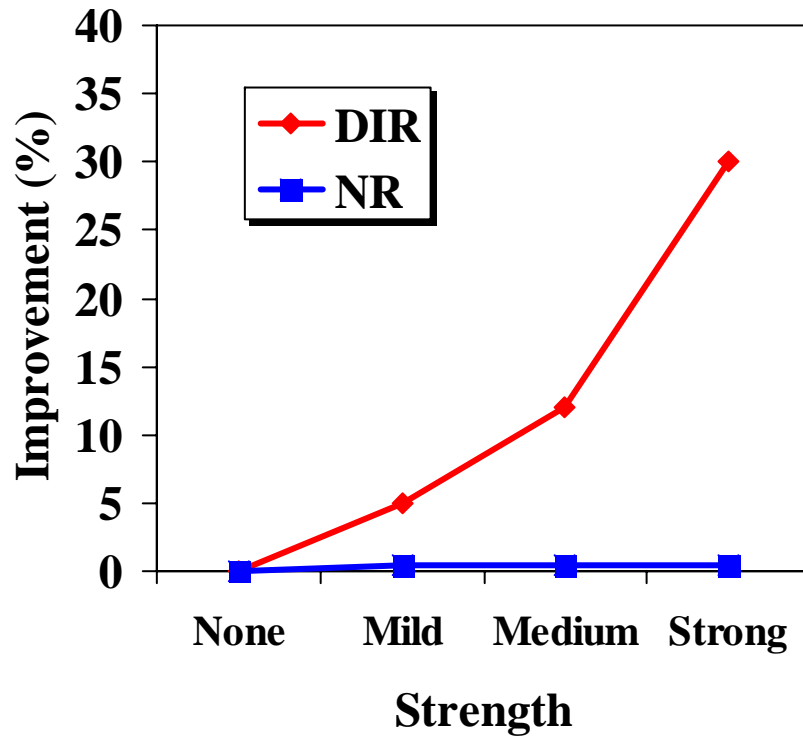
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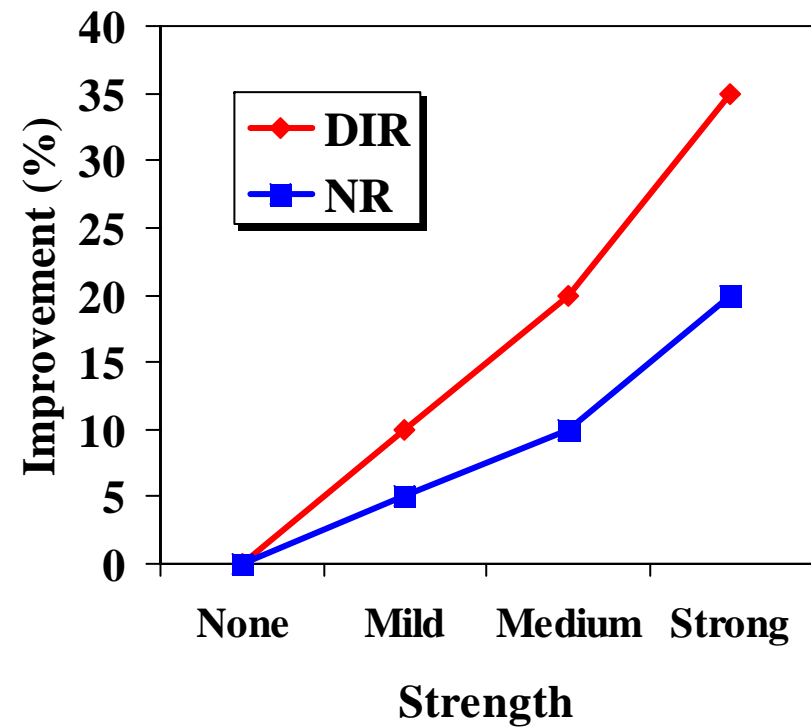
# Measured Patient Benefit

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## Speech Benefit



## Cognitive Benefit



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- ◆ **Auditory Scene Analysis**

# Auditory Scene Analysis

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- ◆ Preserving Auditory Scene Analysis (ASA) ability should be an important goal
- ◆ What is ASA?
  - ⇒ “the organization of sound scenes according to their inferred sources” (Bregman, 1990)
  - ⇒ Ability to know your environment and identify objects through sound (Me, Now)

# Auditory Scene Analysis

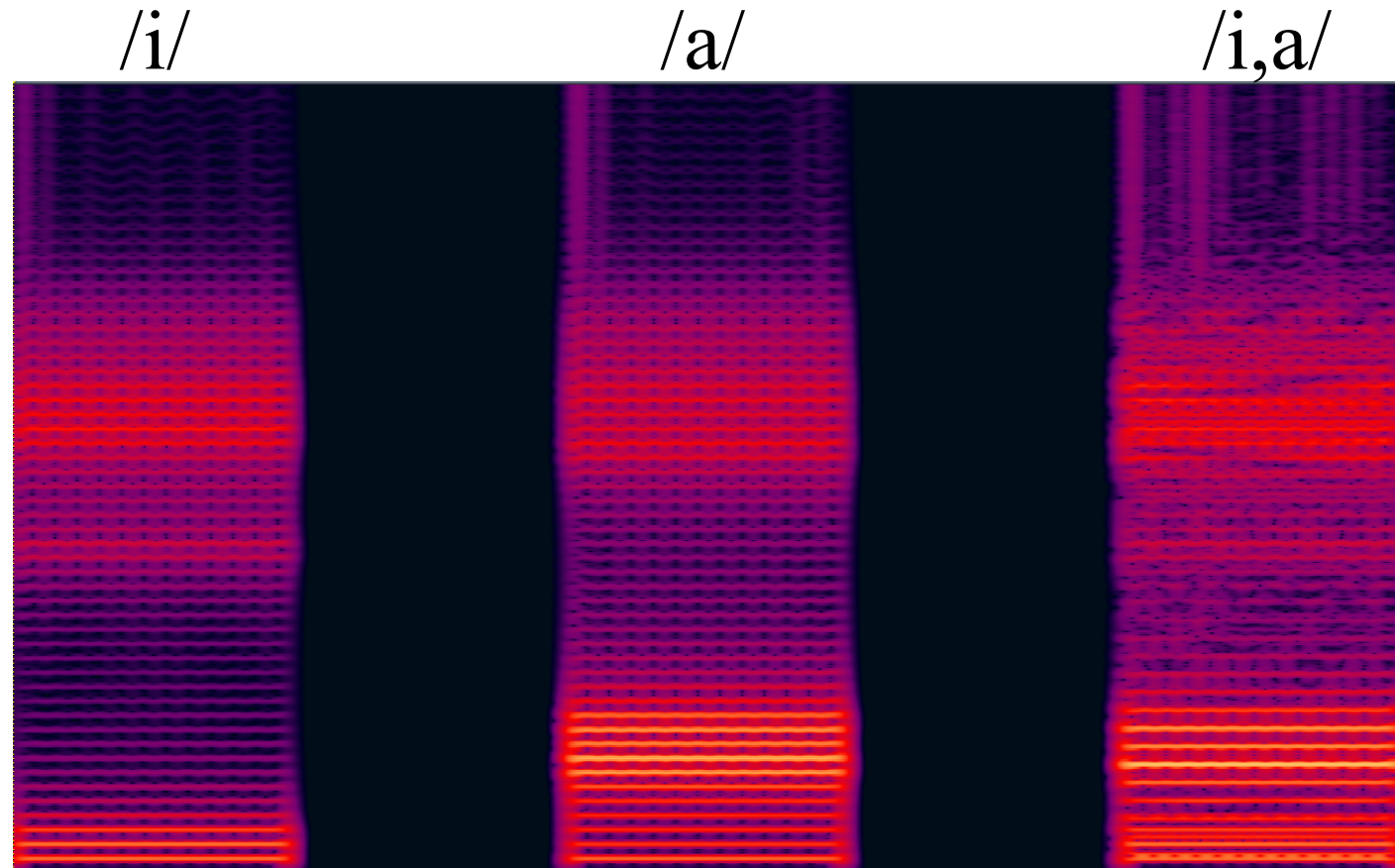
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- ◆ Humans are adept at separating sounds into their sources
- ◆ Need to ensure that hearing aid processing does not impair ability to separate sounds

# Vowel Segregation

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- ♦ Humans can hear two concurrent vowels when fundamental frequencies are different enough



# Vowel Segregation

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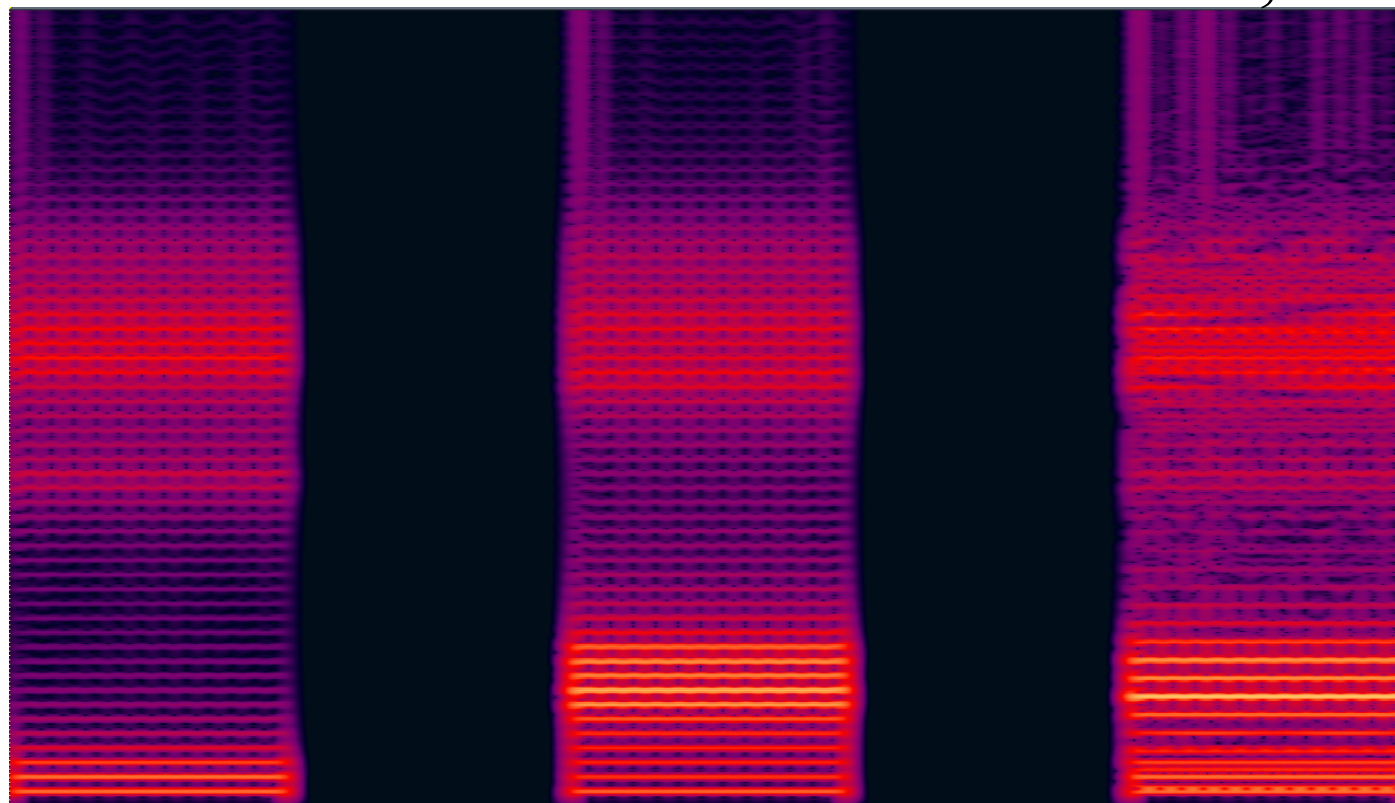
/i/

/a/

/i,a/

i: f0=100 Hz

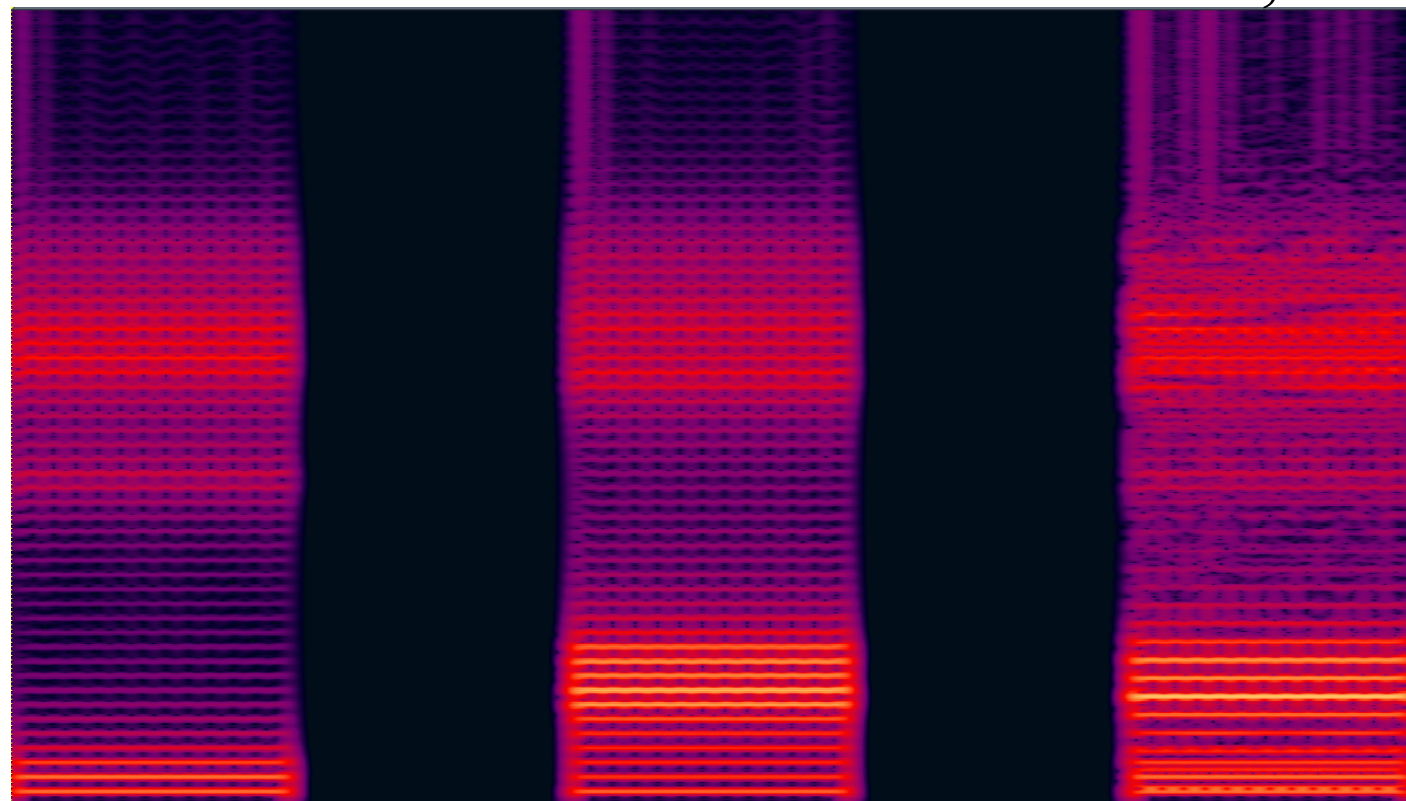
a: f0=100 Hz



# Vowel Segregation

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- ♦ Humans can hear two concurrent vowels when fundamental frequencies are different enough



i: f0=100 Hz

a: f0=126 Hz

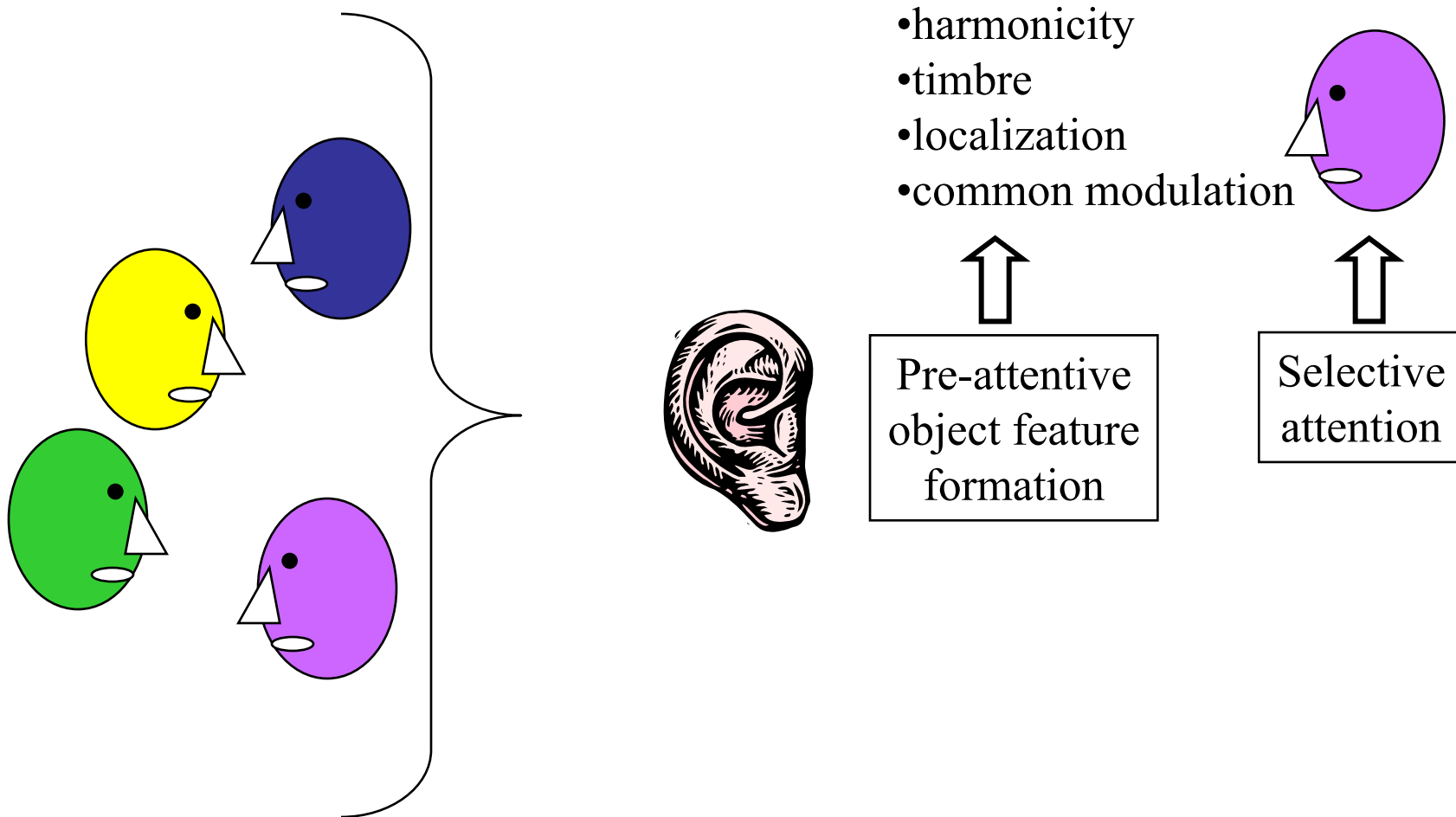
# ASA Cues

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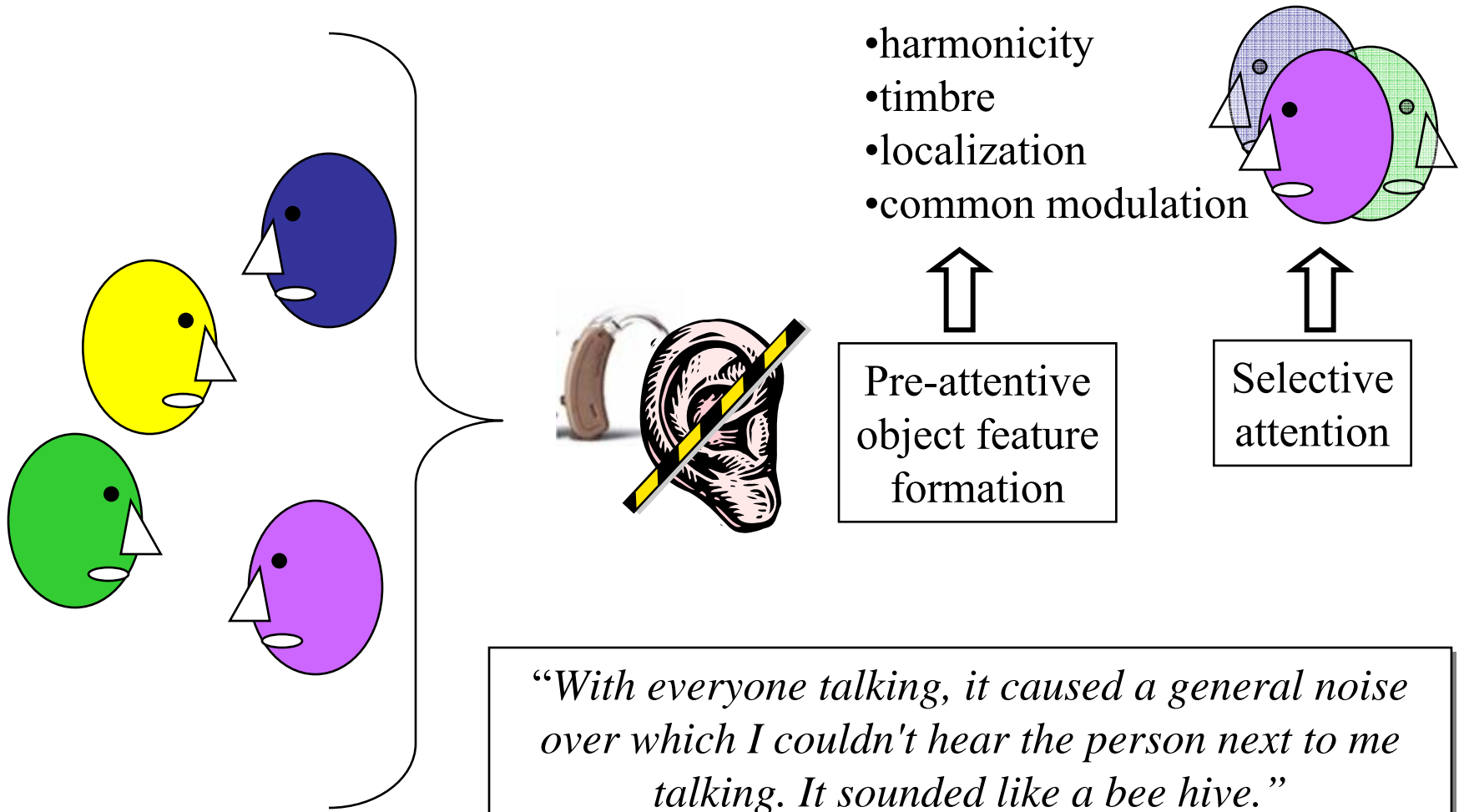
- ◆ Harmonicity
- ◆ Common onsets/offsets
- ◆ Common amplitude modulations
- ◆ Common frequency modulations
- ◆ Spatial location
- ◆ Timbre

# Cocktail Party

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# Cocktail Party



*“With everyone talking, it caused a general noise over which I couldn't hear the person next to me talking. It sounded like a bee hive.”*

ABC News, 4/14/05

# Continuity Illusion

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Bregman, 1993

# Continuity Illusion

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Bregman, 1993

# ASA Example 2: Picket Fence Speech

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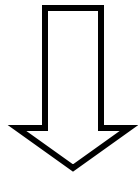
# What does this all mean?

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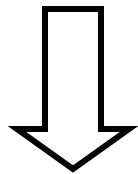
- ◆ The brain uses many different cues to focus attention on sounds
  - ⇒ Proper organization allows listener to focus attention on select sounds
  - ⇒ Hearing aids should preserve those cues
  - ⇒ Ongoing research will identify how to ensure that maximal information is allowed for cognitive processing

## Current Situation

Imperfect auditory cues



Imperfect features



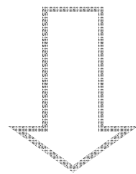
Difficulty for higher-  
level functioning

## Current Situation

Imperfect auditory cues



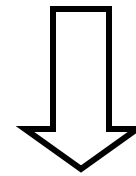
Imperfect features



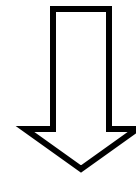
Difficulty for higher-level functioning

## Desired Situation

Normalize auditory cues



Preserve auditory features



Preserve higher-level ability

Thank you

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