Harnessing the Brain to Improve Communication in Older Adults

SPOTLIGHT ON HEARING IN NOISE

Nina Kraus

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www.brainvolts.northwestern.edu

ROADMAP

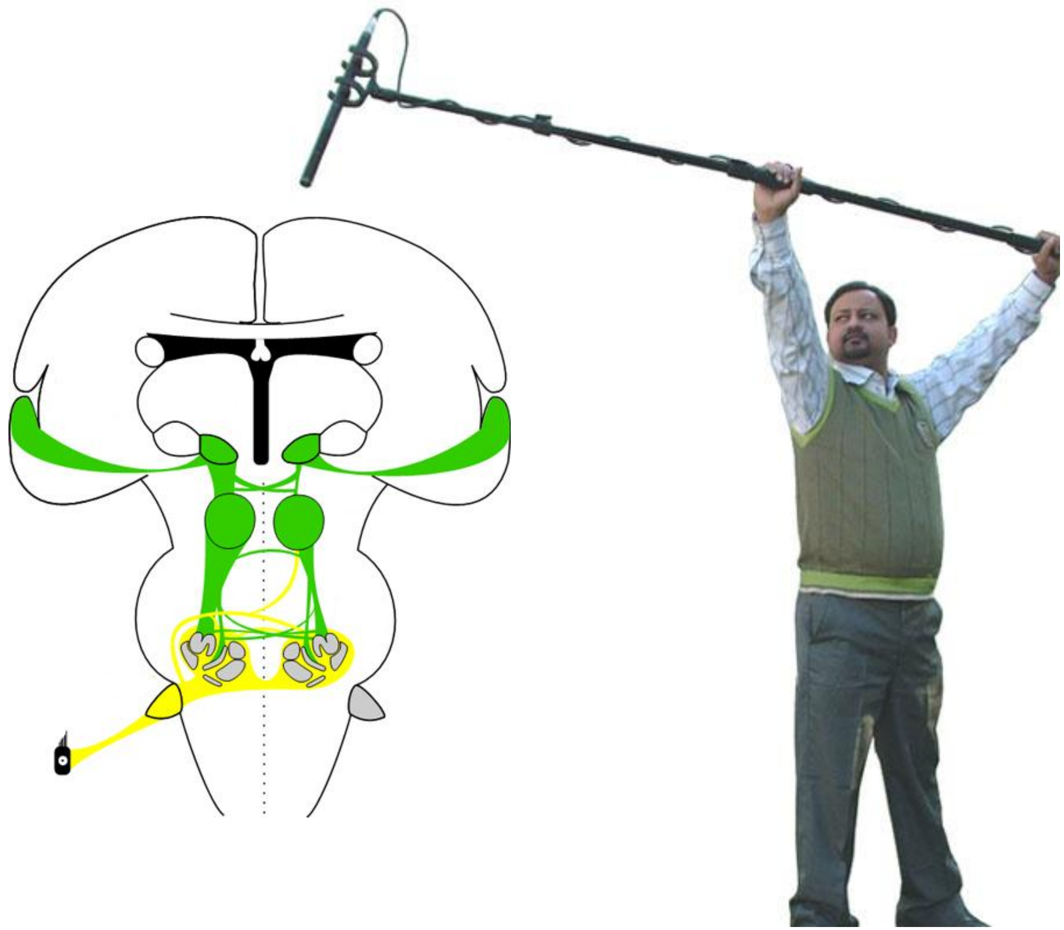
Our biological approach

Biological effects of aging

Training
- lifelong music
- software-based

Outcomes - hearing in noise, biological

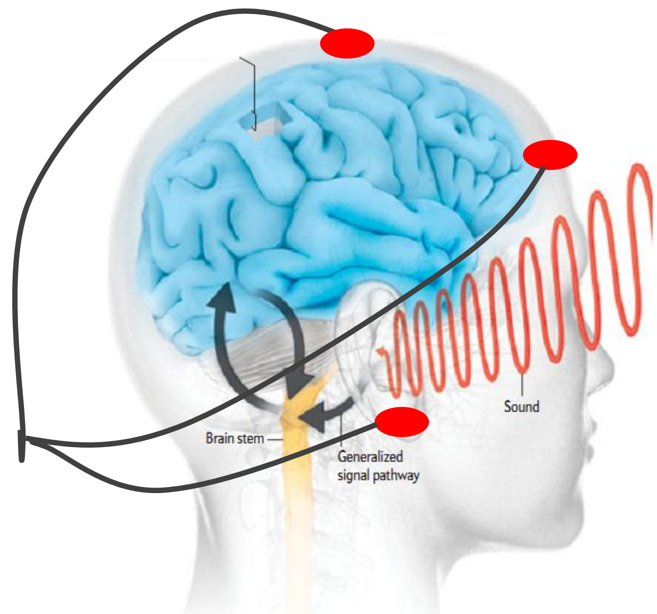
HOW TO ACCESS BIOLOGY IN HUMANS?



a biological probe of HEARING cABR

cABR

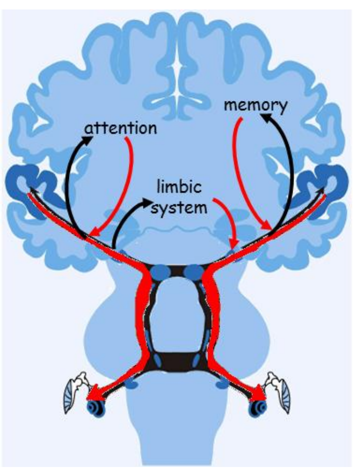
auditory brainstem response to complex sounds

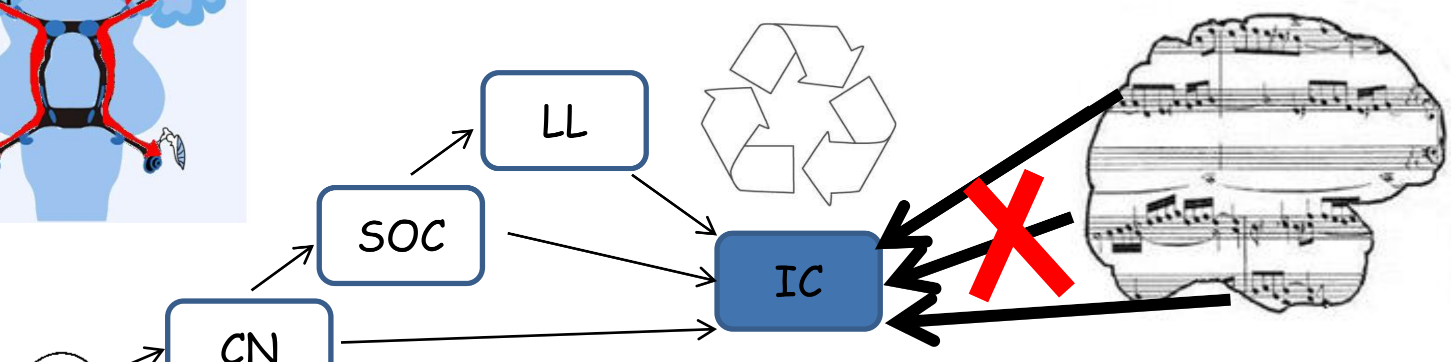


Inferior colliculus (largely)

Convergence

IC plays critical role in learning
(e.g.,Suga & Ma 2003; *Nat Rev Neurosci;*
Bajo et al., *Nat Neurosci* 2010)





metabolic hub

He (2003) *Exp Brain Res*

Sokoloff (1977) *J Neurochem*

cABR attributes

—captures acoustic characteristics of the stimulus

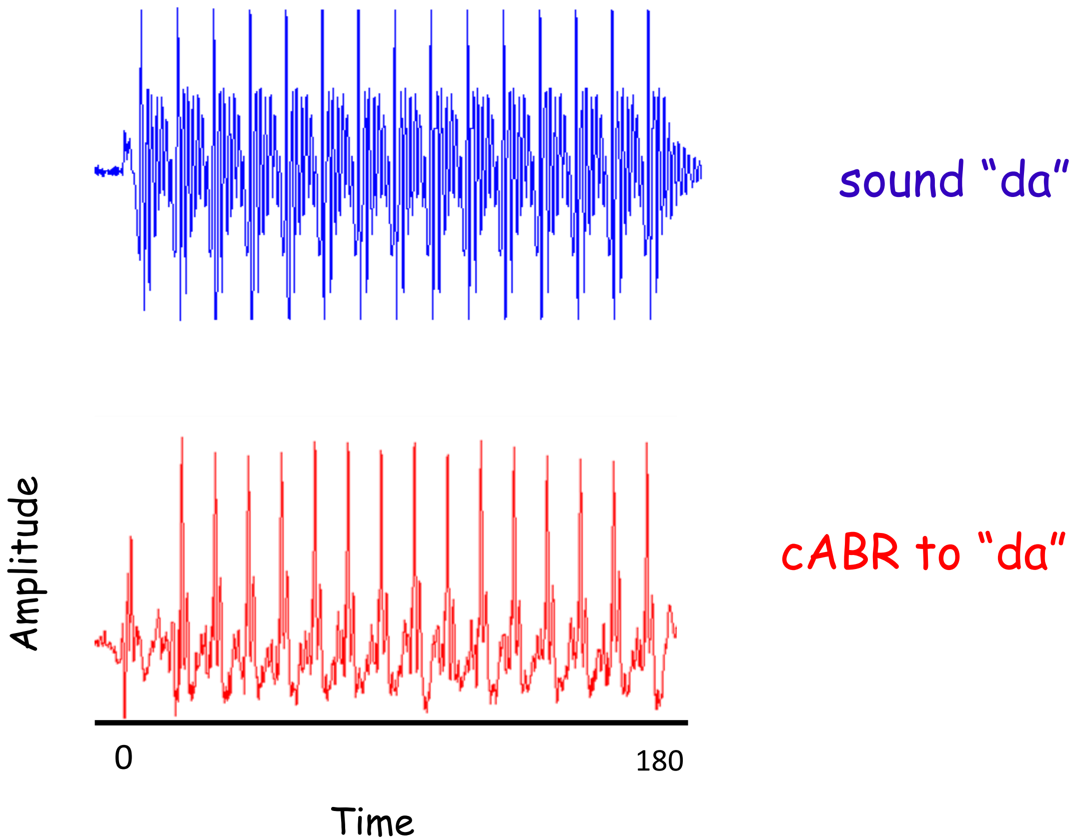
—experience-dependent

—reflects communication skills:

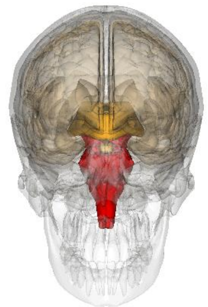
hearing in noise reading

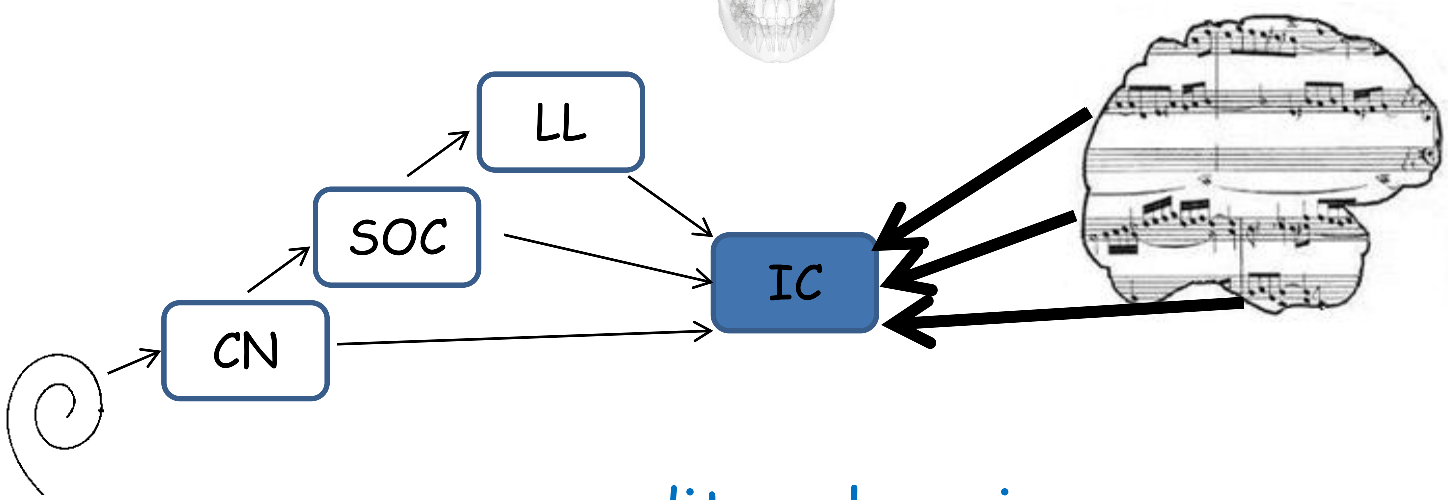
meaningful in individuals

cABR - captures acoustic characteristics of the stimulus



cABR – experience-dependent



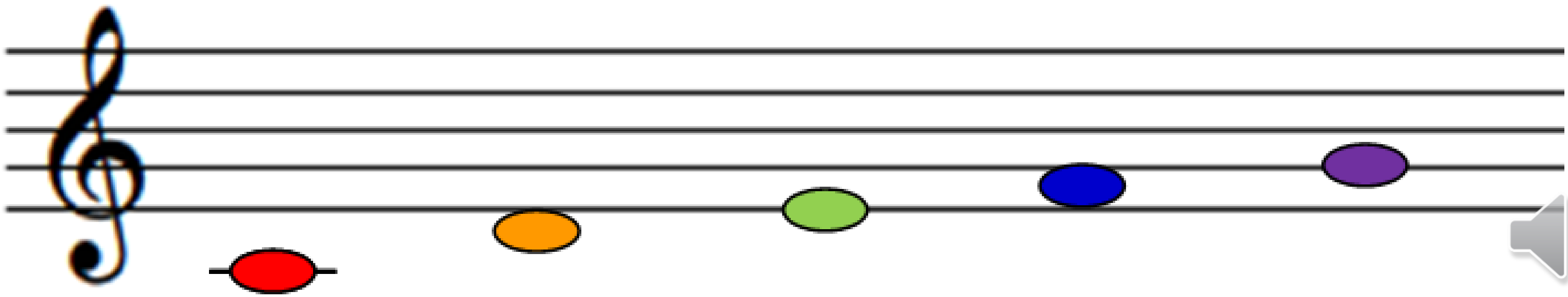


…auditory learning

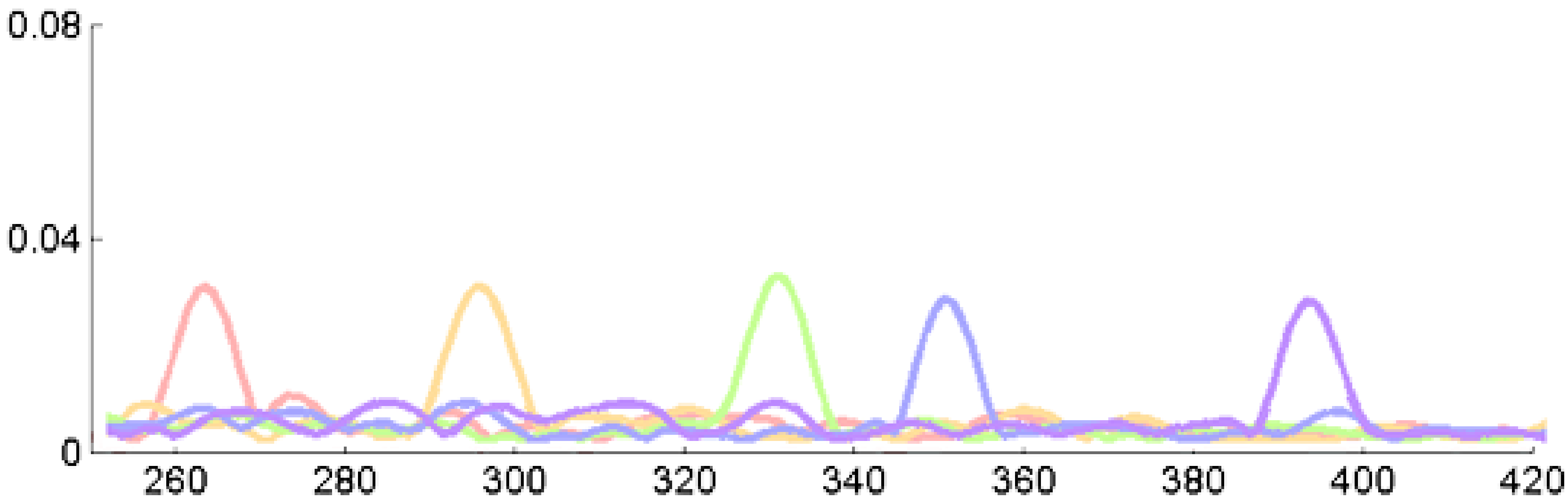
- On many time scales

Kraus & Chandrasekaran (2010) *Nat Rev Neurosci*; Chandrasekaran et al., *Neuron*, 2009; Strait et al., *Behav Brain Func*, 2011; Song et al., *J Cogn Neurosci*, 2008; Carcagno & Plack, *JARO*, 2011; Anderson et al., in prep; Hornickel et al., in prep.; Parbery-Clark et al., *Neurobiol Aging*, 2012; Strait et al., *Cortex*, 2012; Strait et al., *Frontiers Psychol.*, 2011; Krishnan-lab work.

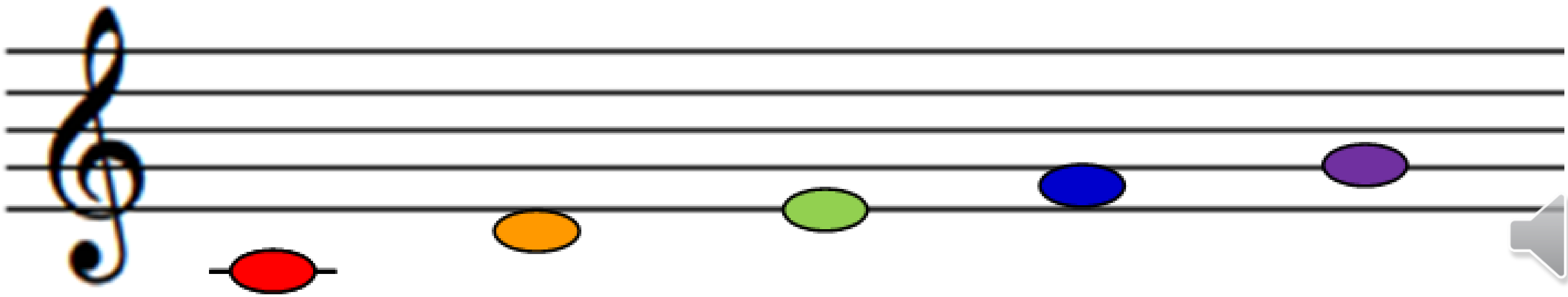
cABR – experience-dependent



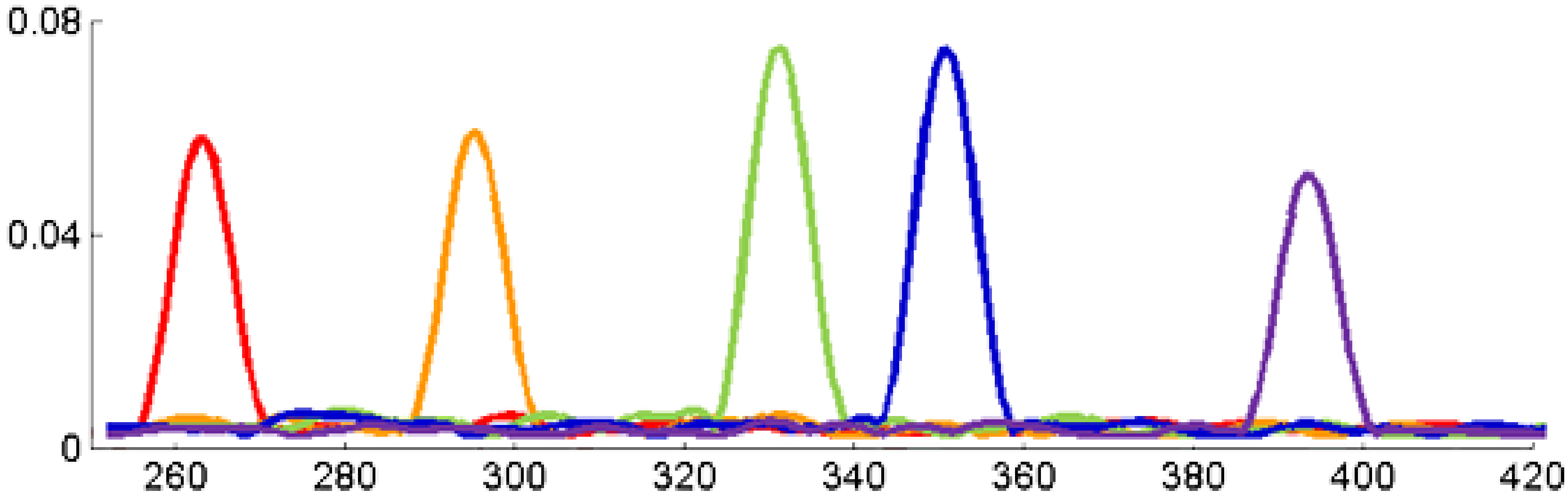
No Music Training



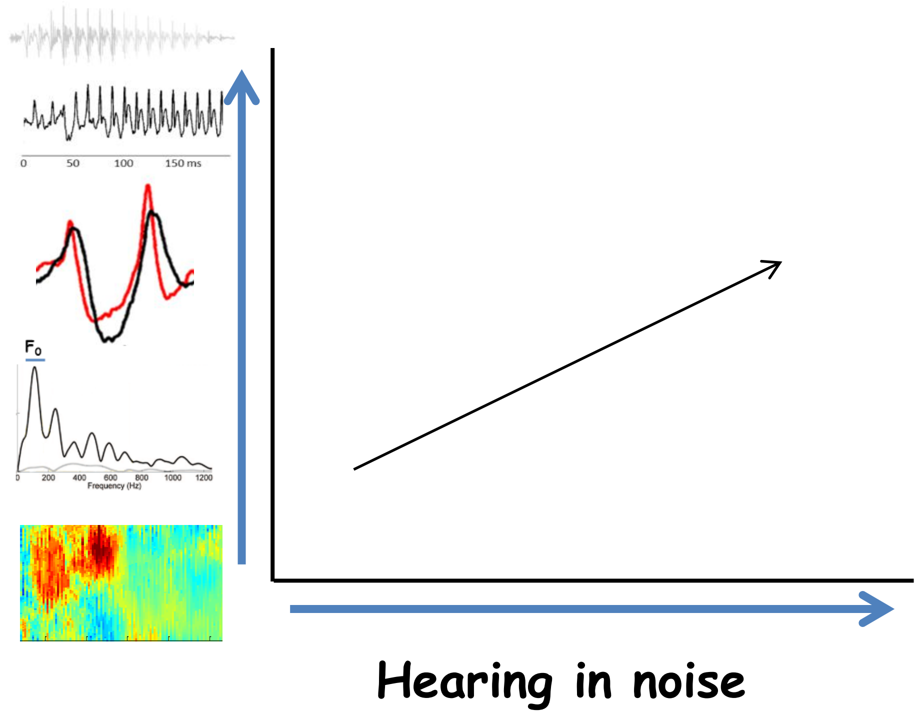
cABR – experience-dependent

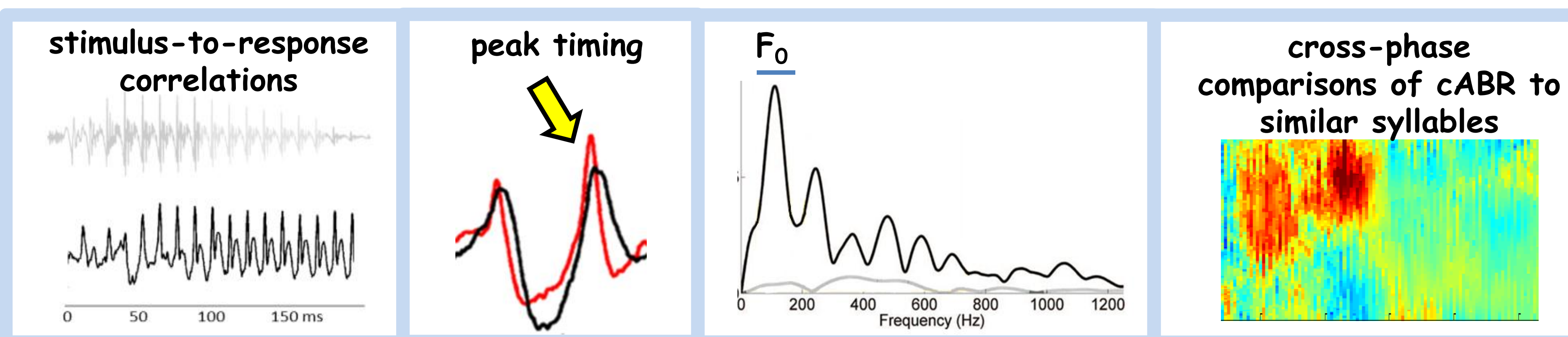


Music Training



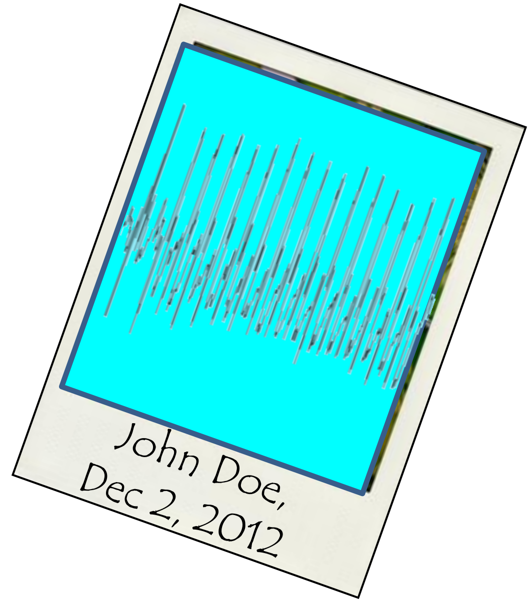
cABR reflects communication skills

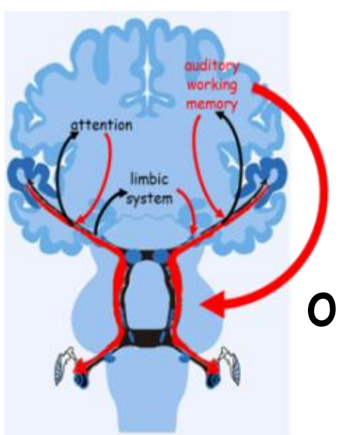




cABR

a snapshot





of auditory processing

Want to know more about cABR?

www.brainvolts.northwestern.edu

(click "technologies")

Listening in on the listening brain

Nina Kraus

The measured response of the auditory brainstem to complex aural stimuli does more than reveal hearing acumen. It also gives insight into how experience molds the perception of sound.

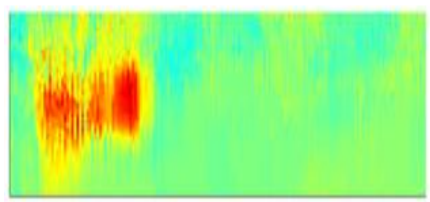
Nina Kraus (http://www.brainvolts.northwestern.edu) holds the Hugh Knowles Chair at Northwestern University in Evanston, Illinois, where she is a professor of communication sciences, neurobiology and physiology, and otolaryngology.

Kraus N. (2011) *Physics Today*

Contents lists available at ScienceDirect

Journal of Neuroscience Methods

journal homepage: www.elsevier.com/locate/jneumeth



Skoe E, Nicol T, Kraus N (2011) *J Neuroscience Methods*

TUTORIAL

Clinical Considerations
Stimulus Selection and Creation
Stimulus Presentation
- Intensity
- *Monaural and binaural stimulation*
- *Left and right ear stimulation*
- *Stimulus polarity*
- *Presentation rate*
- *Transducer*
- *Multiple stimulus conditions*

cABR collection
- *Electrodes and electrode montage*
- *Filters*
- *Sampling rate*
- *Signal averaging*
- *Simultaneous cABR-cortical recordings*
- *Avoiding, detecting and eliminating artifact*
- *Active and passive test conditions*

Data Analysis:
- Analyzing transient responses
  - *peak latency and amplitude*
  - *differences in latency over time*
- Analyzing transient responses
  - *static and sliding-window analysis*
  - *root-mean-square (RMS) amplitude*
  - *cross-correlation*
  - *autocorrelation*
  - *Fourier analysis*

Skoe E, Kraus N. (2010) cABR: a tutorial. *Ear Hearing*

Aging

...hearing in noise
(Souza et al., 2007; Hargus & Gordon-Salant)

Aging

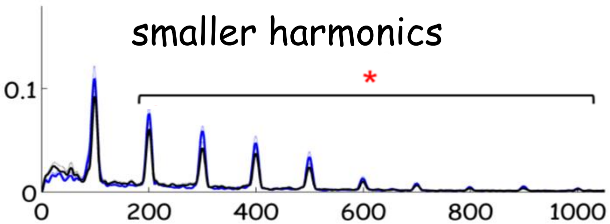
Biology

Neural timing – slowing down
(Caspary et al, 2008; Grose & Marmo, 2010; Harris et al., 2010; Lister et al., 2011; Ross et al., 2010; Walton et al., 2010; Tremblay et al., 2003; Humes et al., 2010)

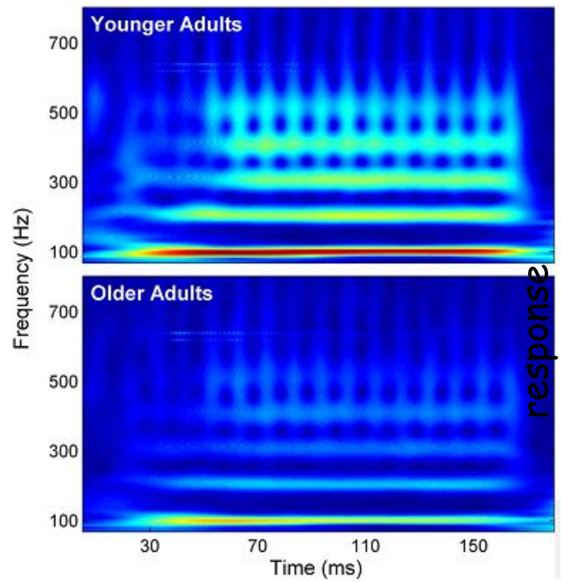
- Decreased inhibition (Caspary et al., *Exp Gerentol,* 2005)
- Broader neural tuning (Juarez-Salinas et al., JoN 2010; Recanzone et al. 2012)
- Longer neural recovery (Walton et al., JARO, 2008)
- ↑ neural noise (Juarez-Salinas et al., JoN 2010)

Biological effects of aging

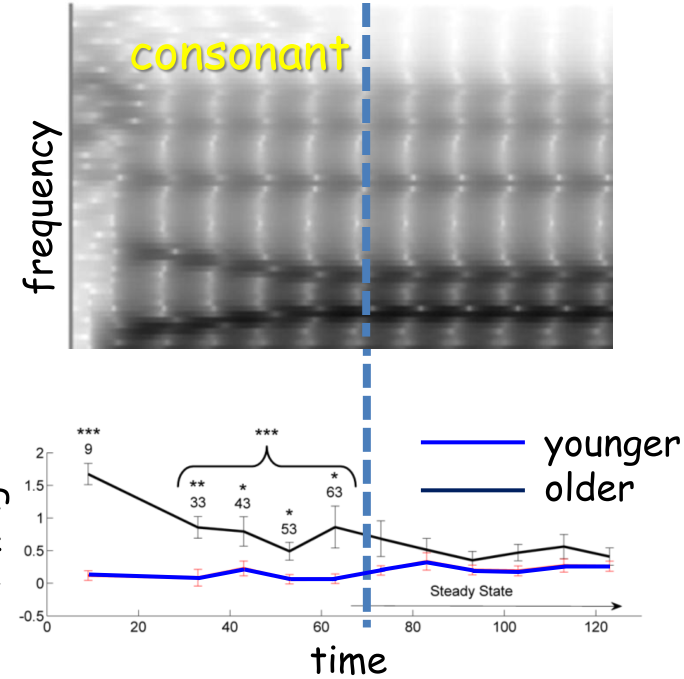
smaller harmonics



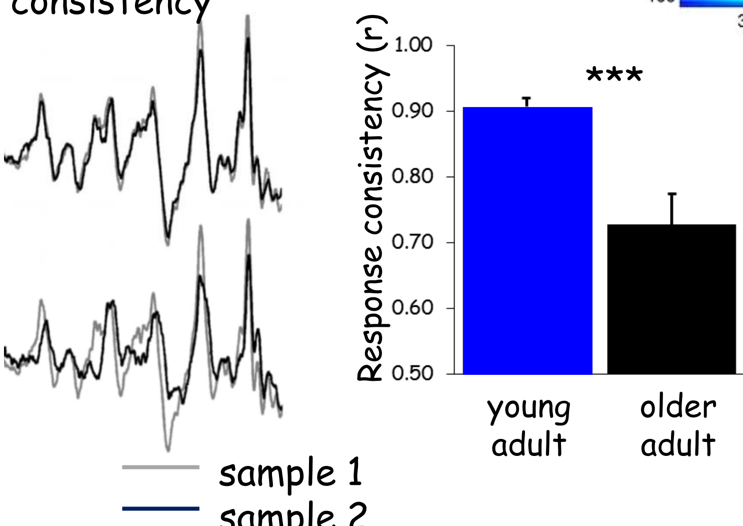
weaker synchrony



delayed neural timing



less within session consistency



Anderson et al., *J. Neurosci*, 2012

Biological effects of aging (summary)

Through lens of cABR, we see impact of aging on

Timing

Harmonics Magnitude

Synchrony phaselocking

Consistency

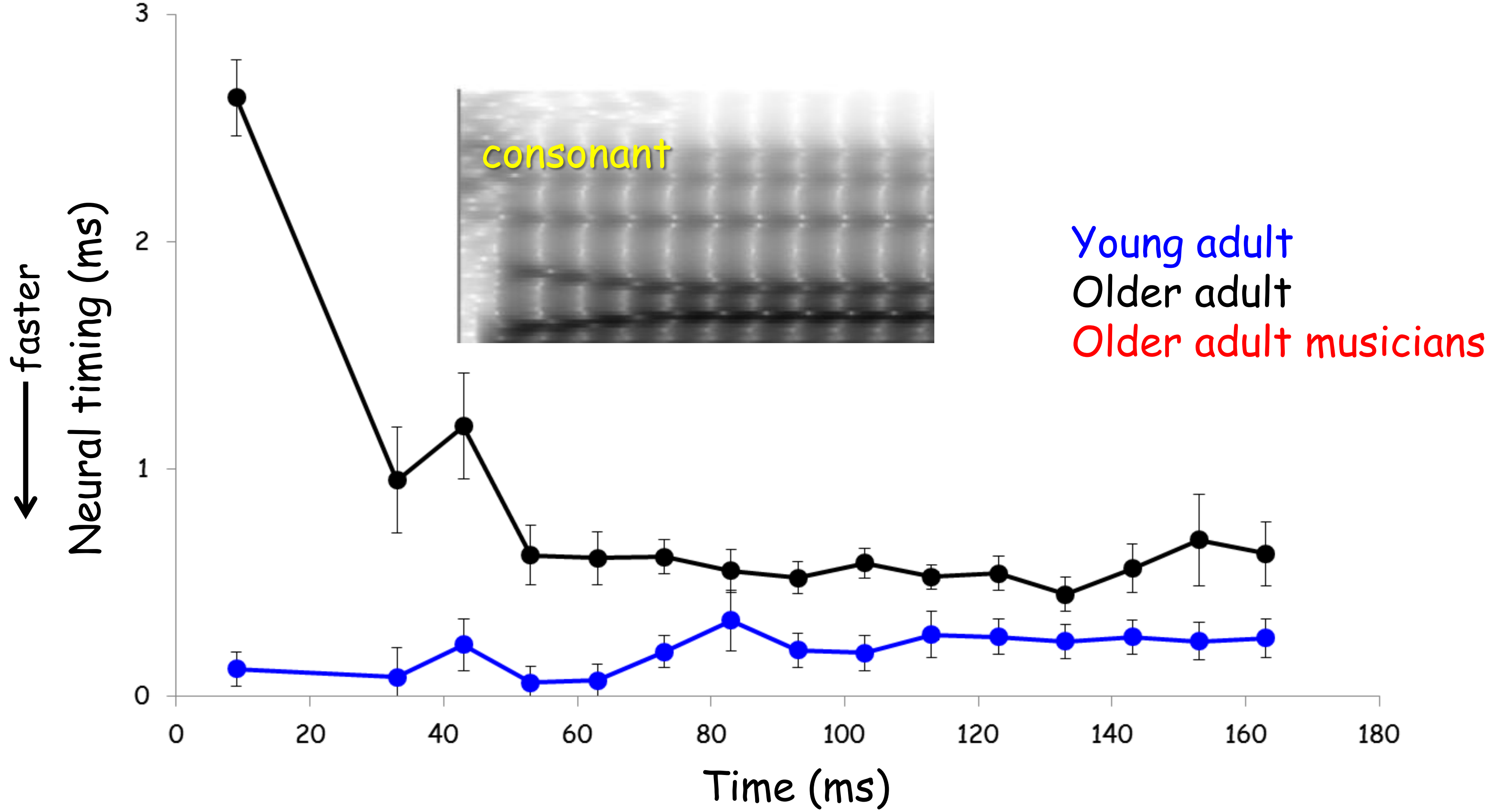
Neural noise

Reversing aging's effect on communication

Music Experience offsets Aging

Music Experience offsets Aging

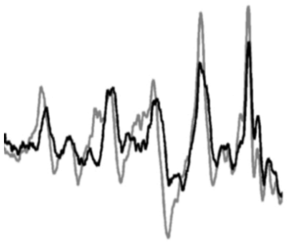
neural timing

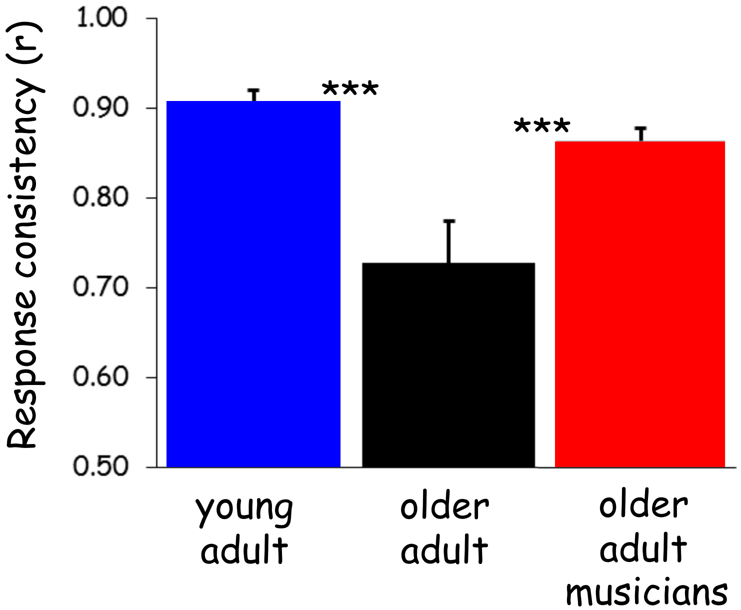


Anderson et al., *J. Neurosci*, 2012
Parbery-Clark et al. *Frontiers*, 2012

Music Experience offsets Aging

neural consistency

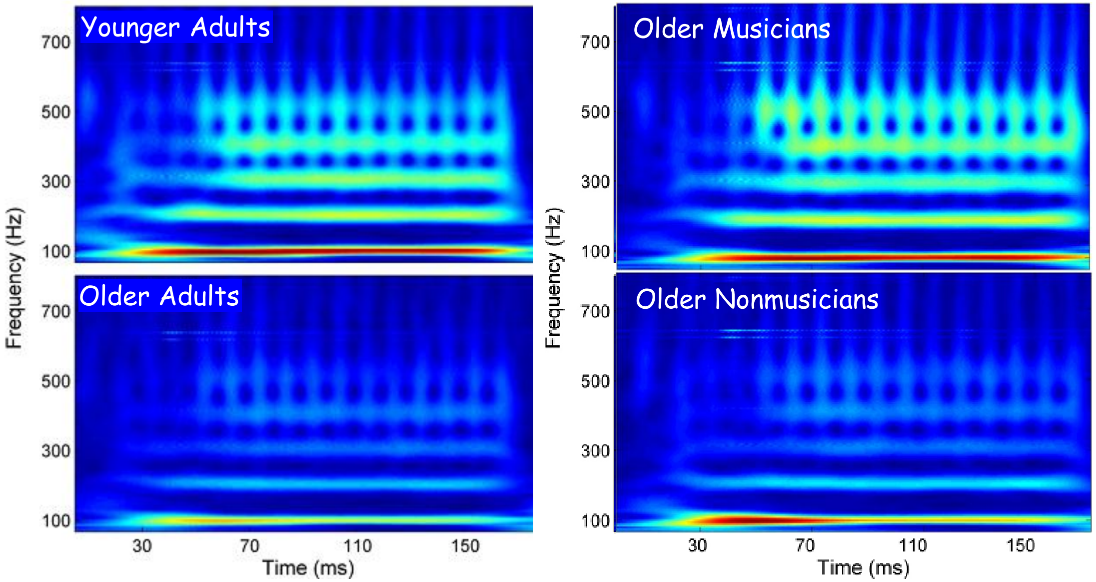




Anderson et al., *J. Neurosci*, 2012
Parbery-Clark et al. *Frontiers*, 2012

Music Experience offsets Aging

neural synchrony - phaselocking

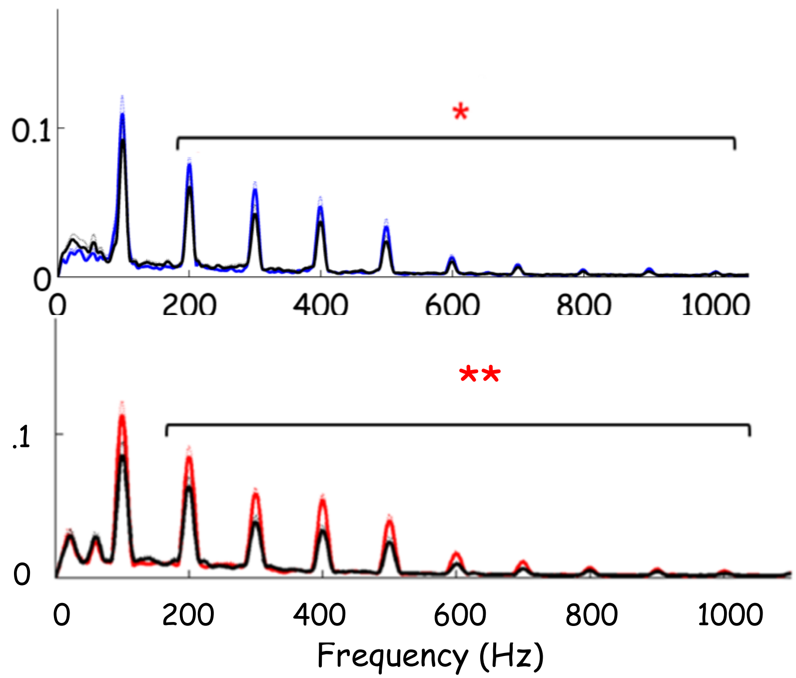


Anderson et al., *J. Neurosci*, 2012
Parbery-Clark et al. *Frontiers*, 2012

Music Experience offsets Aging

harmonics magnitude

harmonics magnitude



Younger adult nonmusicians

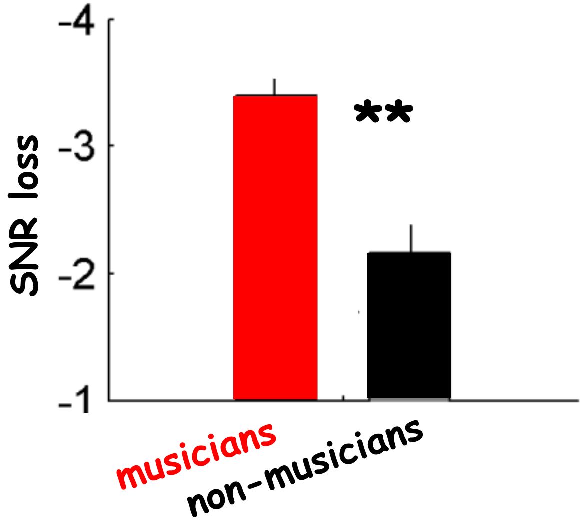
older adult nonmusicians

older adult musicians

Anderson et al., *J. Neurosci*, 2012
Parbery-Clark et al. *Frontiers*, 2012

Music Experience offsets Aging

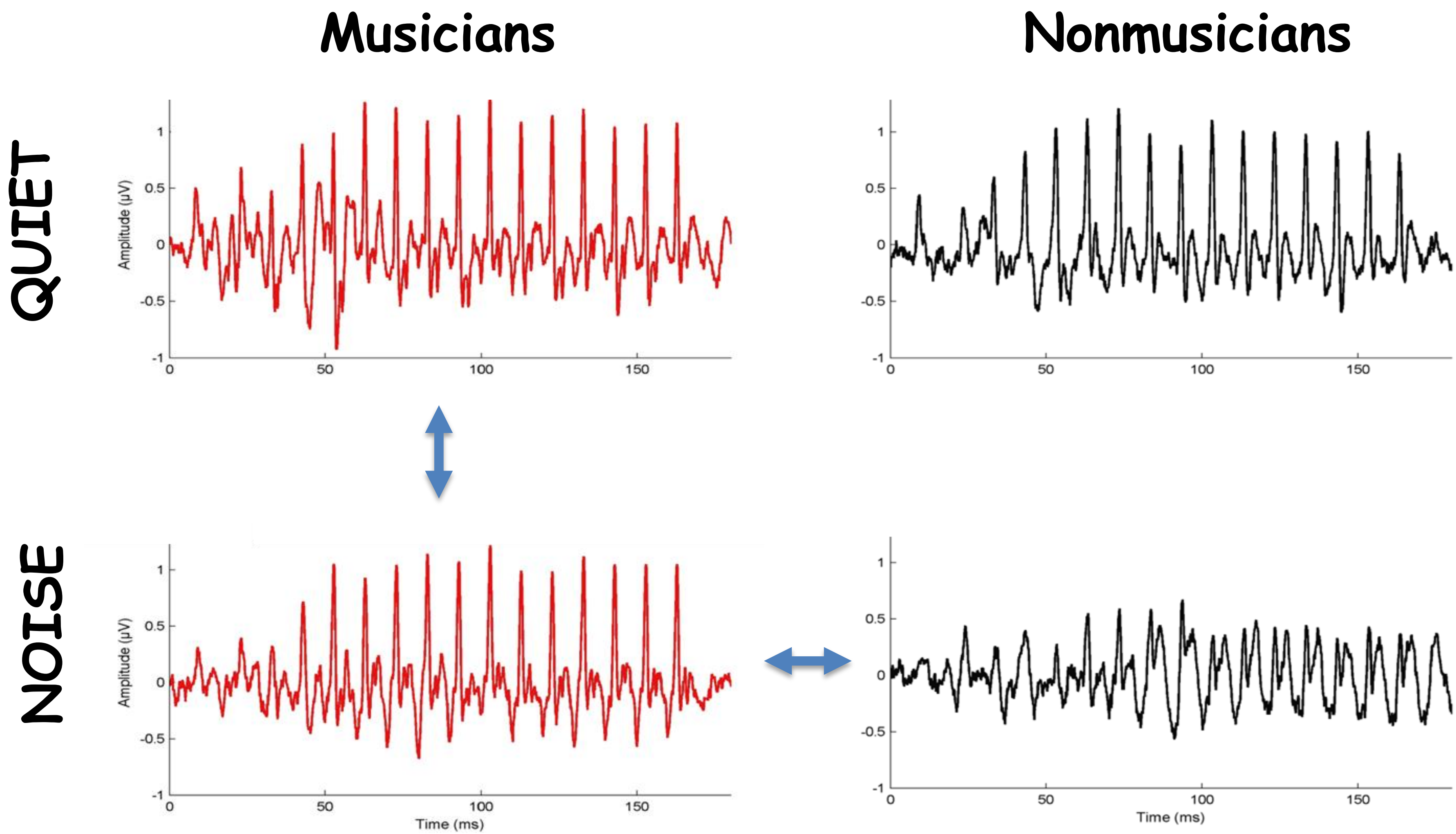
better hearing in noise…



biological metrics?

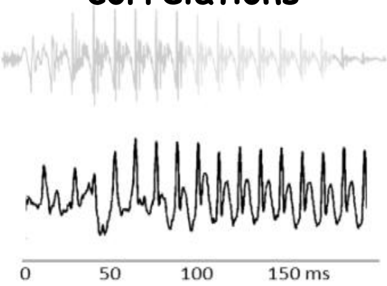
Parbery-Clark et al., *PLoS ONE* , 2011
Zendel & Alain, *Psy and Aging,* 2011

cABR in noise → musician advantage

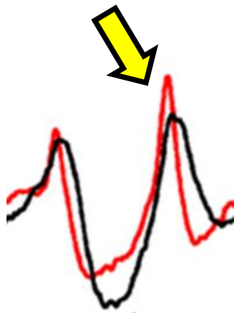


cABR metrics – musician signature advantages in noise

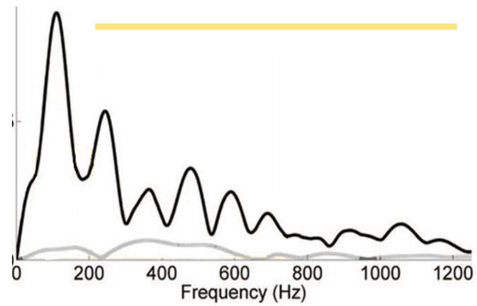
stimulus-to-response correlations



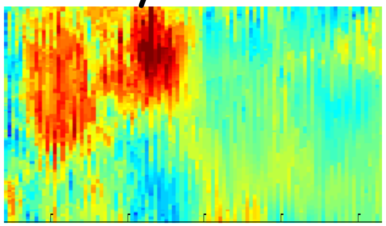
peak timing



harmonics

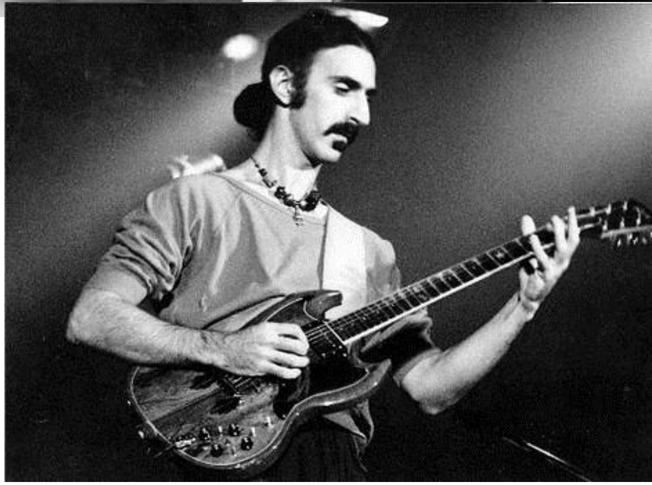


cross-phase comparisons to similar syllables



- ✓ **stimulus-to-response correlations in noise**
- ✓ **response timing in noise**
- ✓ **harmonics in noise**
- ✓ **more distinct responses to similar sounds: ba versus ga**

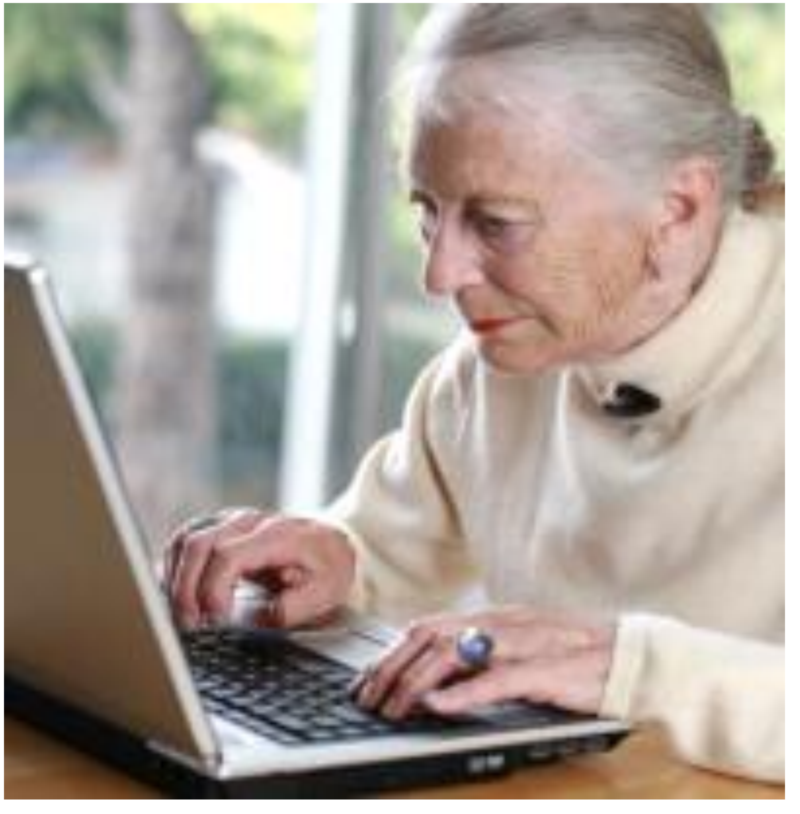


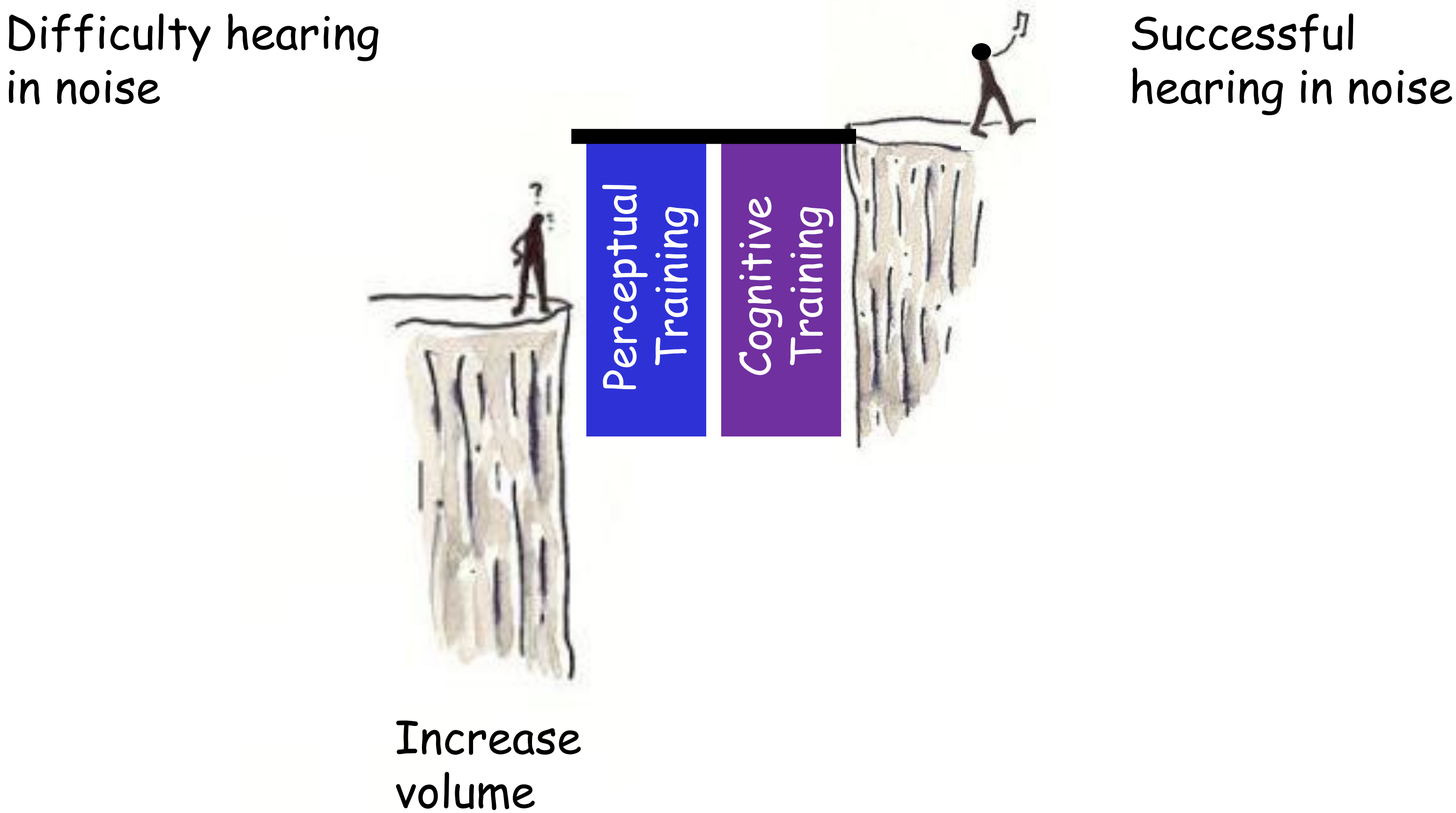



a lifetime of making music positively impacts:
- hearing in noise
- biological health

.....challenge for other training strategies to harness this impact

Auditory training in older adults?

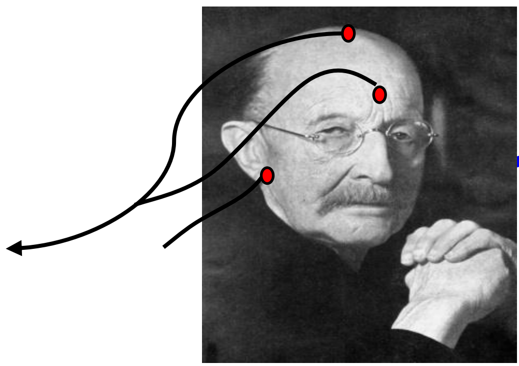



Difficulty hearing in noise
Perceptual Training
Cognitive Training
Successful hearing in noise
Increase volume

software-based training

Older adults aged 55 to 79

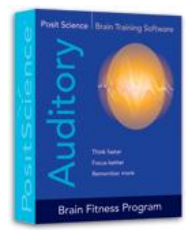
n = 75



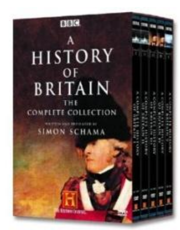
Testing at Northwestern

- **cABR**
- **Speech-in-noise** (QuickSIN, HINT, WIN)
- **Cogntive tests** (Memory, Attention)

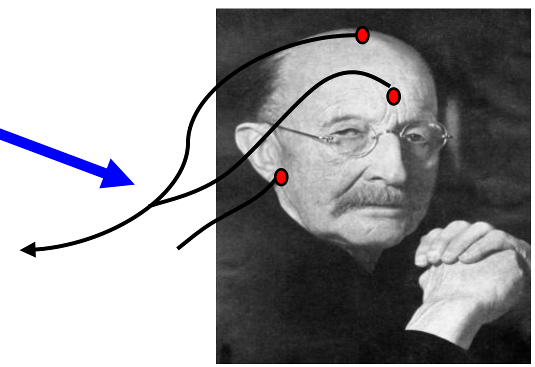
Brain Fitness Program



Eight weeks



Educational Videos



Testing at Northwestern

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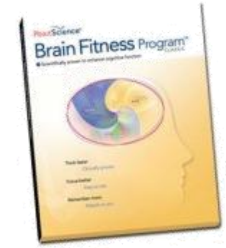
software-based training

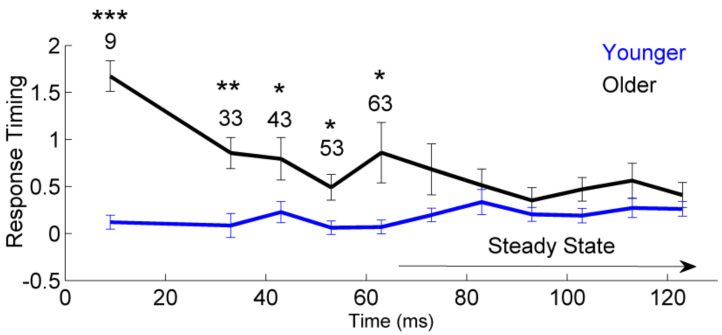


Based on 2 principles:

1. Adaptive contraction of the consonant –vowel transition
2. Adaptive increase in memory demands

Combined perceptual and cognitive training

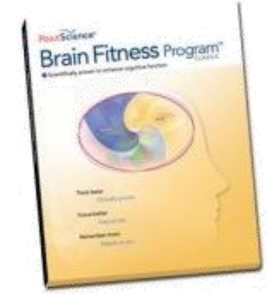
reversal of aging effects

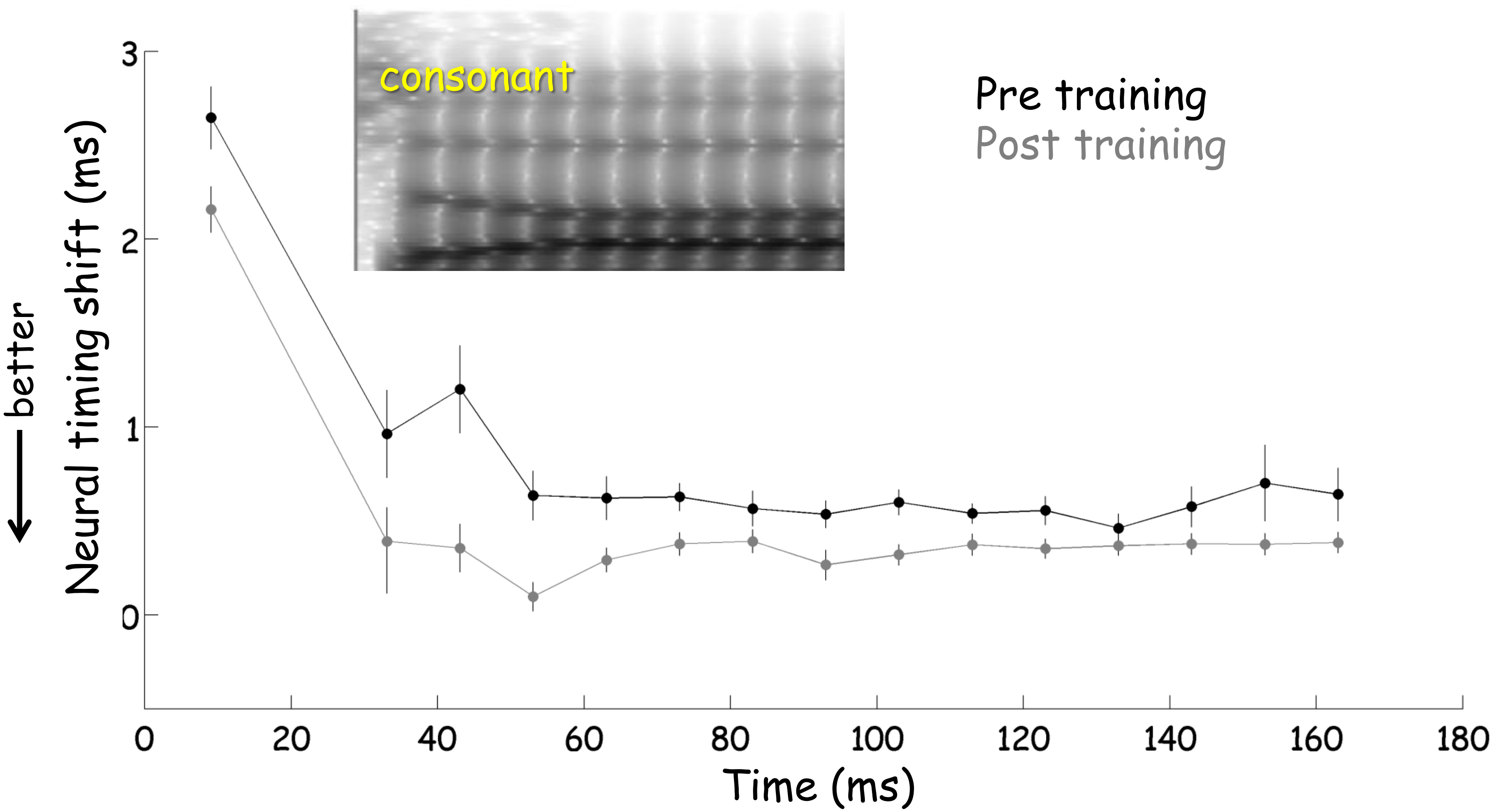


Hypothesis:

Auditory training that focuses attention on the rapidly changing consonant-vowel transition improves neural timing

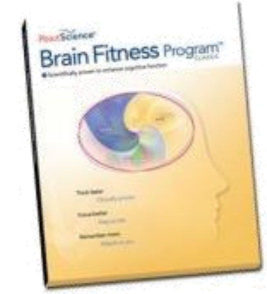
software-based training
older adults





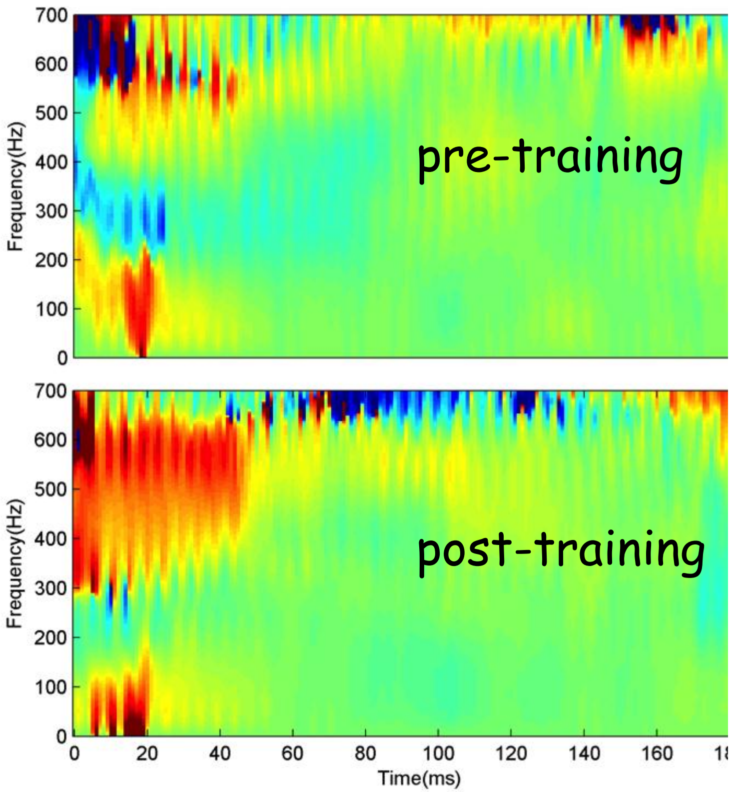
Anderson et al. *Not yet rejected*

software-based training



cross phase comparison of ba and ga

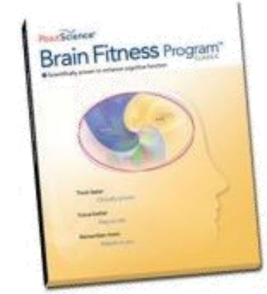
Auditory Training



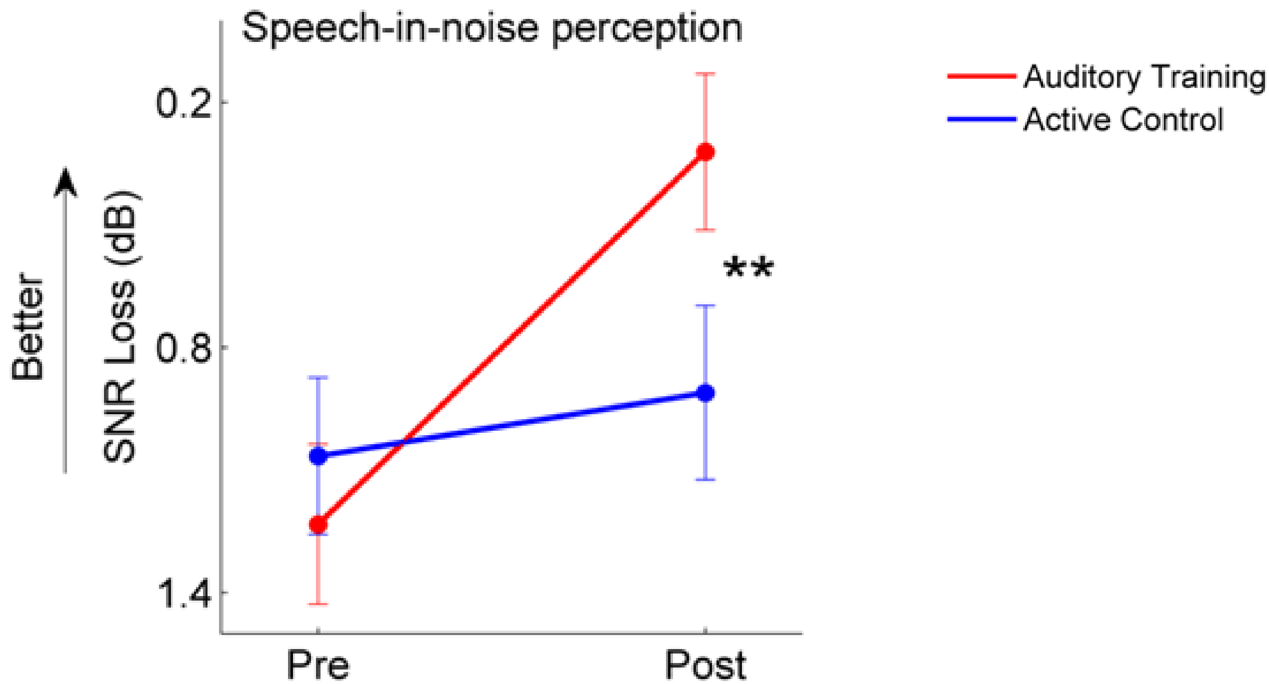
Active Control: no change

Anderson et al. *Not yet rejected*

software-based training



Training: n = 35
Active control: n = 32



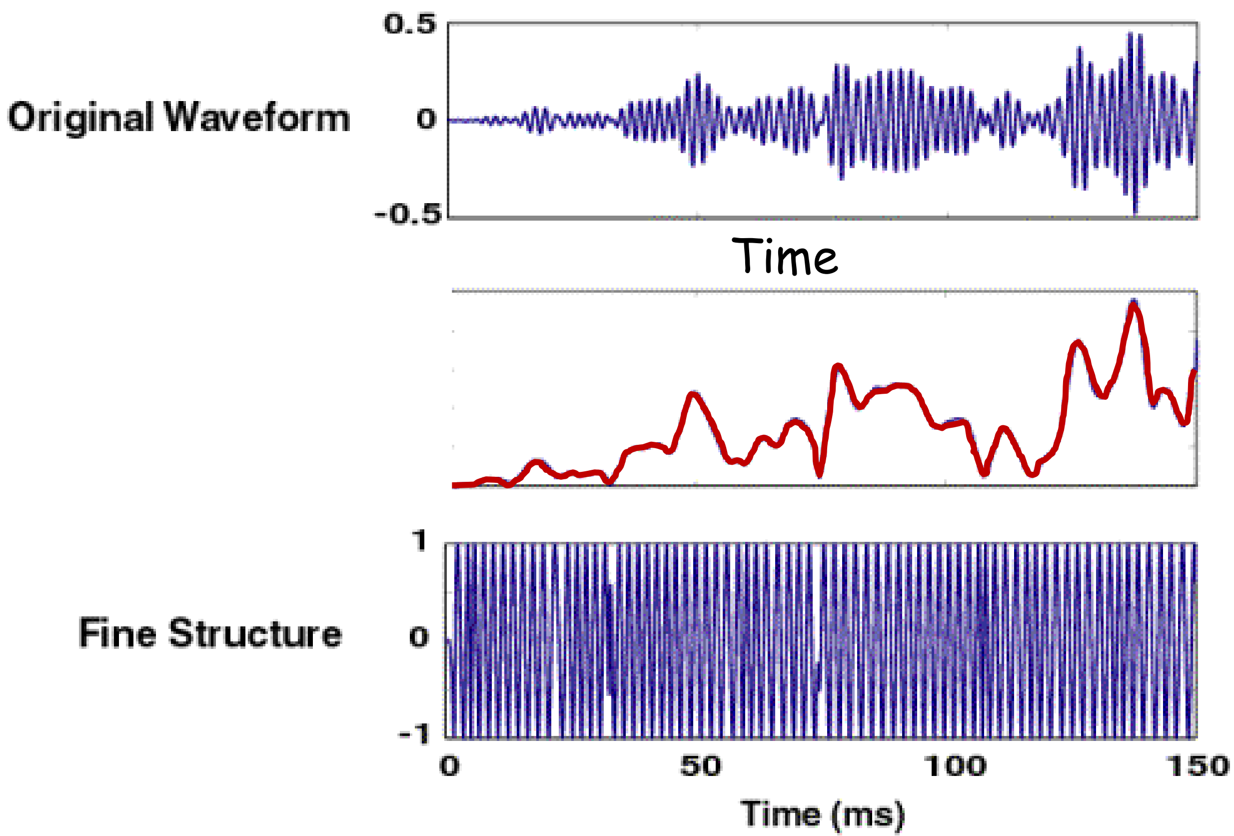
Anderson et al. *Not yet rejected*

reversal of hearing loss effects

Hypothesis

Older adults with hearing loss can be trained to reweigh envelope cues relative to the temporal fine structure.

Envelope vs. Temporal Fine Structure?

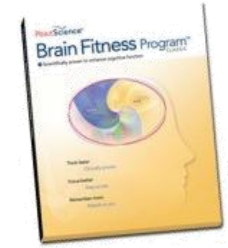


- Envelope cues adequate for hearing in quiet.
- Fine structure cues important understanding speech in fluctuating noise.

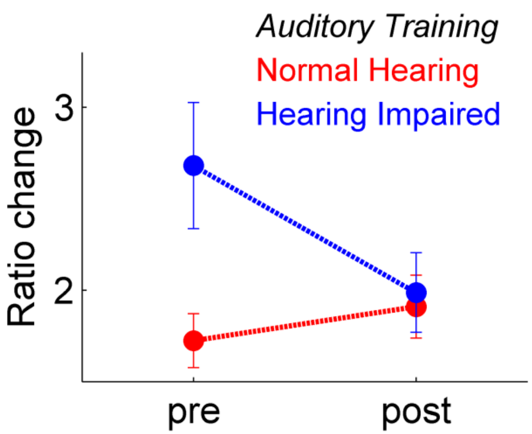
Kale & Heinz *JARO* 2010; Ardoint et al *Intl J Audiology* 2010 (Qin & Oxenham, 2003; Zeng et al., 2005)

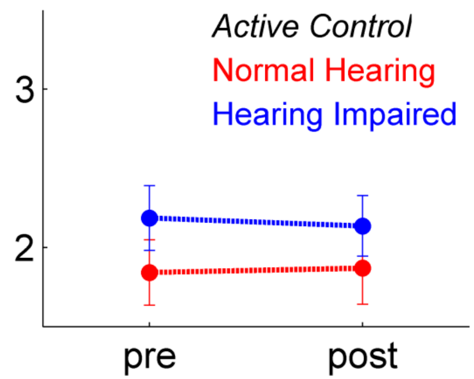
- Overrepresentation of the envelope may swamp the details of the response so that the temporal fine structure is not audible.

software-based training
Envelope vs. Temporal Fine Structure



ENV/TFS





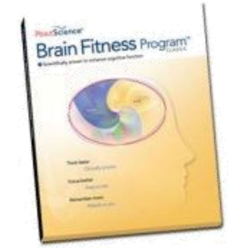
Training:
n = 12 Normal Hearing
n = 12 Hearing Impaired

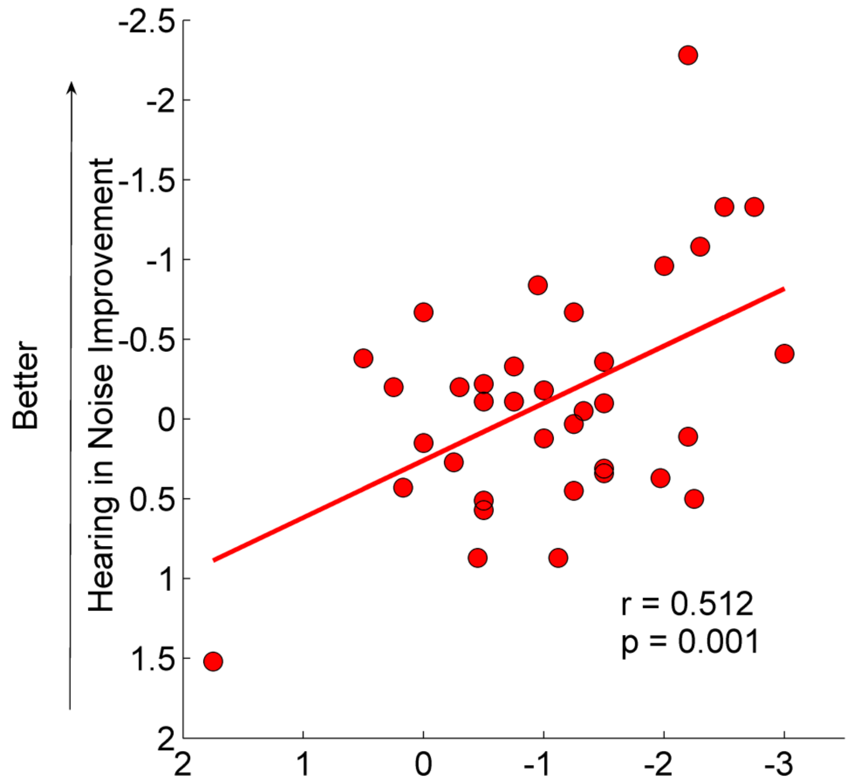
Active control:
n = 12 Normal Hearing
n = 12 Hearing Impaired

Anderson et al. *Not yet rejected*

software-based training

Envelope vs. Temporal Fine Structure

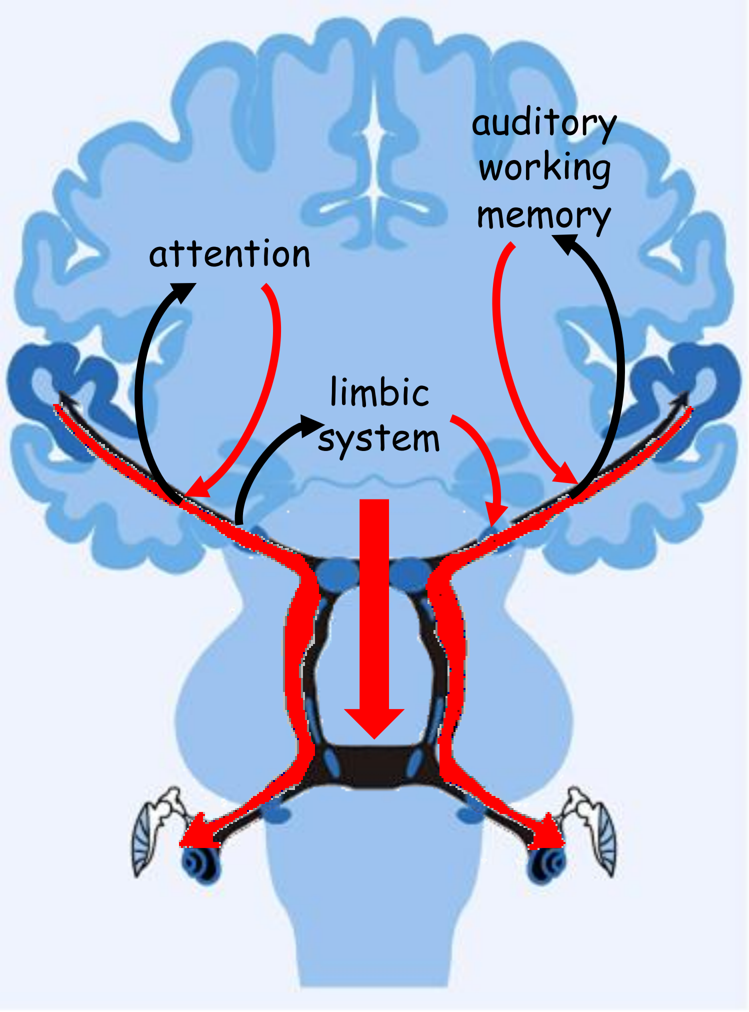




Increase in relative weighting of TFS

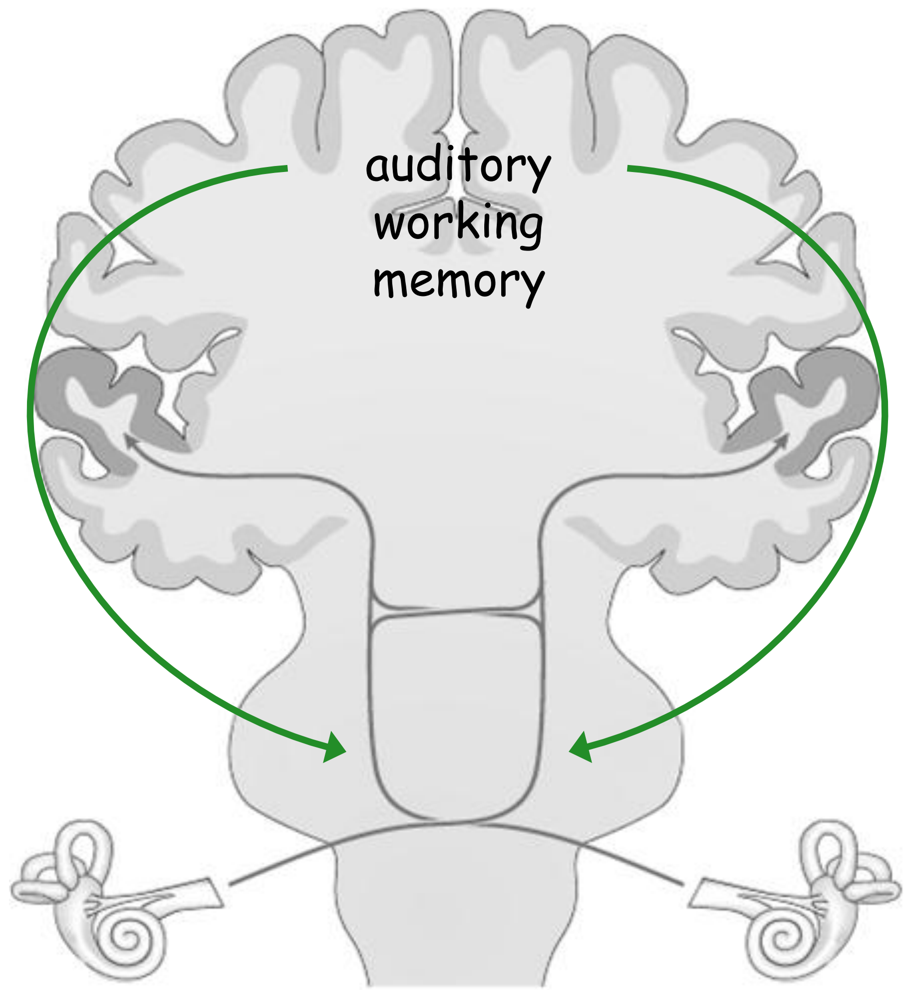
Anderson et al. *Not yet rejected*

theoretical considerations



auditory learning reflects strengthened top-down control of sensory processing

Cognitive abilities shape neural processing of sound



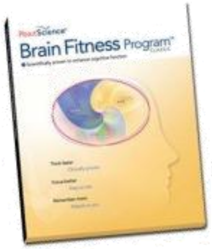
Kraus N, Chandrasekaran B. (2012) *Nat Rev Neurosci*

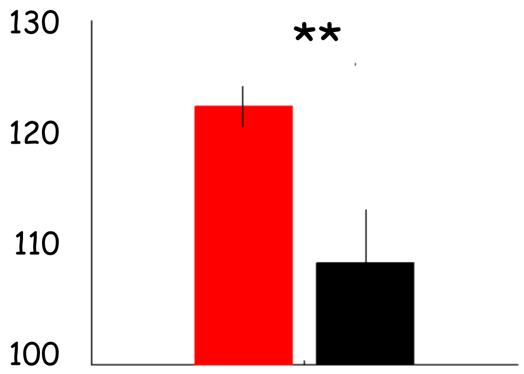
Cognitive abilities shape neural processing of sound

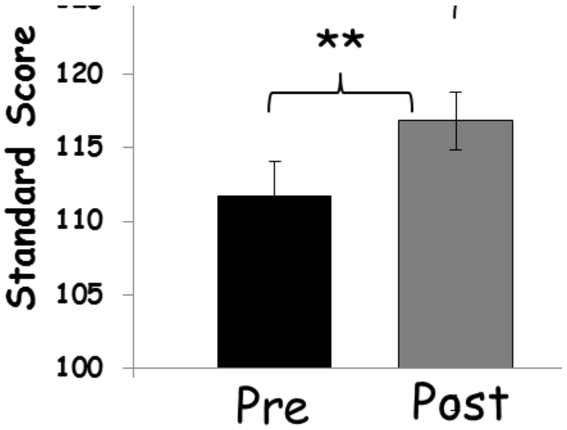
Auditory Working Memory enhanced.....

music

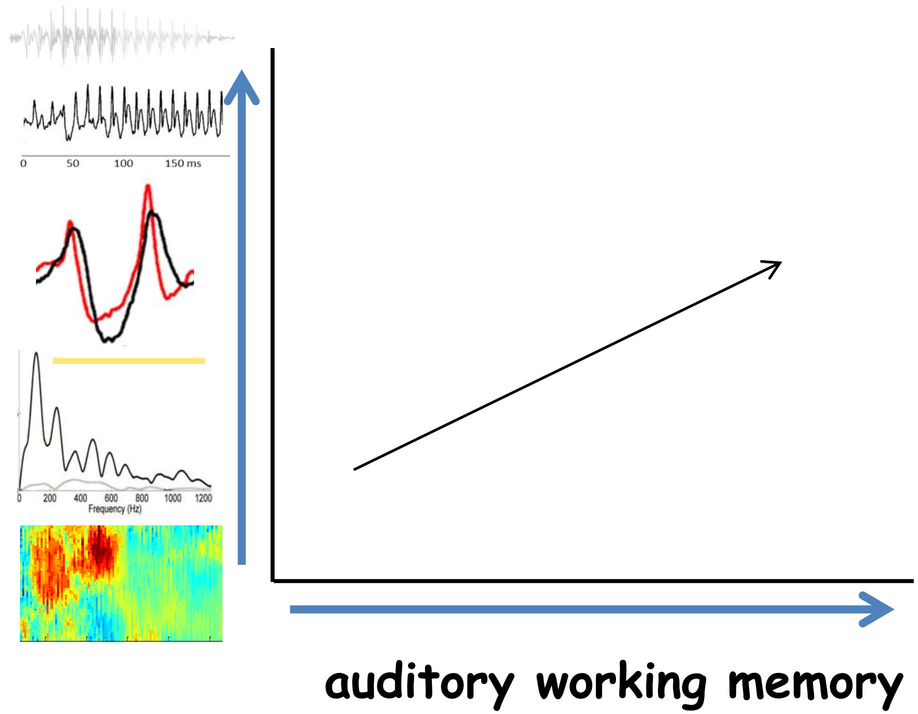
software-based



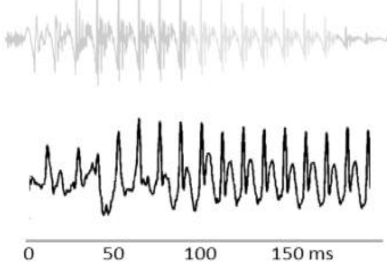




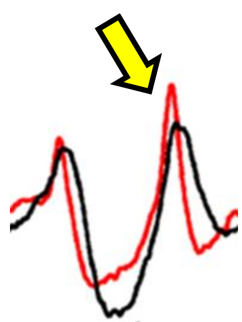
Cognitive abilities shape neural processing of sound



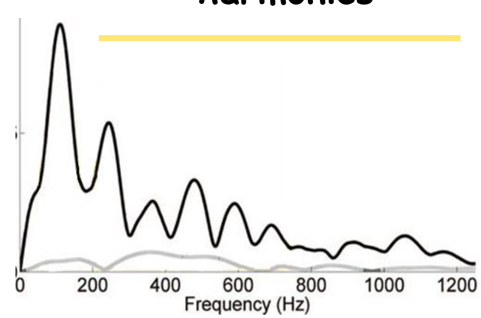
stimulus-to-response correlations



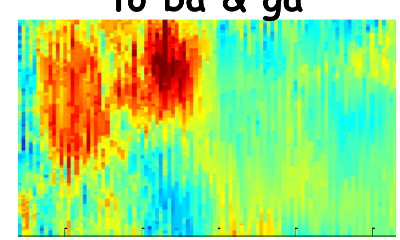
peak timing



harmonics



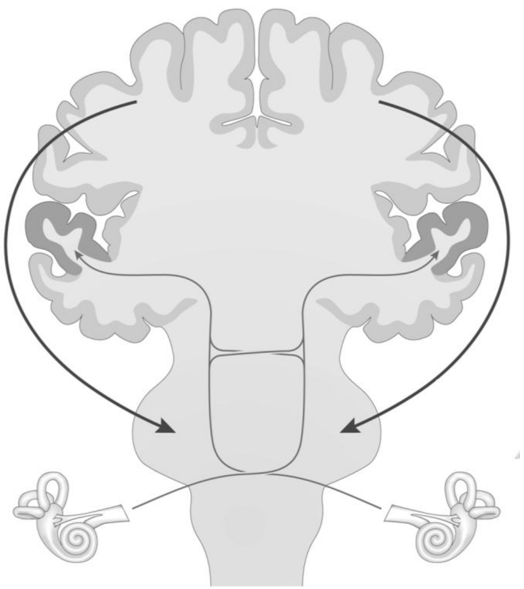
cross-phase comparisons of cABRs to ba & ga



Cognitive abilities shape neural processing of sound

Building the Case for Trickle Down Learning

Top-down learning



<u>Reverse Hierarchy Theory of Learning</u>
M. Ahissar et al. 2009

<u>Back-Propagation Hypothesis</u>
Baldeweg 2006

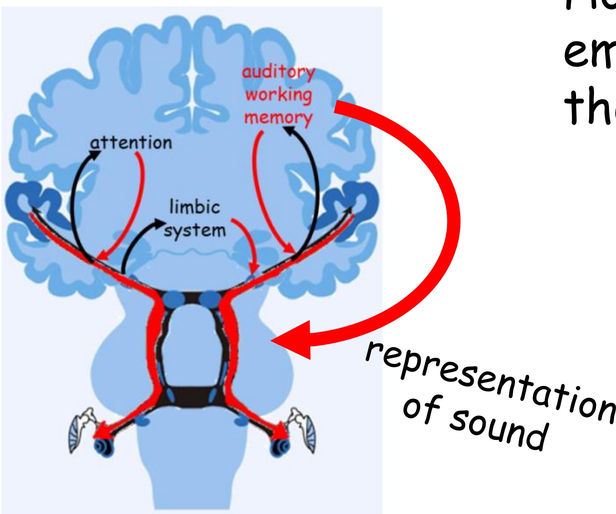
<u>Top-down stimulus specific adaptation</u>
Nelken & Ulanovsky 2007

variations on a theme….

Summary
Training in Older Adults

- Reverses age-related delays in neural timing
- Reverses imbalance in envelope/TFS encoding
- Improves hearing in noise and auditory memory
- Management of hearing loss should include training

Overall Summary



How we interact with sound (memory, attention, emotion) shapes basic response properties of the auditory system.

...leads to more effective neural representation of sound

We have access to underlying biology!

What Next????   Research Gaps

Impact of resuming/initiating music training later in life?

Training strategies?   music; software-based; learn another language

Dosage: How much training is needed to effect changes?

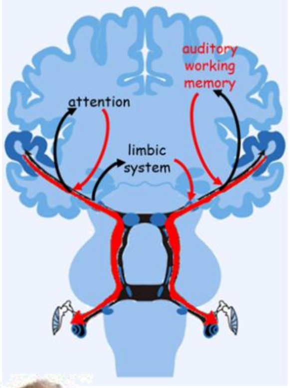
Impact of amplification over time?

How do training needs change with age?

How to obtain uniform large-scale biological outcomes in humans?

cABR

Biological snapshot of hearing health



Hearing aids/CI: fitting; inform device development

make technology readily available
and user-friendly

Auditory Neuroscience Laboratory

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Project Coordinator: Rafael Escobedo

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Knowles Hearing Center

Northwestern University
School of Communication

www.brainvolts.northwestern.edu

auditory neuroscience lab
people
lab projects
technologies

publications

talks (upcoming & previous)
in the news

i would like to participate
directions to the lab

Auditory Neuroscience Laboratory

Lab Projects

For overview, see slideshow under each project link

- Music
- Reading
- Speech in Noise
- Autism
- Learning and the Brain
- Hemispheric Specialization

- Technologies
- Listening Learning and the Brain

The Auditory Neuroscience Laboratory investigates the neurobiology underlying speech and music perception and learning-associated brain plasticity. We study normal listeners throughout the lifespan, clinical populations (poor-readers; autism; hearing loss), auditory experts (musicians) and an animal model.

NSF: Finding Your Science - Spring 2010
Music and the Brain

Demonstration:
Brainstem Responses to Complex Sounds

Lecture - Spring 07
Music and Language Shape How We Hear

start with 'slide shows'

Music, Science & Medicine at the
New York Academy of Sciences - Spring 2011