MUSICAL TRAINING, HEARING LOSS AND THE AGING BRAIN

Claude Alain, Ph.D.

Senior Scientist, Rotman Research Institute at Baycrest &
Professor, Department of Psychology, University of Toronto

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Enhancing Knowledge
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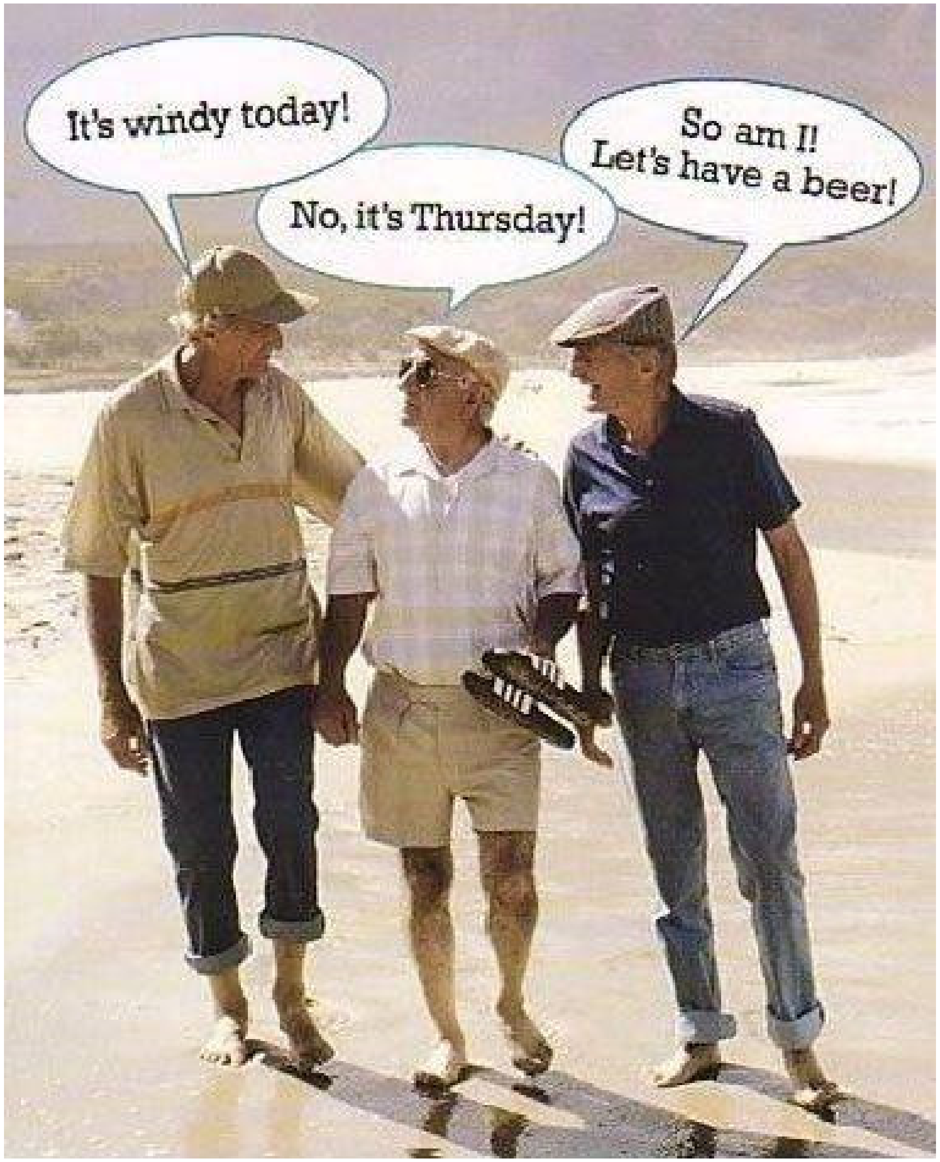
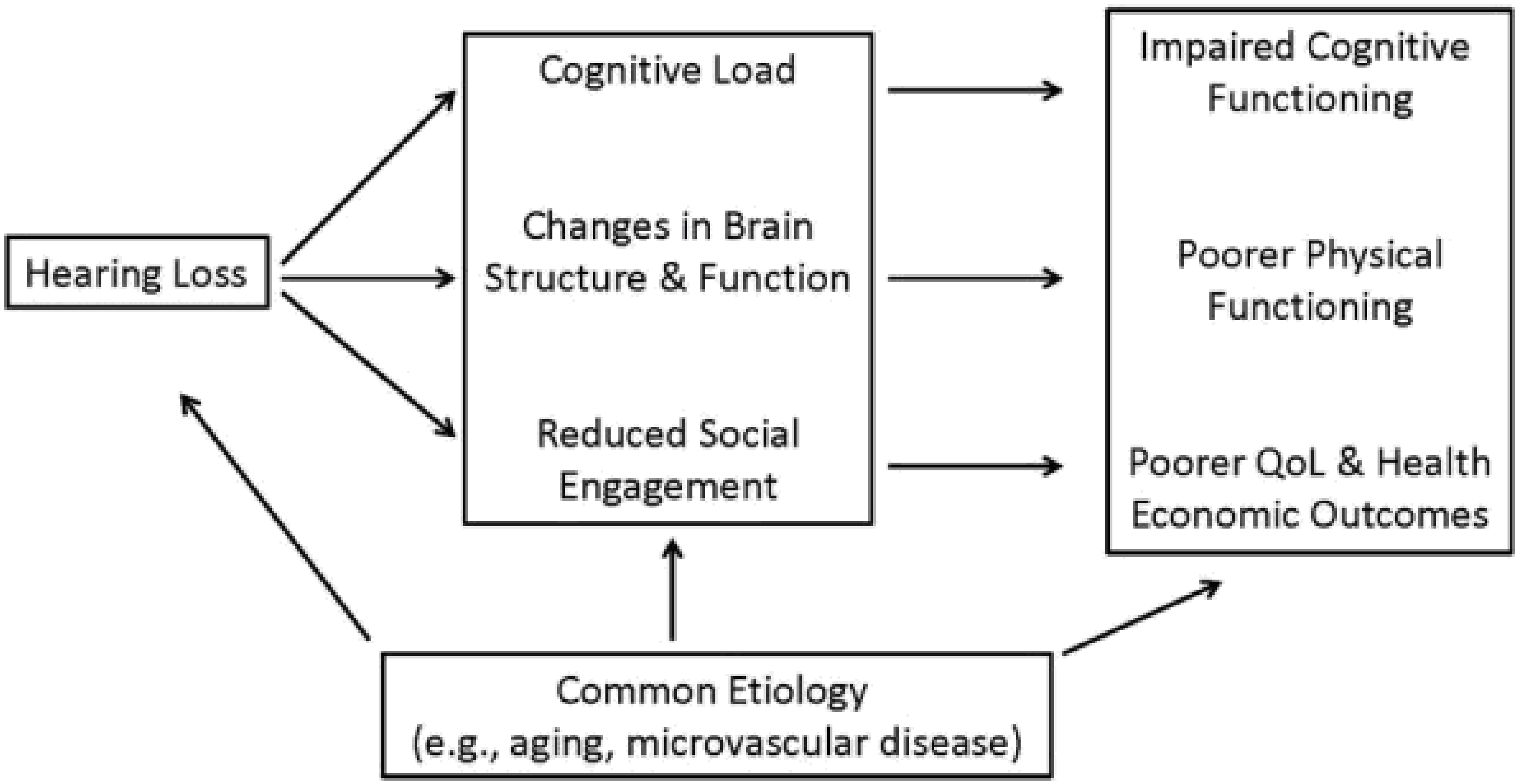
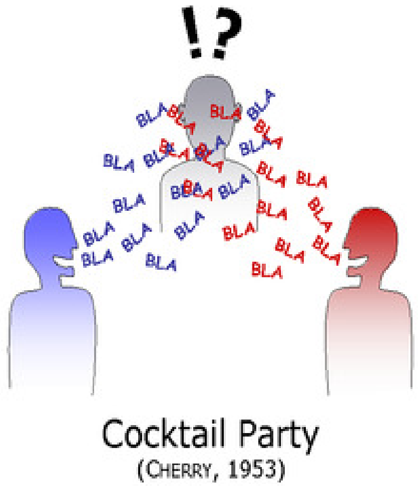

It's windy today!
No, it's Thursday!
So am I!
Let's have a beer!


Hearing Loss
Cognitive Load
Changes in Brain Structure & Function
Reduced Social Engagement
Impaired Cognitive Functioning
Poorer Physical Functioning
Poorer QoL & Health Economic Outcomes
Common Etiology (e.g., aging, microvascular disease)

Aging and auditory perception

- Speech in noise
- Temporal discrimination
- Pitch discrimination
- Sound localization
- Auditory attention
- Auditory working memory
- Sound identification
- …



Aging and auditory perception: A multi-stage problem

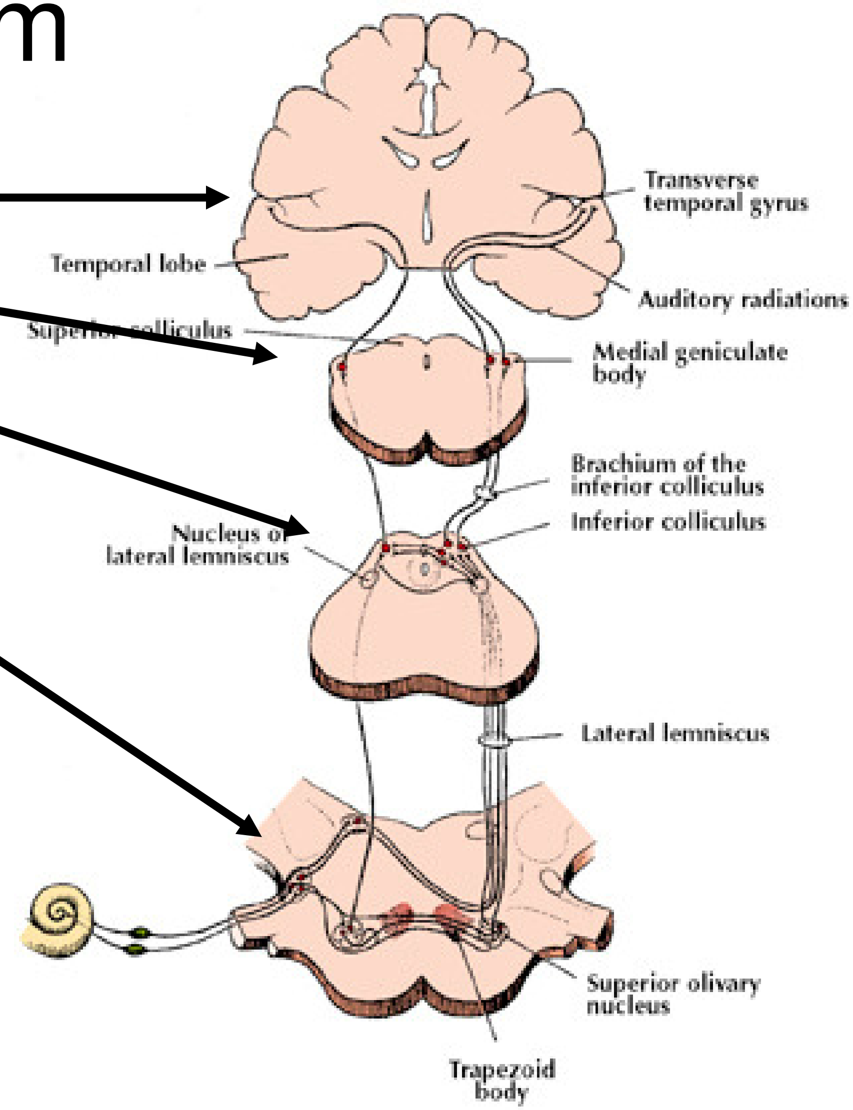
Sound detection

Sound discrimination

Sound Synthesis &
Auditory Object

Alain & Tremblay *(2007) JAAA*

Aging and auditory perception: A multi-level problem



- Peripheral
- Central
- Higher-level factors (e.g., attention, memory)

Sensory ⟷ Cognitive

- Age-related changes in auditory system reduce the fidelity of the signal being delivered to higher cognitive systems.
- Impair performance in cognitive tasks may be related to impoverish sensory processing.
- Controlling for age-related changes in sensory processing can attenuate and even abolish age differences in tasks involving attention and/or memory.

While hearing is a sense, listening is a skill that depends on cognitive abilities such as attention and memory.

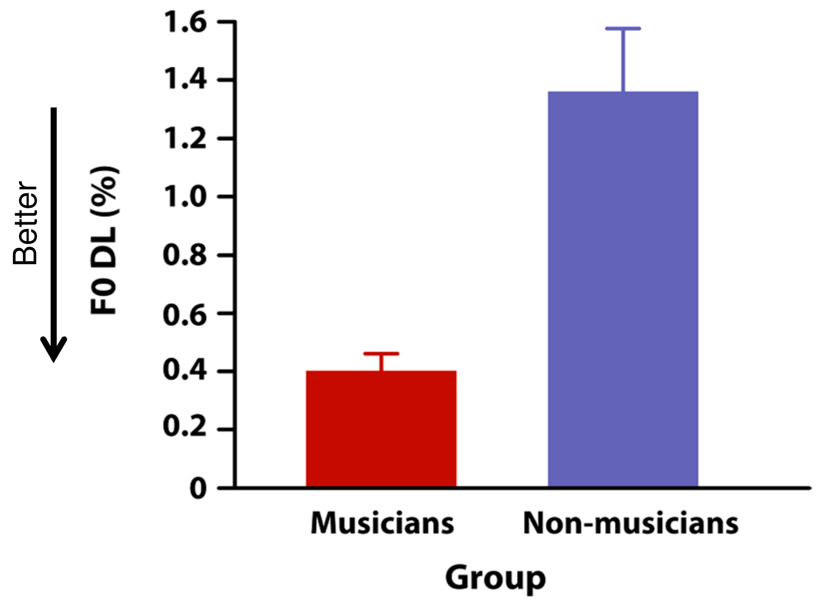
Lifestyles which demand an acute auditory system (e.g., being a musician) may enhance cognitive reserve which in turn could mitigate some of the age-related decline in auditory processing abilities (e.g., following a conversation in noisy environment such as a restaurant).

What so special about musical training?

- Playing a musical instrument is a complex task
- Many hours of daily practice
- Fine hand/finger audio-motor coordination
- Musicians listen attentively (apply meaning) to the musical sounds
- Audio-visual processing
- Musicians are often faced with complex listening problems where multiple sound sources are present.
- Music playing has cognitive, physical and social components, so it engages many brain networks.

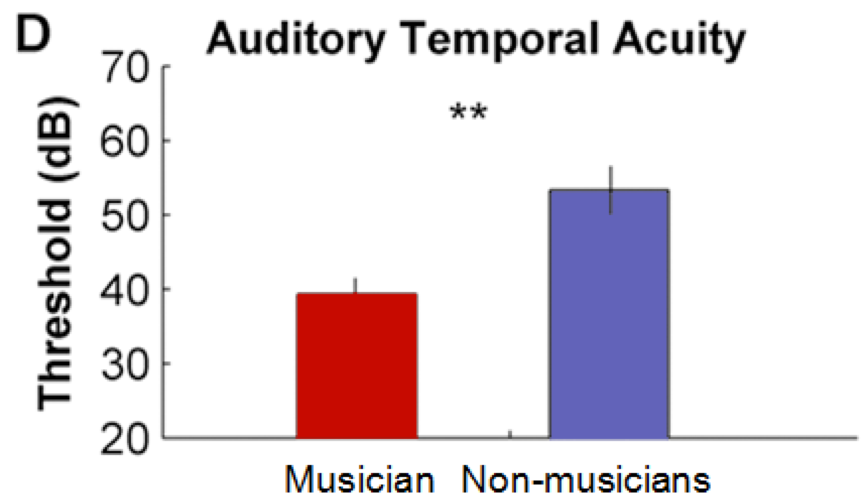
Music training improves basic spectro-temporal acuity

Pitch discrimination



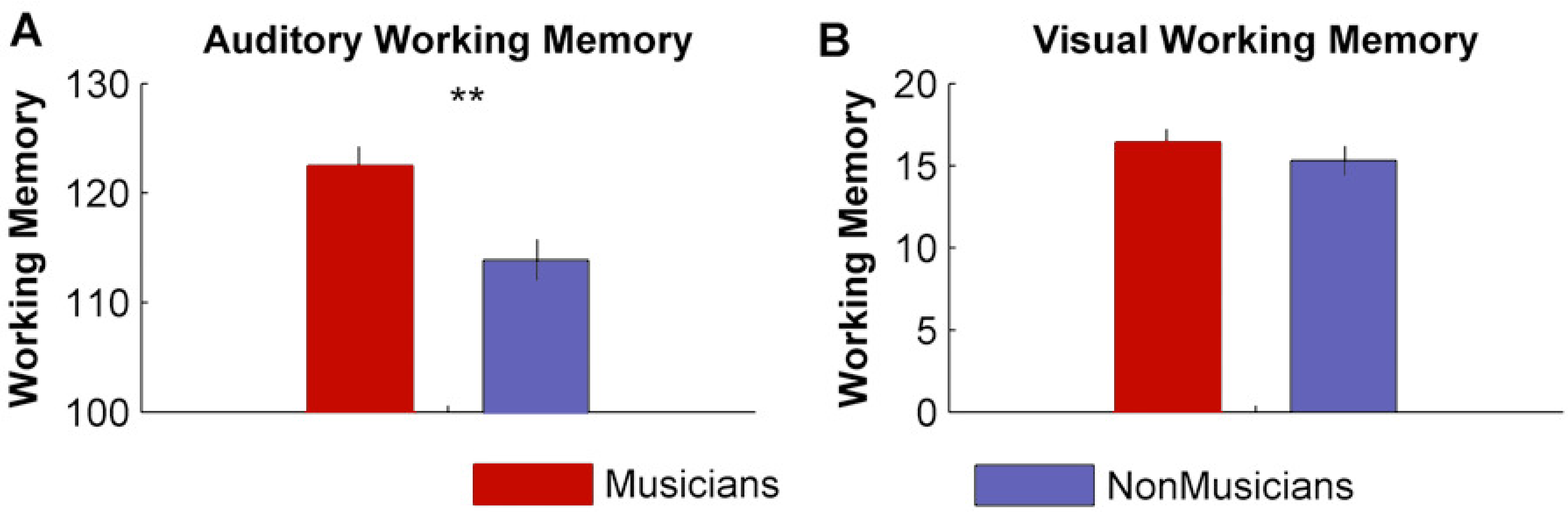
Bidelman et al, *EJN*, (2011)

Auditory temporal acuity:
Backward masking



Parbery-Clark et al, *PLoS ONE,* (2011)

Music training enhances performance in auditory working memory

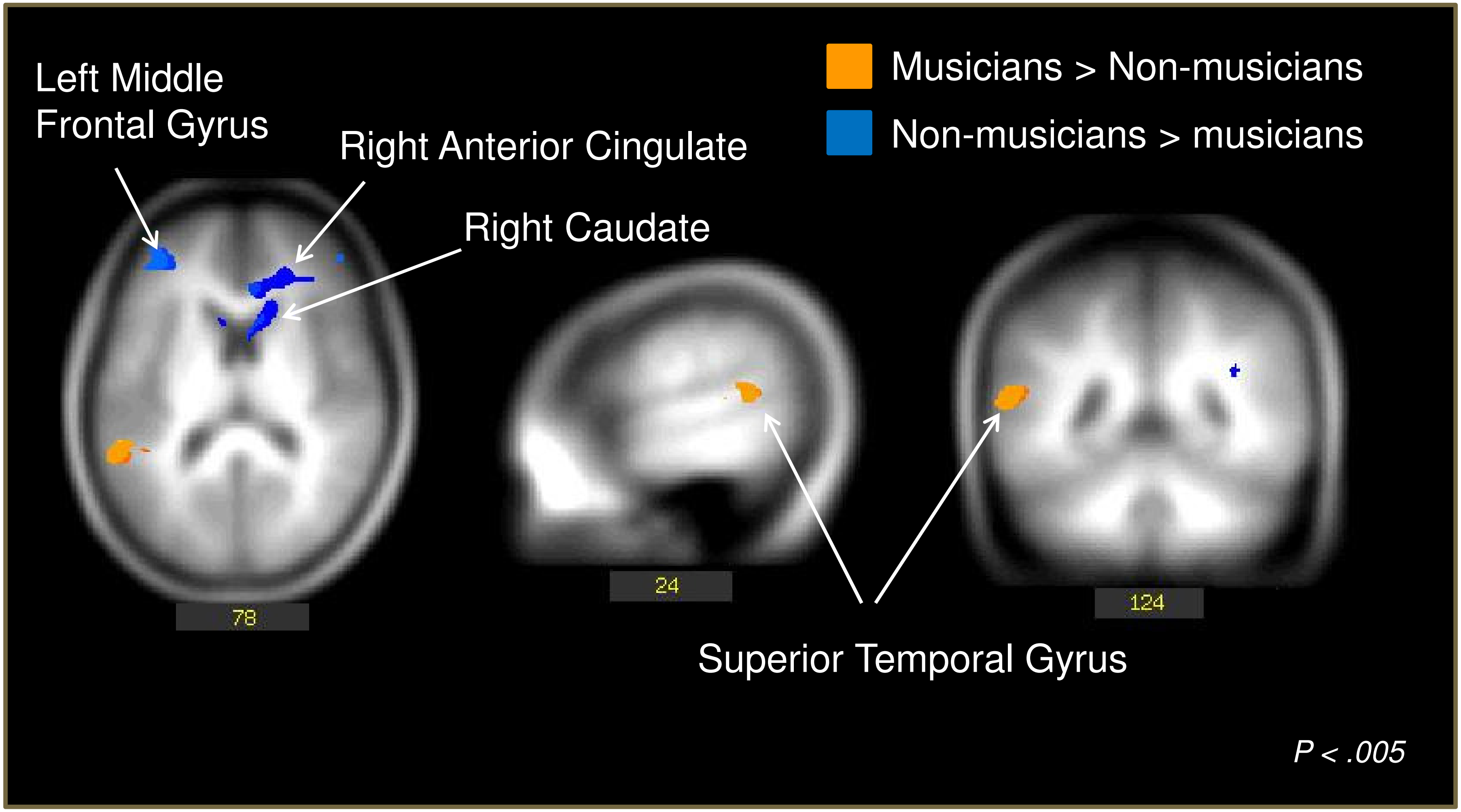


Woodcock-Johnson III Test of Cognitive Abilities Subtest for auditory working memory and memory for number reversed.

The Colorado Assessment Test's visual working memory subtest.

Parbery-Clark et al. (2011) *PLoS ONE*

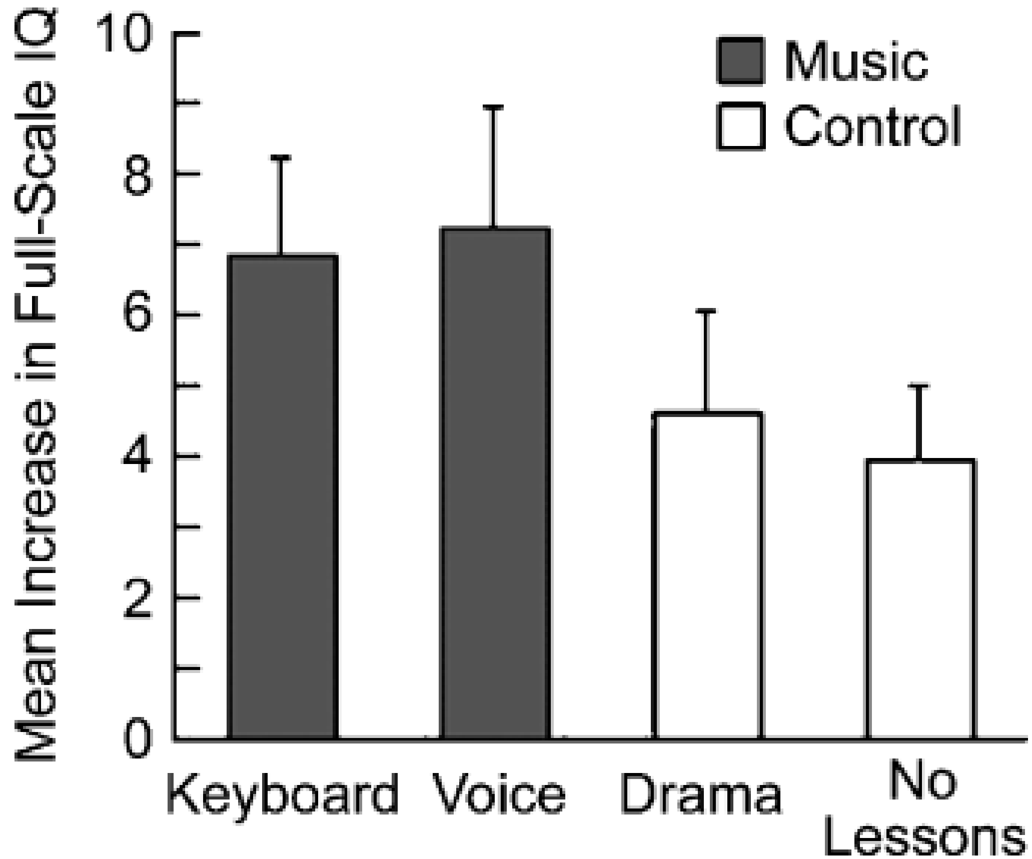
Music training enhances performance in auditory working memory



Alain et al. in progress

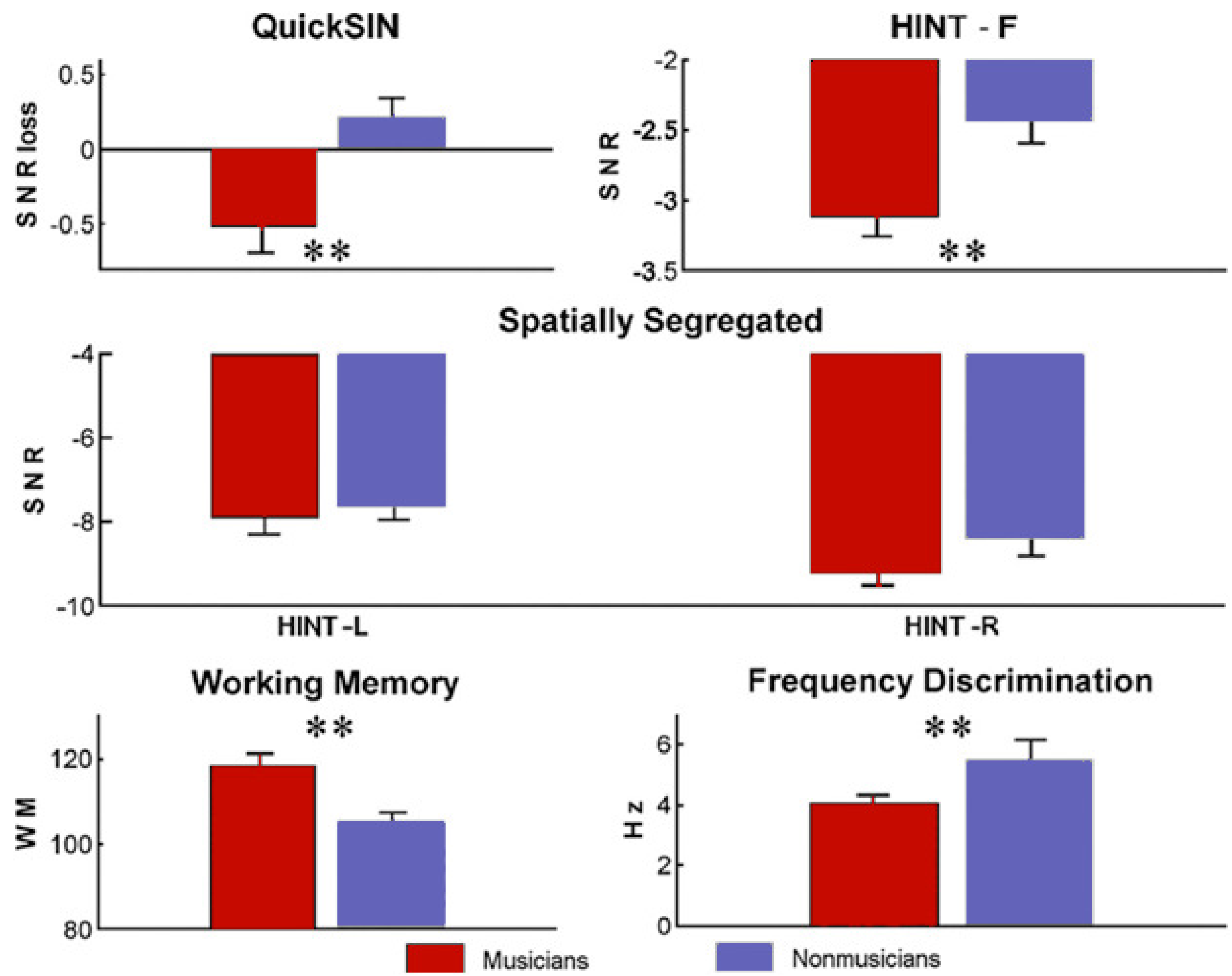
Music Lessons Enhance IQ

Mean increase in full-scale IQ (Wechsler Intelligence Scale for Children–Third Edition) for each group of 6-year-olds who completed the study. Error bars show standard errors.



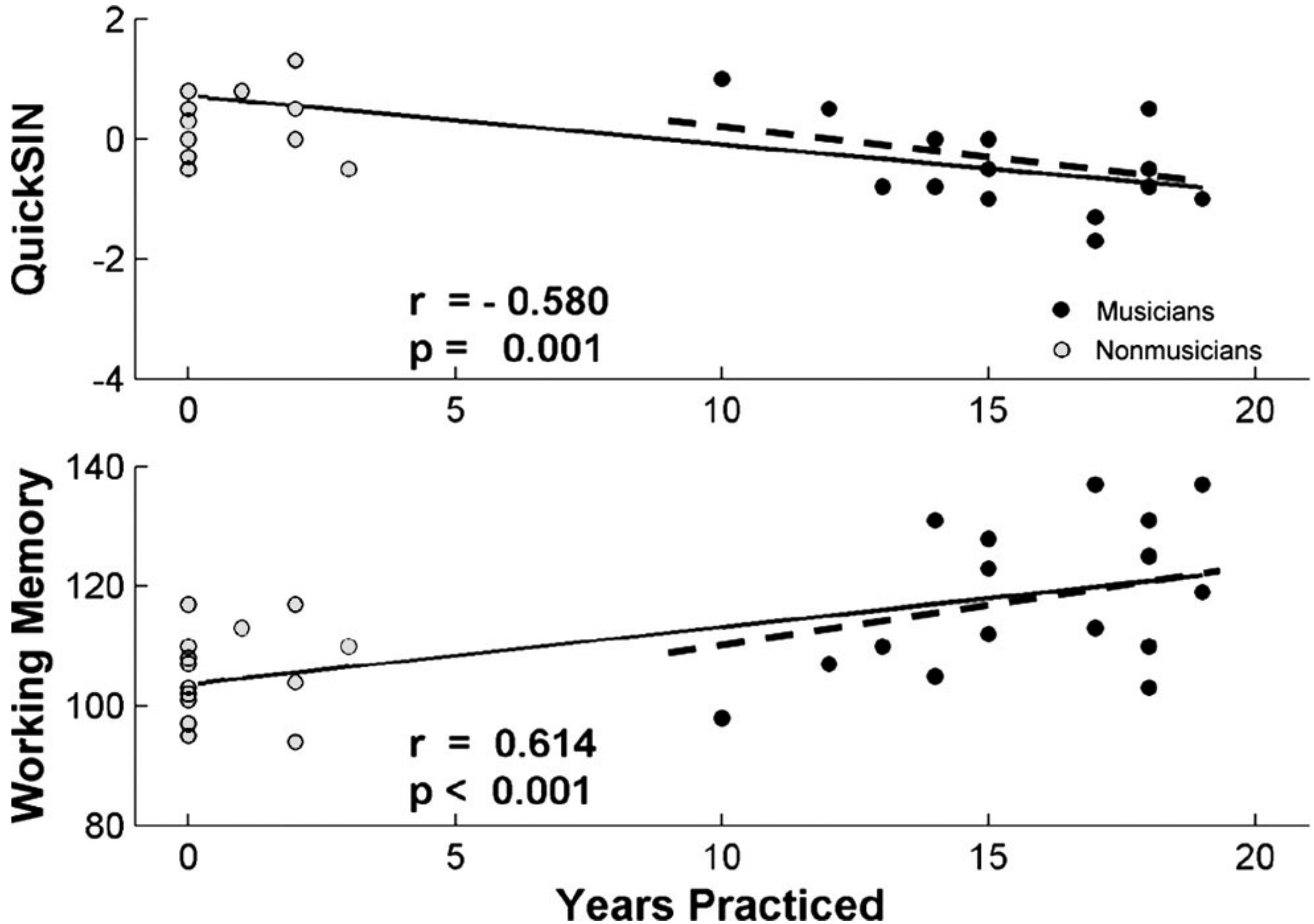
Schellenberg, E.G. (2004) *Psychological Science*

Are there implications for music training affecting the ability to hear and understand speech in real-world environments?



Musicians (black) were found to perform significantly better than Non-musicians (gray) on QuickSIN (*p 0.004), HINT-F* (*p 0.008), working memory (p 0.004) and frequency* discrimination (*p0.001). No group differences* were found for HINT-R or HINT-L. ***, p 0.01.*

Parbery-Clark et al. (2009) *Ear and Hearing*



Years of consistent practice correlated (solid line) with QuickSIN (*r 0.580, p 0.001) and working* memory ability (*r 0.614, p 0.001). When considering just the musician* group, years of consistent practiced correlated (dashed lines) with Quick-SIN (*r 0.579, p 0.019) and working memory (r 0.494, p 0.052)* scores. Musicians are plotted in black and non-musicians in gray.

Music training improve speech in noise understanding

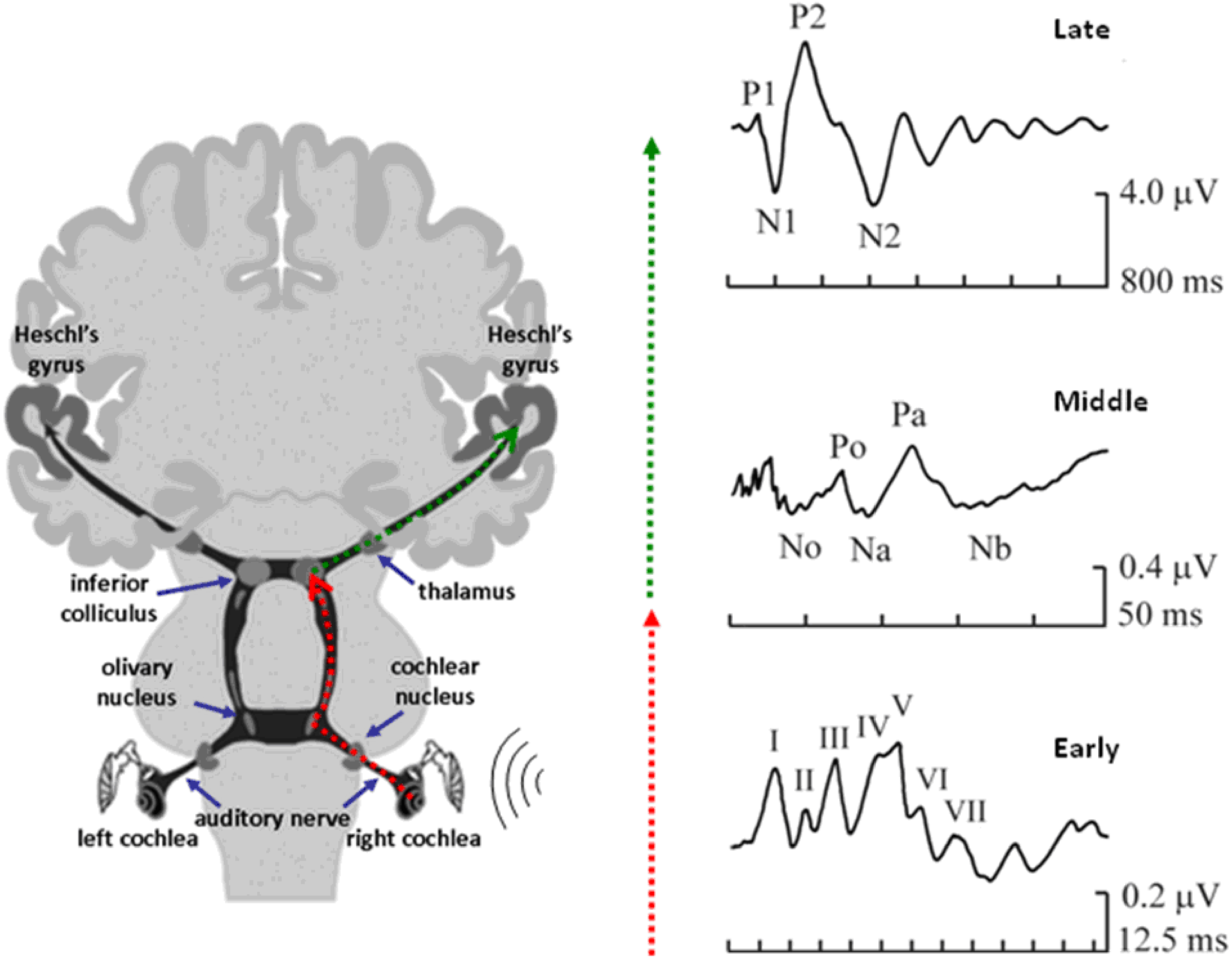
- Music as a form of long-term auditory training that induces learning-associated neuroplasticity that may extent to clinical population.

- Our studies are based on the assumption that the effect of music training translate to enhance neural encoding of speech stimuli.

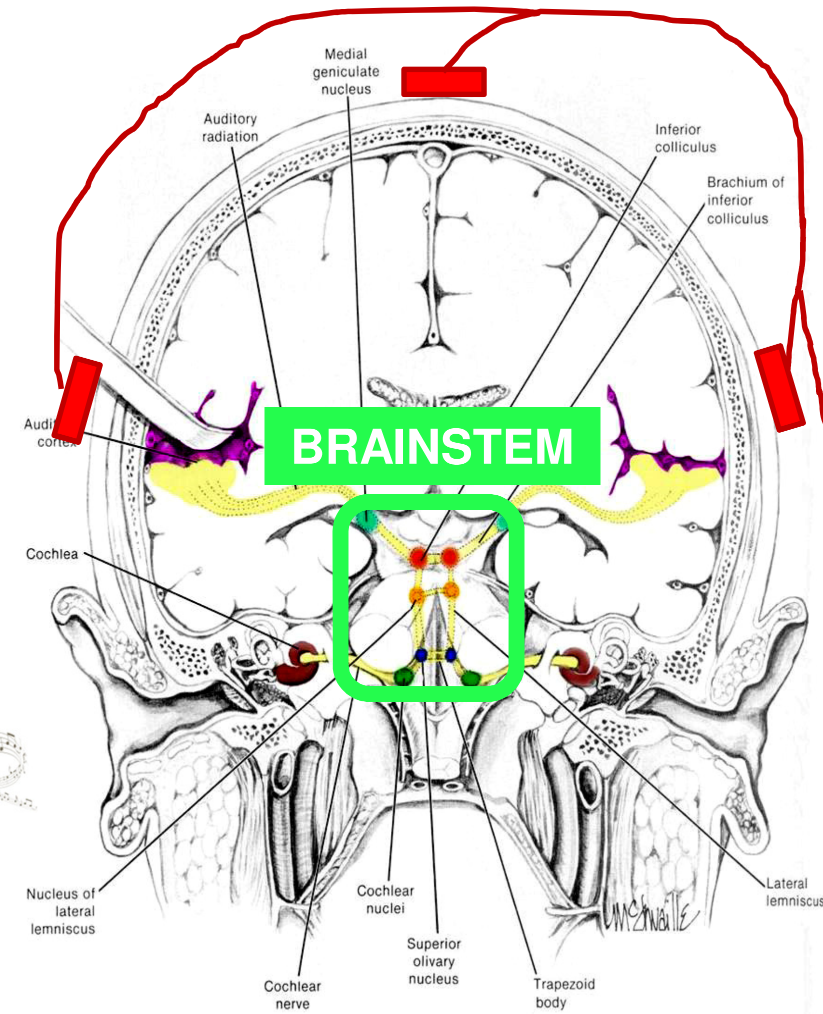
The OPERA Hypothesis

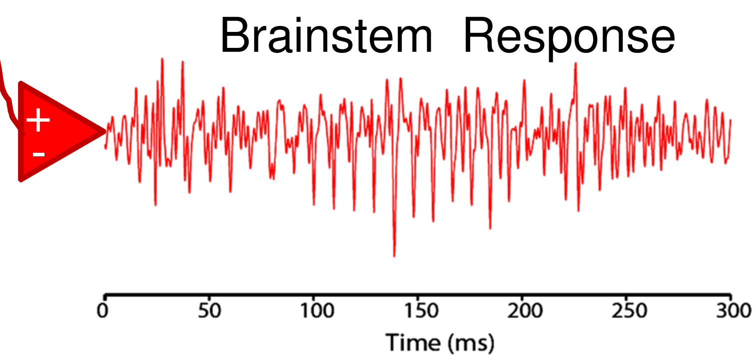
- **Overlap:**
  - The biological circuitry that process sound is common to speech and music;
- **Precision:**
  - The neural processing in these shared anatomic networks is more precise for music than for speech;
- **Emotion:**
  - Music activities that engage these networks invoke strong emotions;
- **Repetition:**
  - Musicians engage in frequent, repetitive practice; and
- **Attention:**
  - Focused attention is necessary to achieve progress.

Human Auditory Evoked Potentials



Brainstem Frequency-Following Response (FFR)



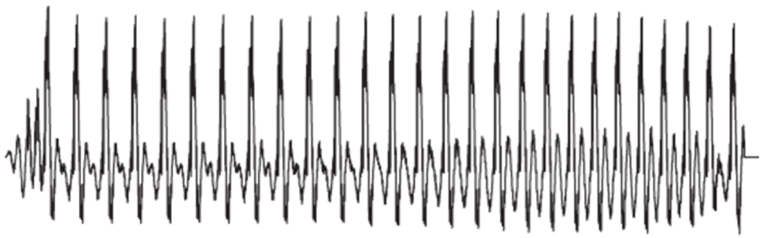


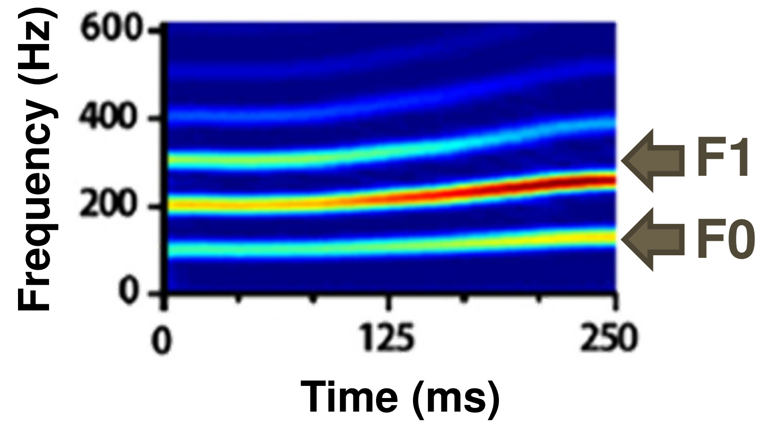
Speech evoked brainstem FFR

TIME WAVEFORM

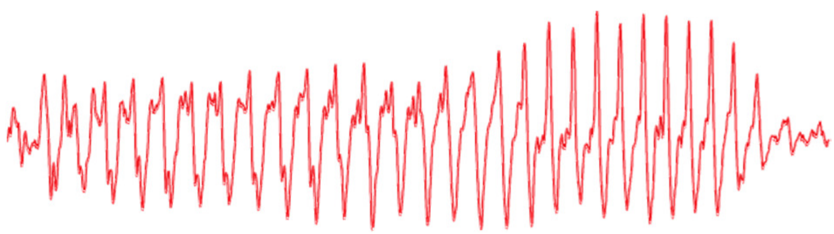
SPECTRUM

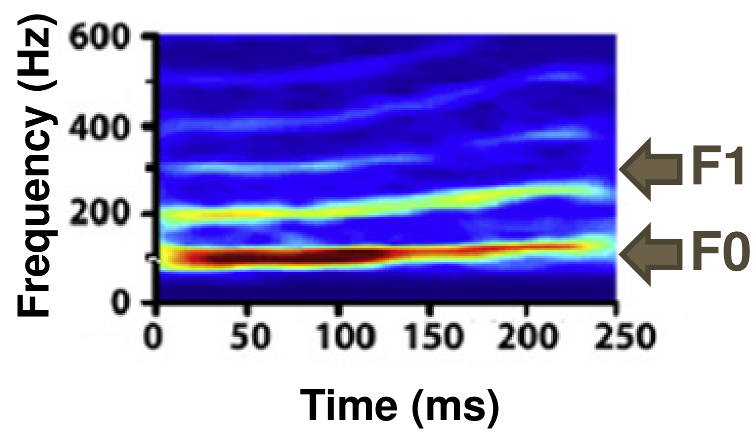
STIM.
/i/





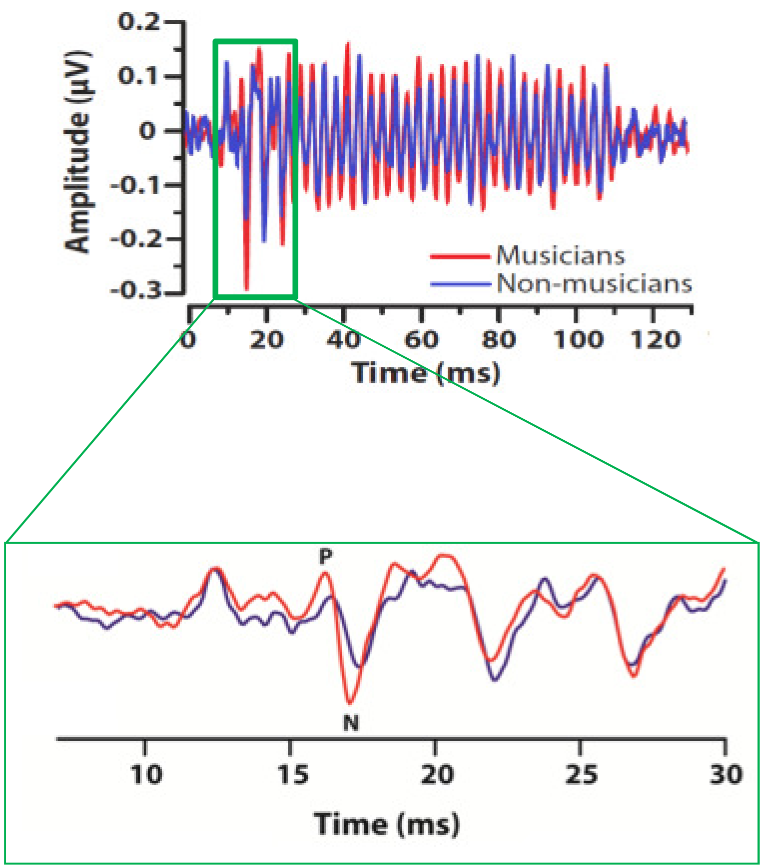
FFR

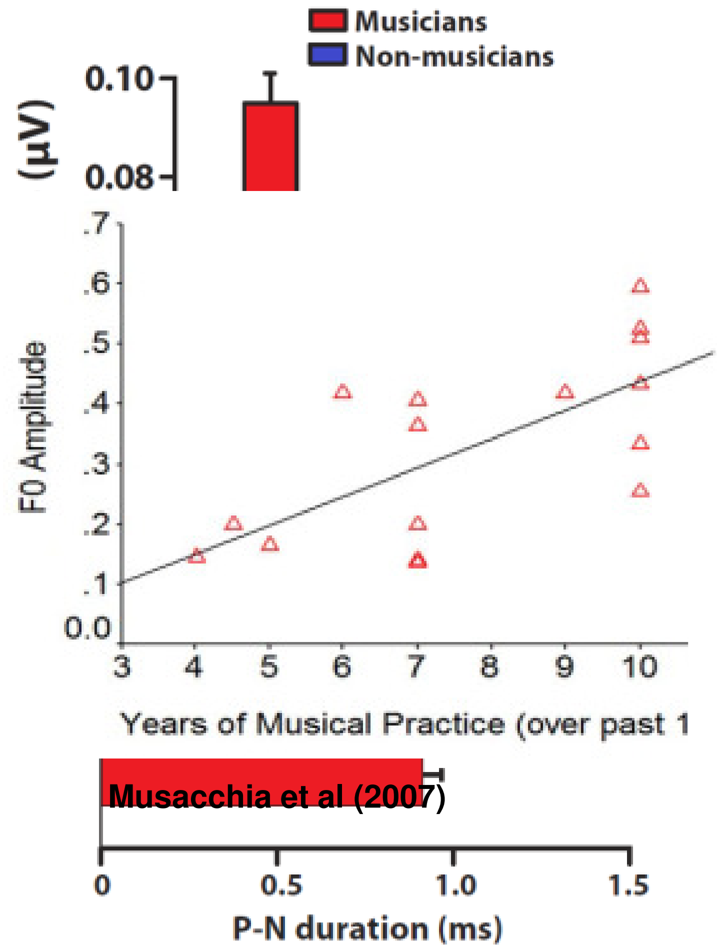




Bidelman & Krishnan, *Brain Res* (2010)

Music experience improves magnitude & precision of brainstem FFR



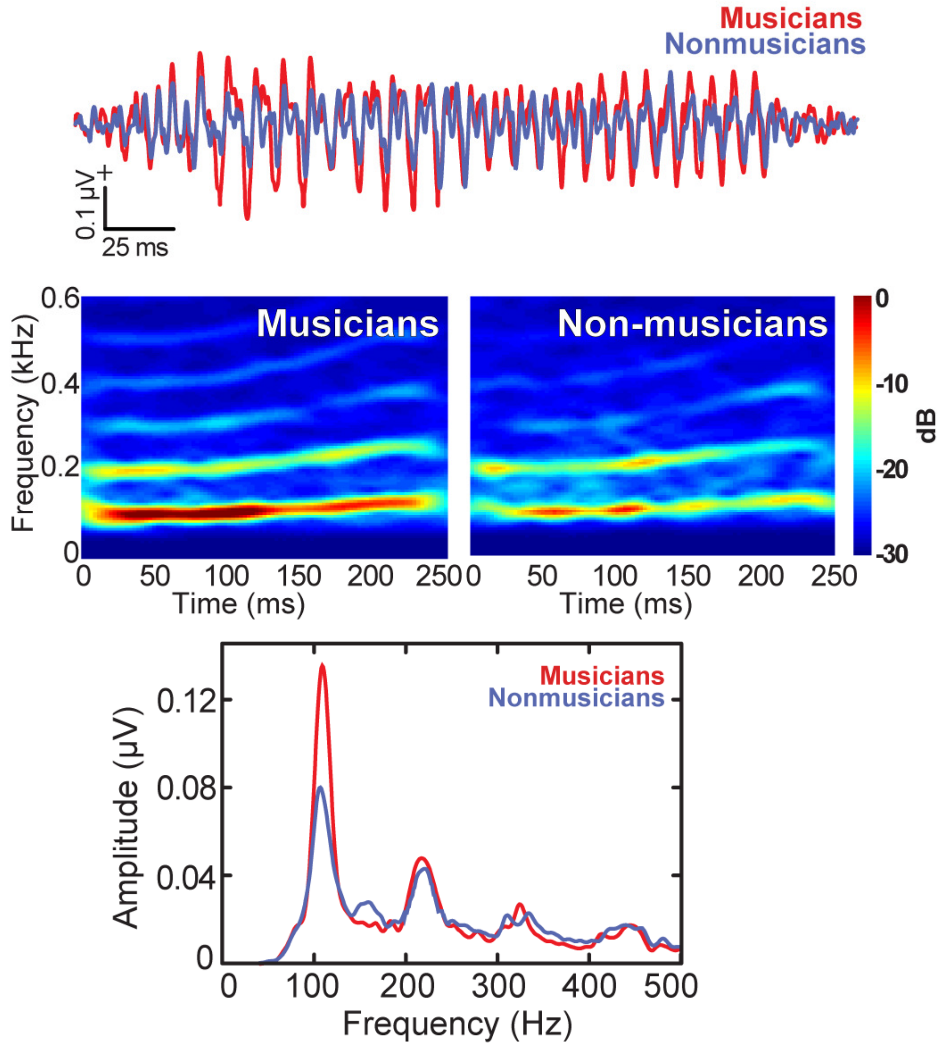


Neural Magnitude

Neural Timing

Bidelman et al. (2011) *Eur J Neurosci*

Musical training enhances brainstem encoding of speech sounds



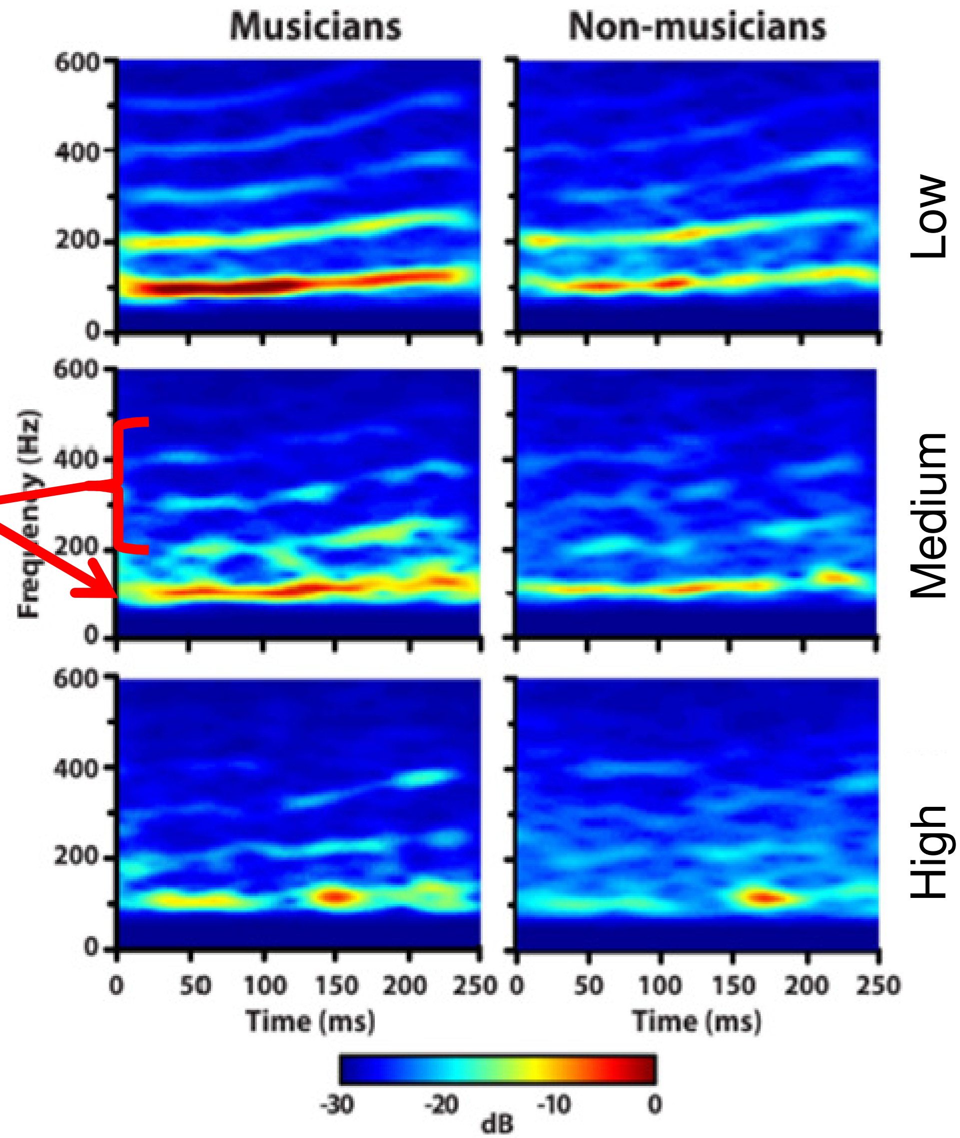
Bidelman & Krishnan (2010) *Brain Res.*

Musician’s brainstem responses are more resistant to the deleterious effect of reverberation

Vowels in reverberation SPECTROGRAMS

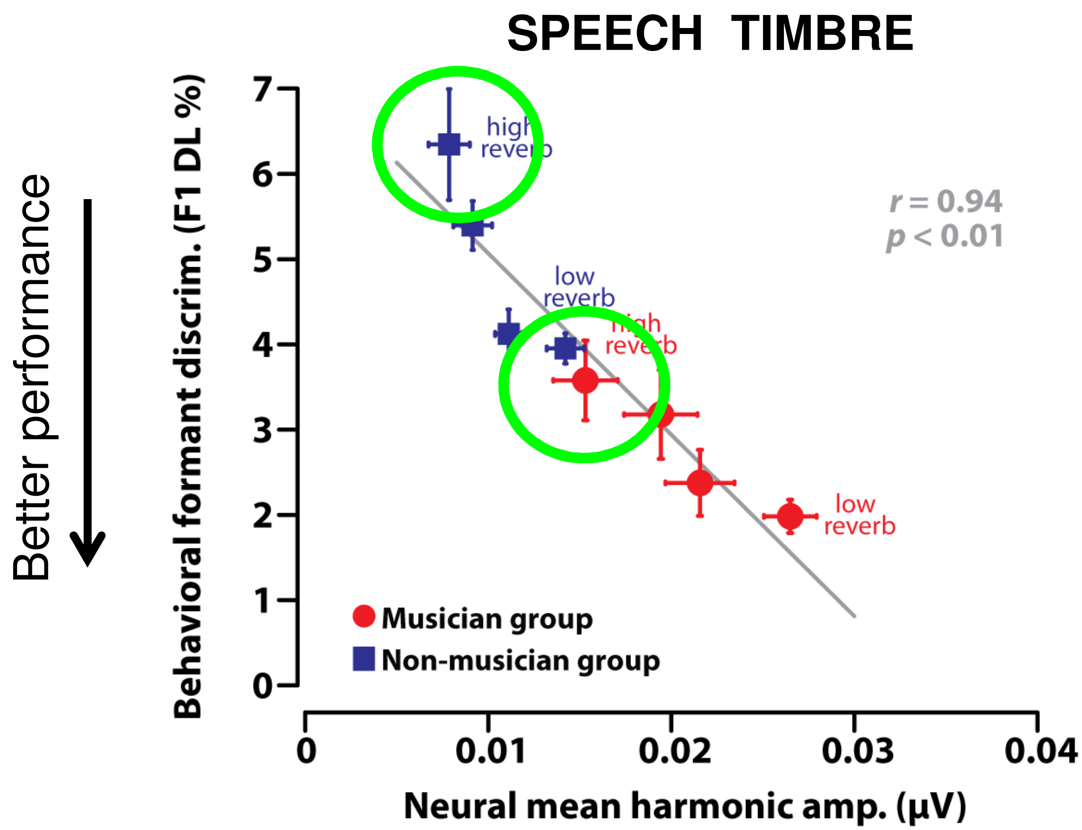
“Pitch” & “timbre” cues registered w/higher salience by musician’s nervous system

Brainstem Resp. SPECTROGRAMS



Bidelman & Krishnan (2010) *Brain Res.*

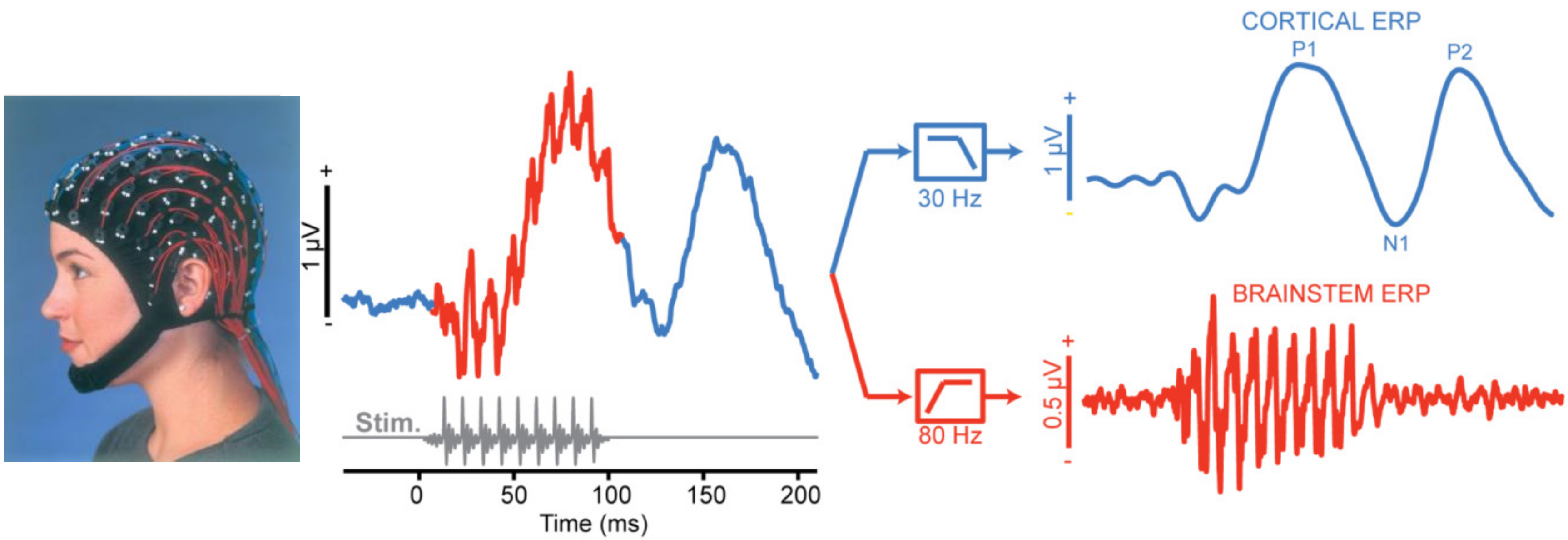
Brainstem encoding predicts speech performance in reverberation



Bidelman & Krishnan (2010)

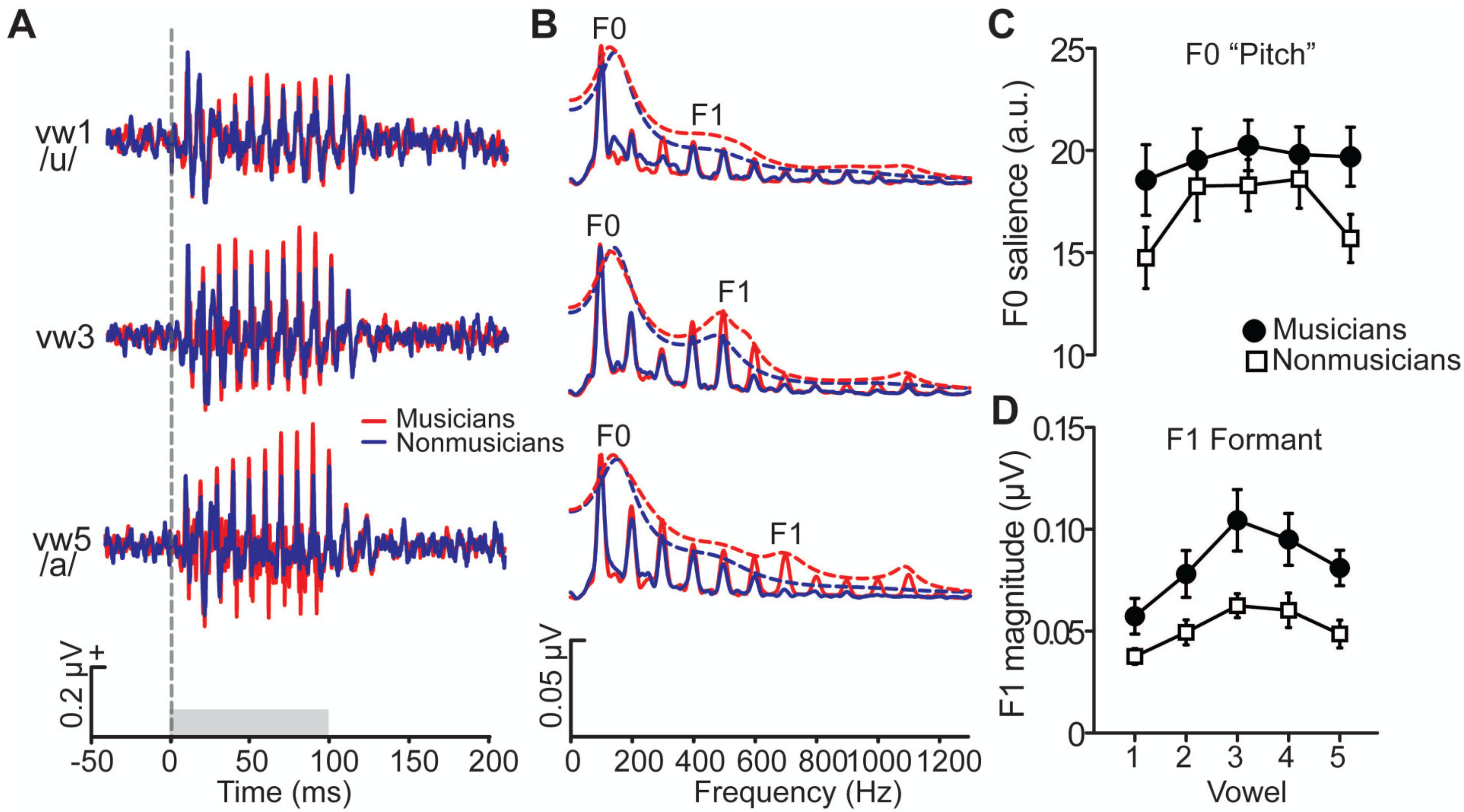
→Perceptual ability in adverse situations is predicted by neurobiological responses
→Musical training sharpens neurobehavioral responses to speech-in-noise

Tracking the emergence of sound perception



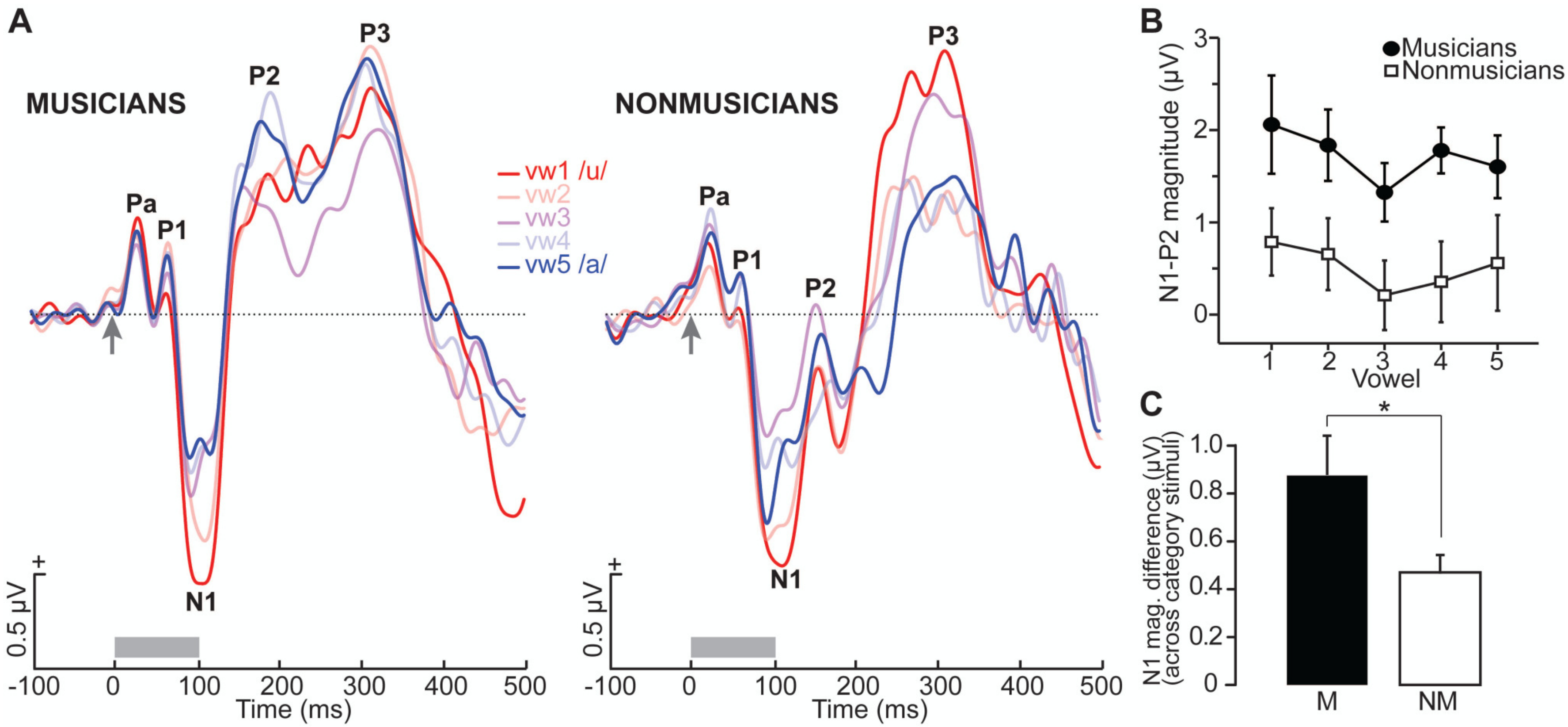
Bidelman et al. (2013)

Musical training shapes brainstem and cortical speech representation



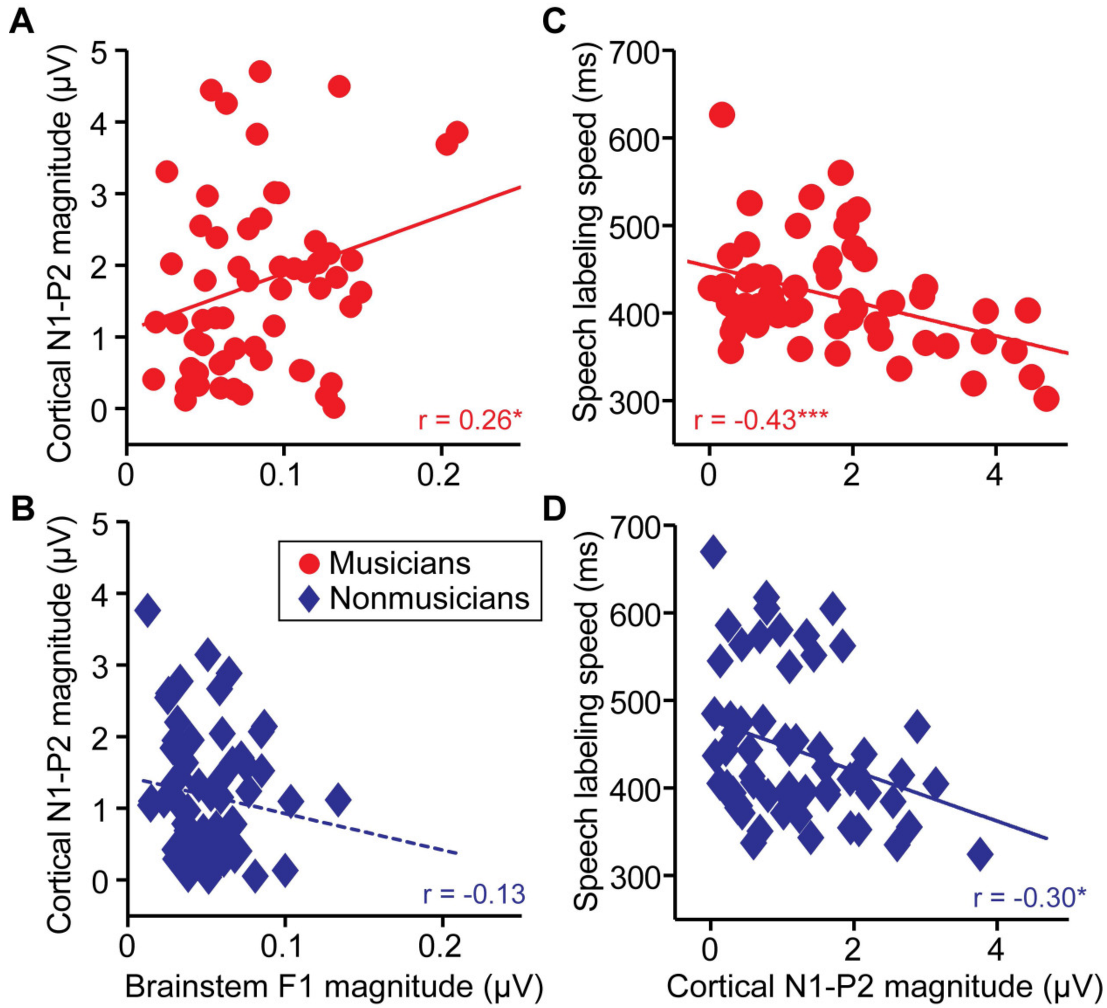
Bidelman, Weiss, Moreno, Alain (2014) *Eur J Neurosci*

Musical training improve speech perception



Bidelman, Weiss, Moreno, Alain (2014) *Eur J Neurosci*

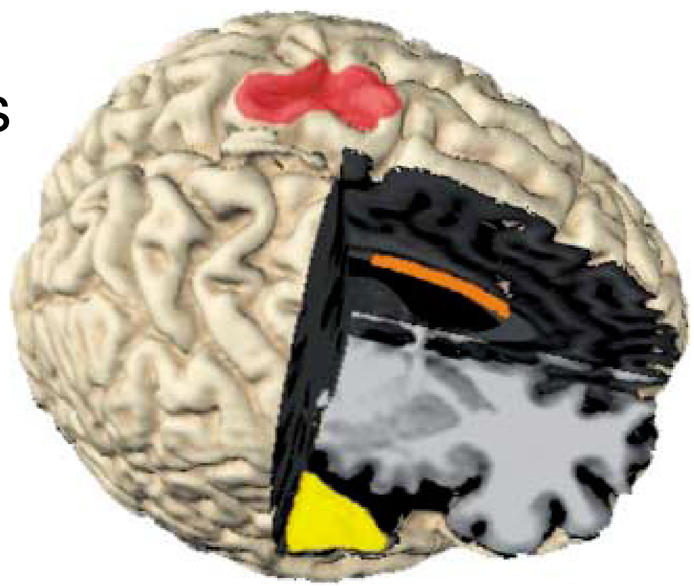
Brain behavior correlations



Bidelman, Weiss, Moreno, Alain (2014) *Eur J Neurosci*

Structural changes in the brains of musicians

- Musicians have increased volumes of:
  - Auditory cortex
  - Motor and somotosensory areas
  - Inferior temporal gyrus
  - Corpus collosum
  - Hippocampus



(Gaser & Schlaug, 2003; Schneider et al. 2002; Herdener et al. 2010; Schlaug et al. 1995)

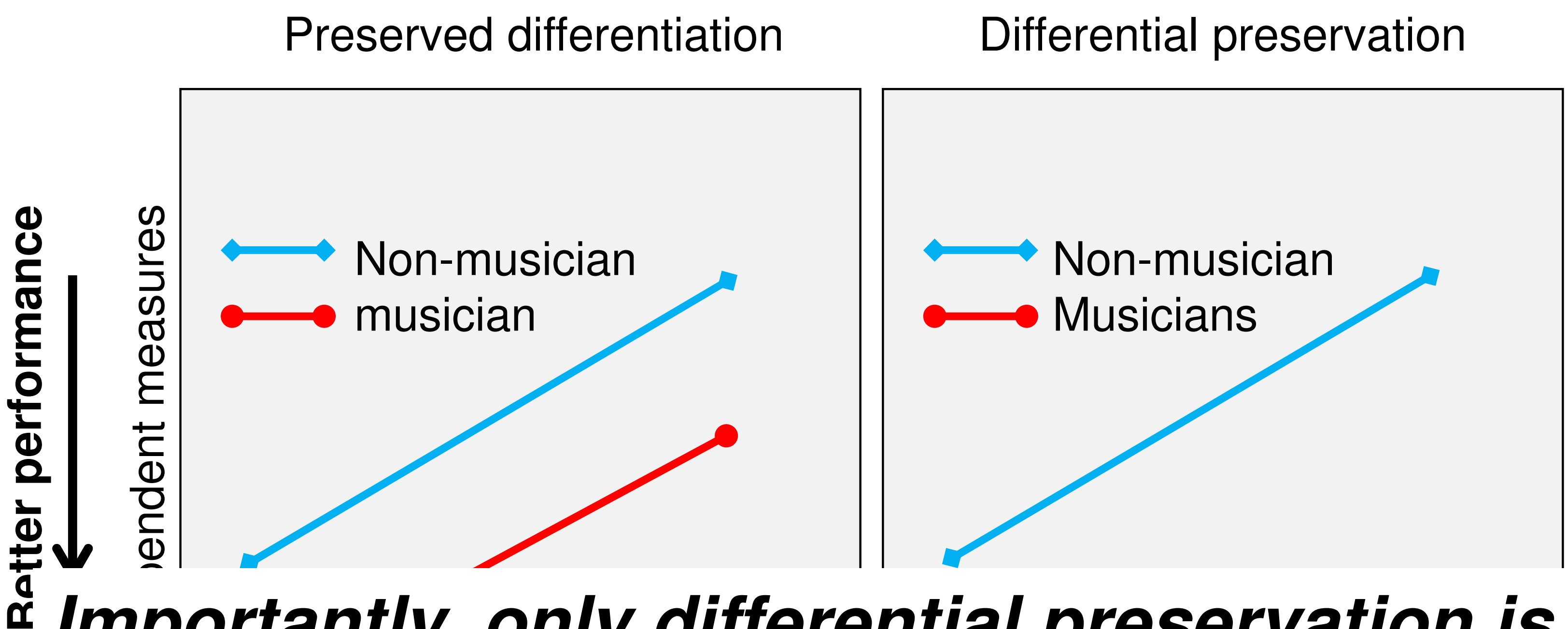
Musical training in young adults: Interim conclusion

- Musical training enhances spectro-temporal acuity, speech understanding in noise, and auditory working memory.

- Cross-sectional and longitudinal studies of musical training revealed neuroplastic changes in brainstem as well as in auditory cortex.

- ***Does lifelong musicianship mitigates age-related decline in auditory perception and cognition?***

Musical training, aging and the processing of auditory stimuli: Two possible outcomes



Importantly, only differential preservation is indicative of a protective effect of expertise because it indicates an additive benefit of experience over time.

Effects of lifelong musicianship

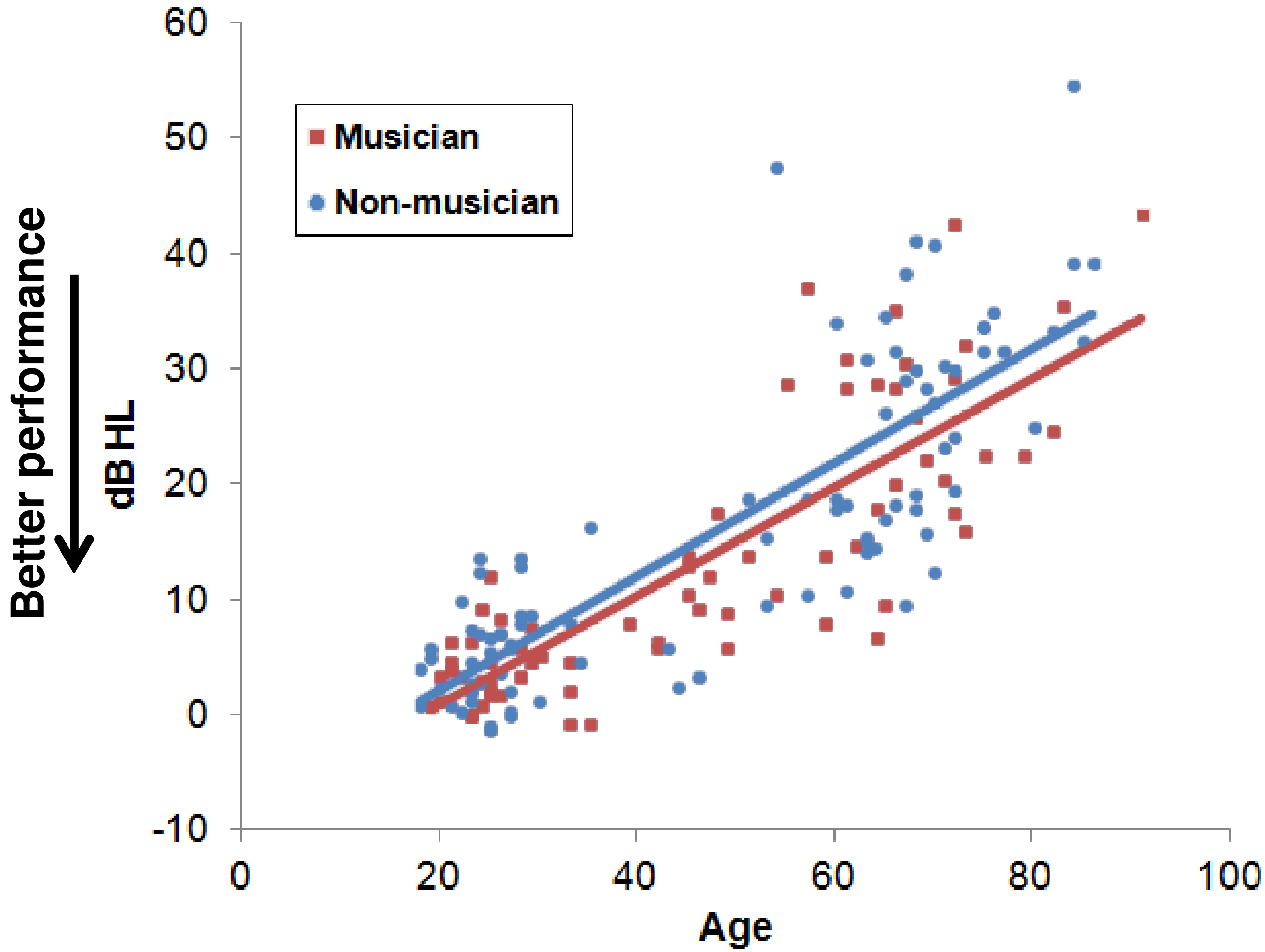
- 163 participants aged between 18 and 91 year.
  - Musicians (N=74, 19-91, 35 women)
    - Started musical training by the age of 16
    - continued practicing music until the day of testing
    - at least six years of formal music lessons
  - Nonmusicians (N=89, 18-86, 51 women)

- Four tests
  - Pure-tone thresholds; mistuned harmonic detection thresholds; gap detection thresholds; and the Speech in noise test (QuickSIN).

Hypothesis

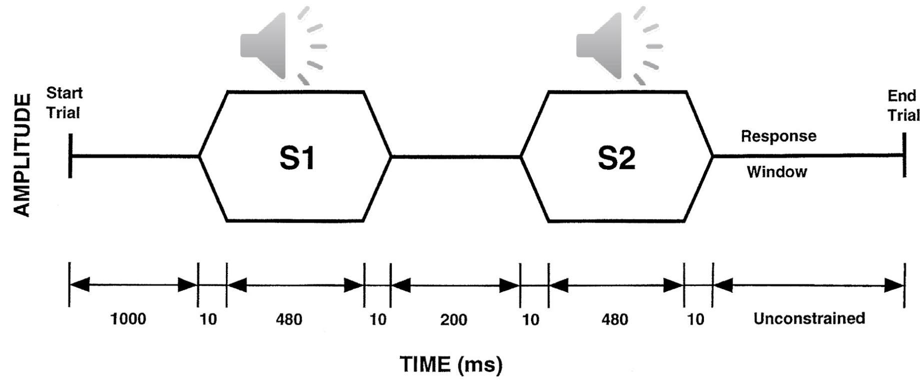
- Rate of age-related decline on task that require central auditory processing will be slower in musicians, while peripheral processing (cochlear transduction) should decline at similar rate in both musicians and non-musicians.

Pure tone thresholds: hearing sensitivity

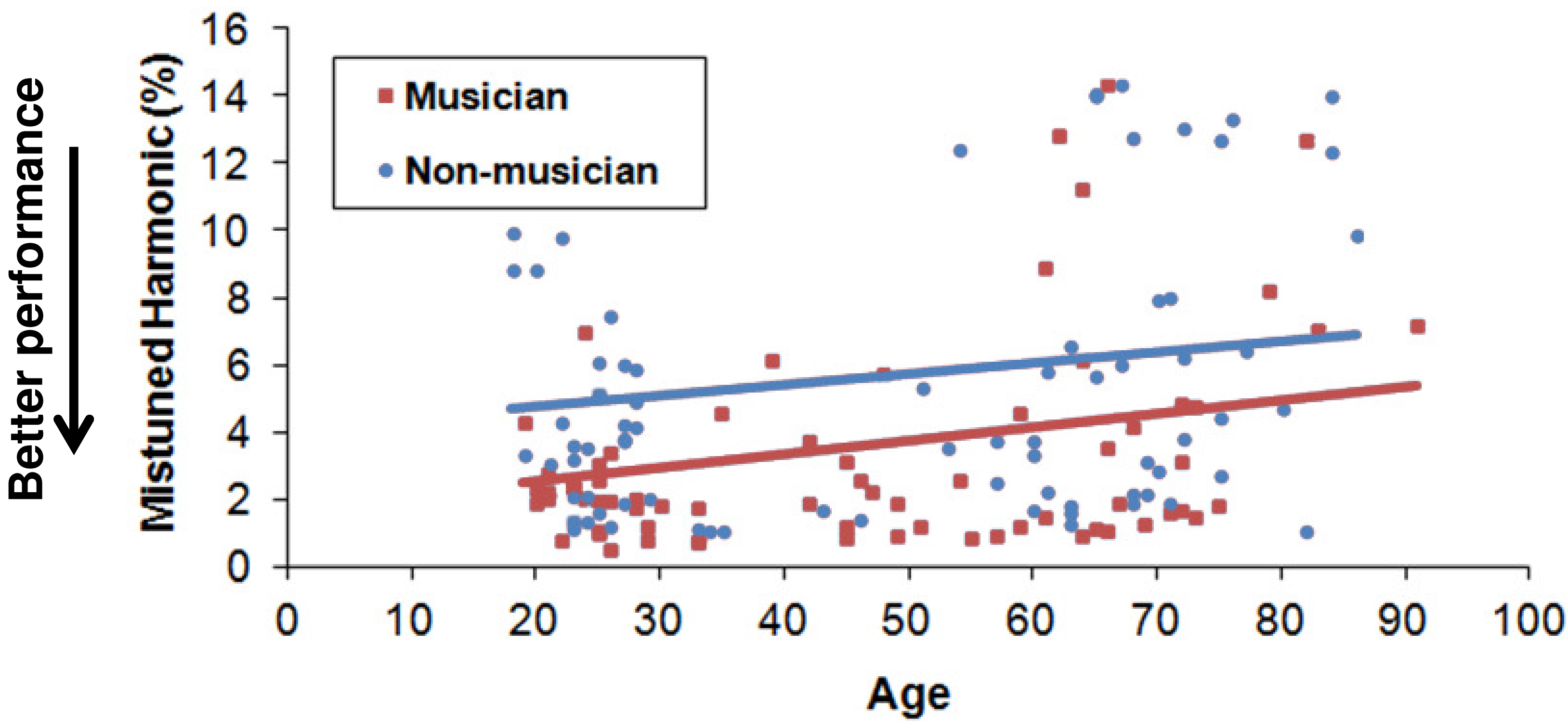


Zendel & Alain (2012) *Psychology and Aging*

Mistuned harmonic detection

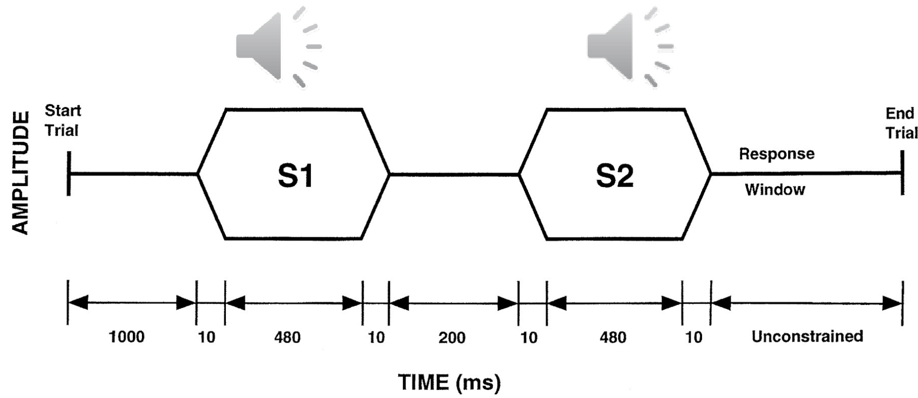


Preserved differentiation

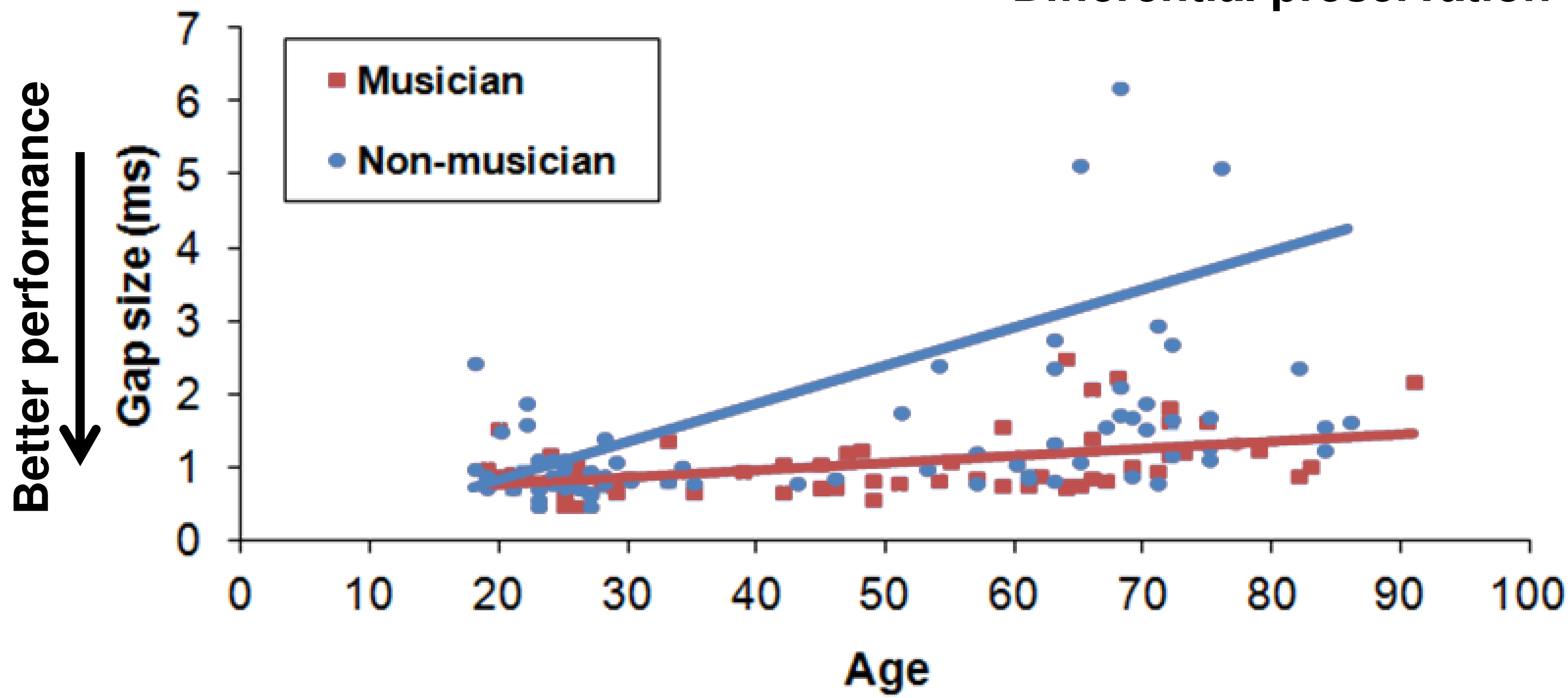


Zendel & Alain (2012) *Psychology and Aging*

Gap detection thresholds

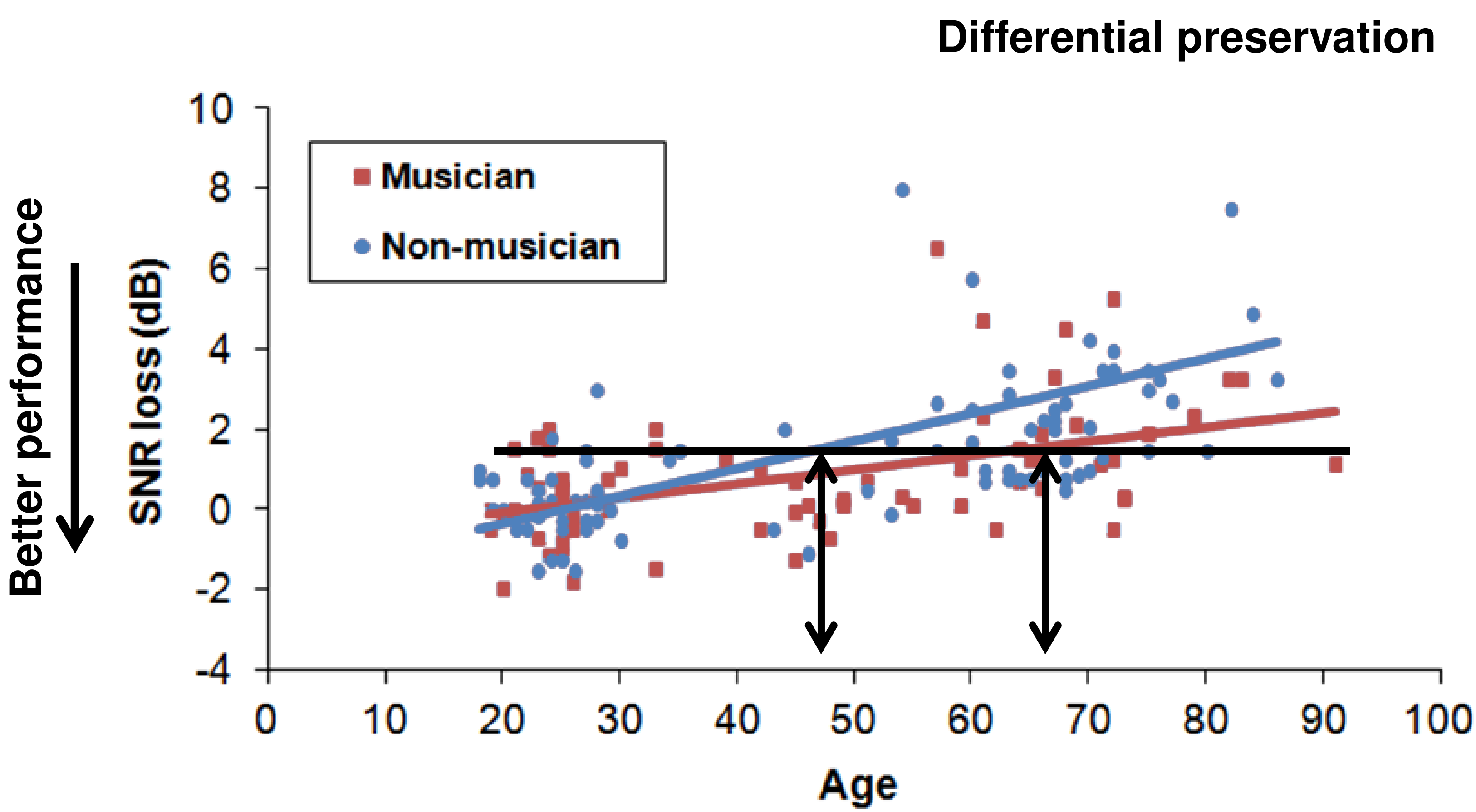


Differential preservation



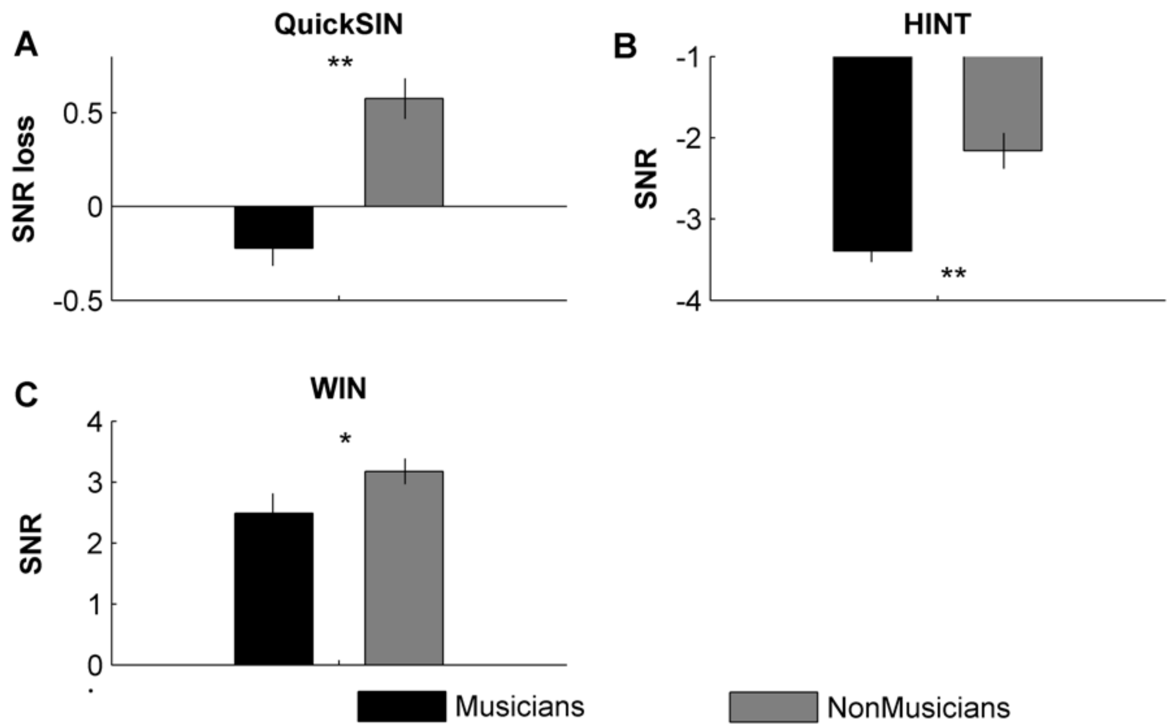
Zendel & Alain (2012) *Psychology and Aging*

Speech in noise



Zendel & Alain (2012) *Psychology and Aging*

Speech in noise



- Compared older musicians (N = 18) and nonmusicians (N = 19)
- Age: 45-65 yrs

Parbery-Clark et al. (2011) *PLoS ONE*

Summary

- Musicians and non-musicians show comparable age-related peripheral hearing loss as measured by pure tone audiometry
- Slower age-related decline in understanding speech-in-noise and gap detection thresholds in musicians (***differential preservation***)
- Lifelong benefit for mistuned harmonic detection thresholds (***preserve differentiation***)
- Central auditory processing benefits from lifelong musicianship

How does musical training mitigates age-related changes in auditory perception?

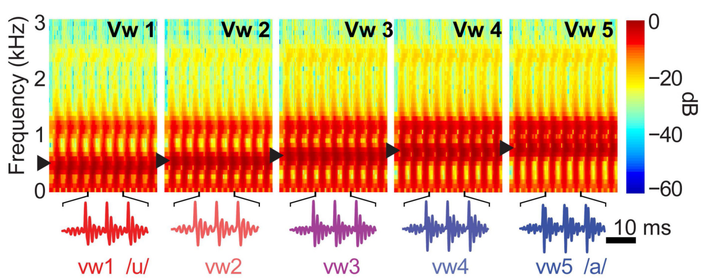
- **Bottom-up:** Musical training through adulthood may help preserved efficient early processing of sounds, so that older adults have better sound representation.

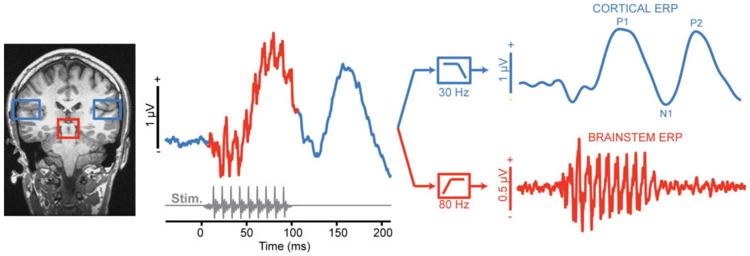
- **Top-down:** Older musicians may be better at engaging compensatory strategy to overcome impoverish sensory processing.

Musical training orchestrates coordinated neuroplasticity in auditory brainstem and cortex

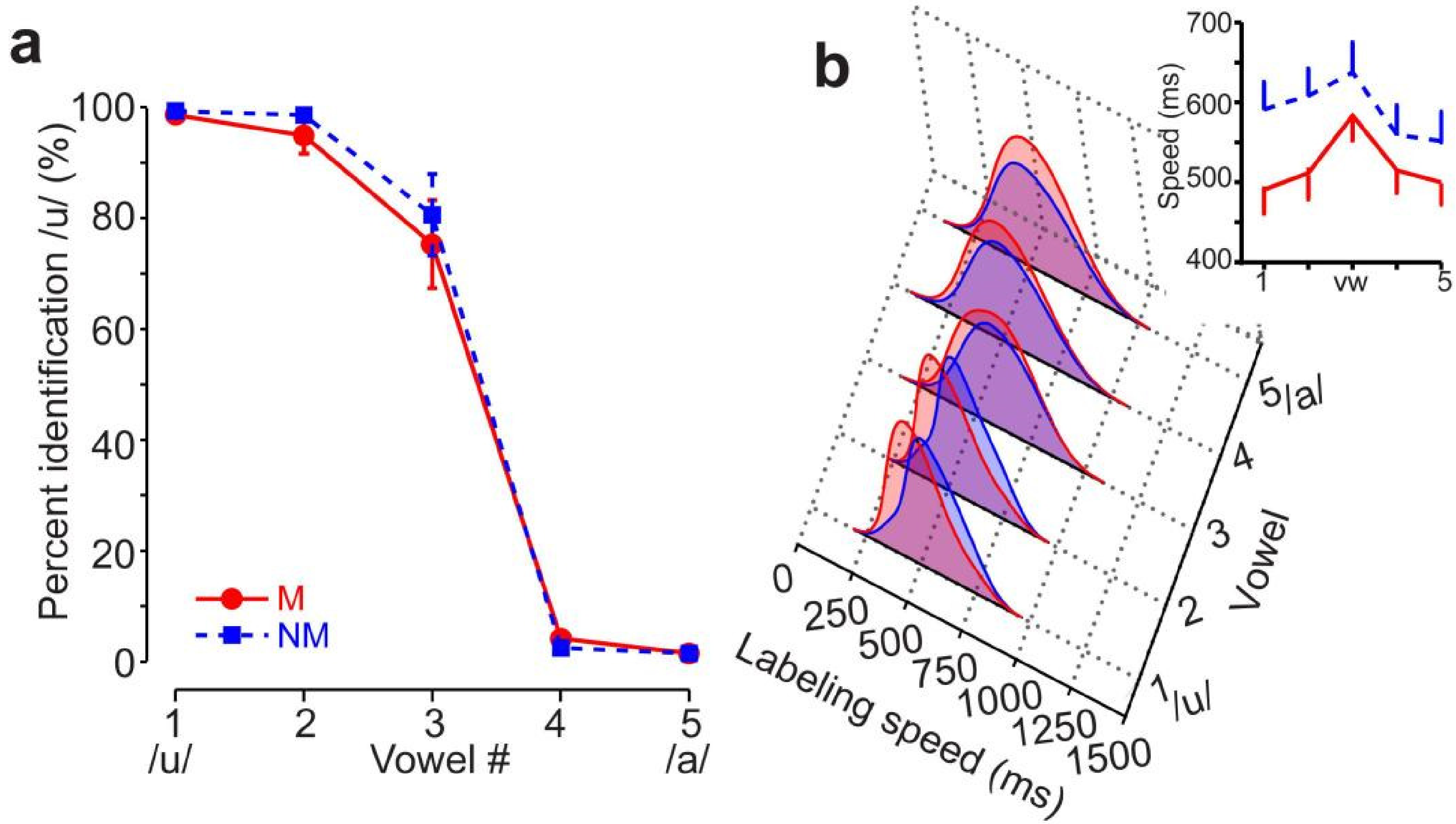
- 10 Musicians (M: 70.1 ± 7.1 yrs)
  - 5 years + of continuous private instruction
  - begin prior to age 14
  - currently active in music practice or ensemble engagement

- 10 non-musicians (69.6 ± 8.5 yrs; *p* = 0.91)



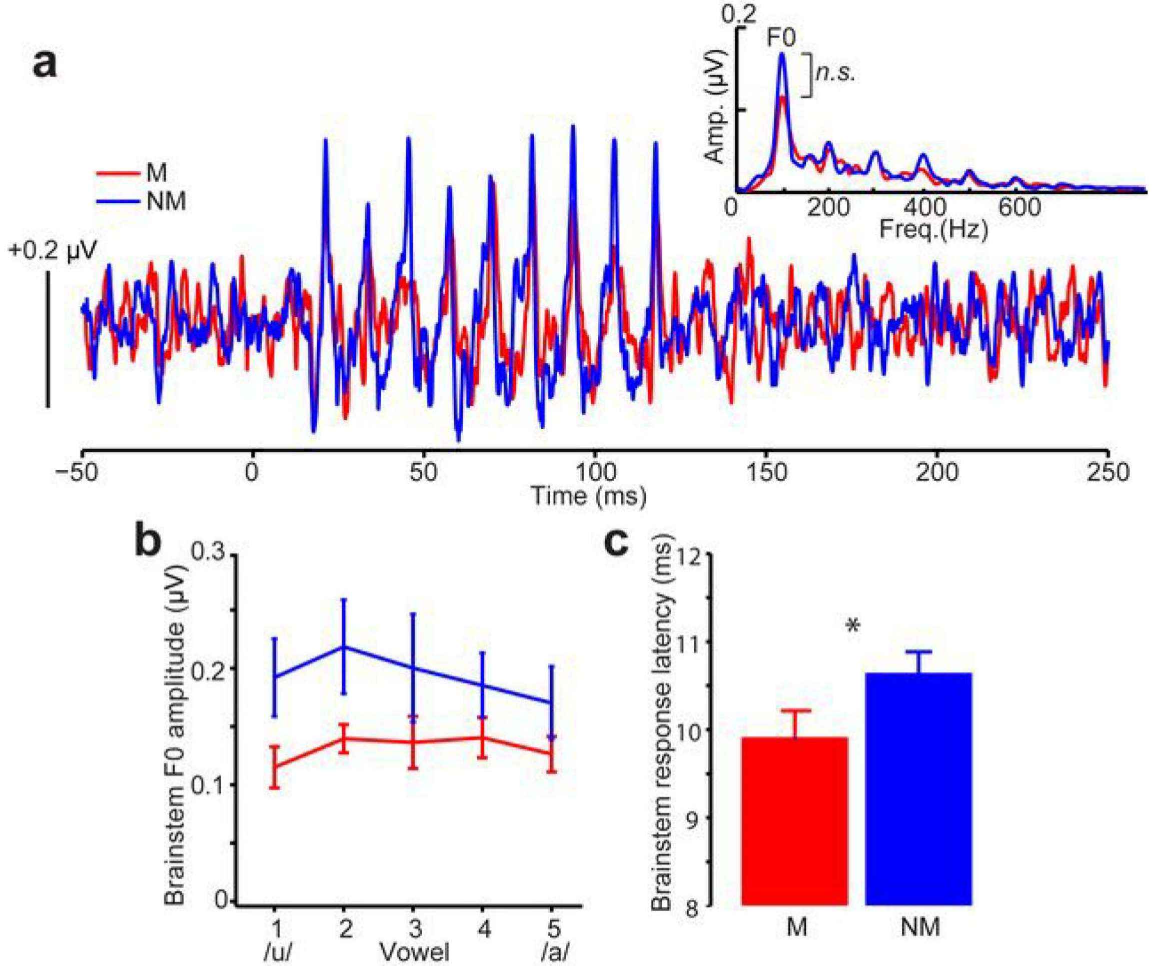


Perceptual speech classification is enhanced in older musicians relative to older nonmusicians.



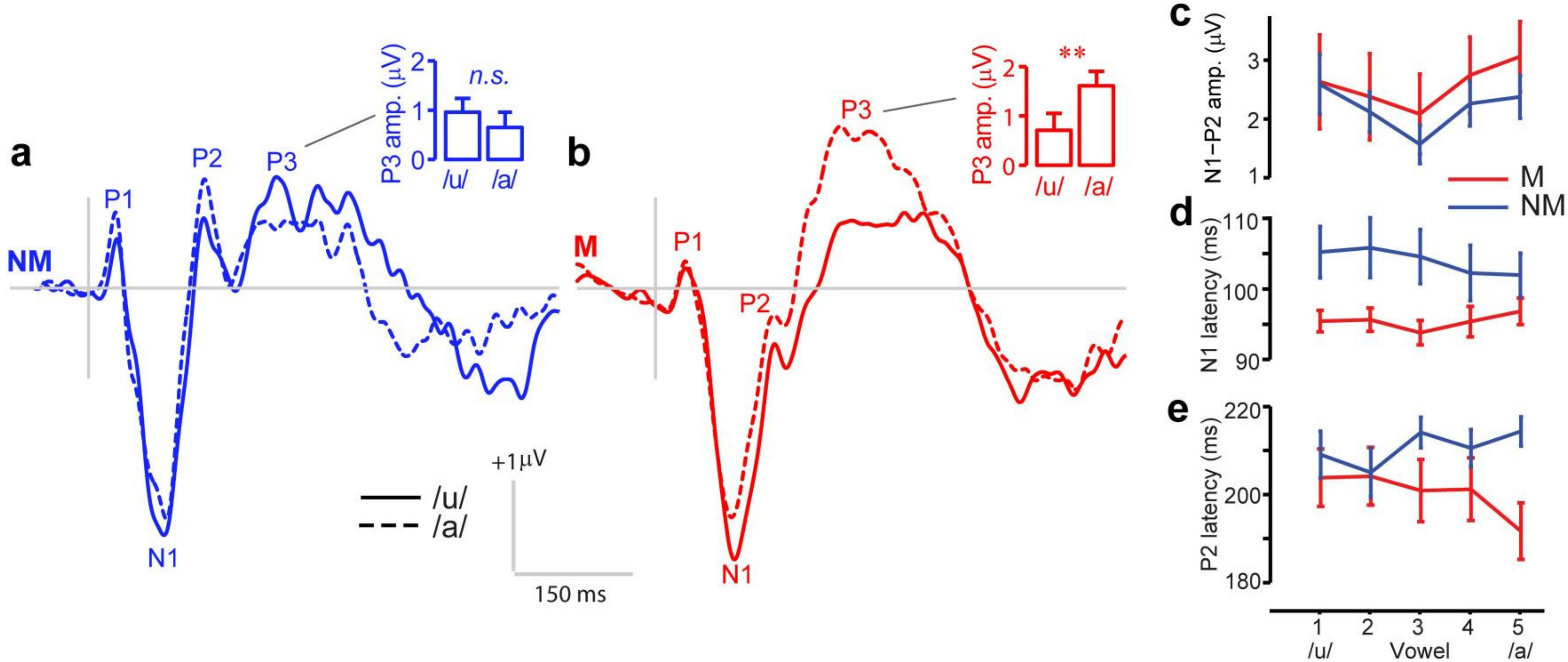
(**a**) Behavioral identification functions. (**b**) Speech labeling speeds (RTs). Probability density functions of response RTs and averages group means (inset). Musicians classify speech sounds faster than age-matched nonmusicians. M, musicians; NM, nonmusicians.

Brainstem speech encoding is more efficient in older adults with musical experience



(**a**) Brainstem response time waveforms and response spectra (inset) for the prototypical /a/ token (vw5). (**b**) No group differences are observed for F0 amplitudes. (**c**) Older musicians show faster responses than non-musicians.

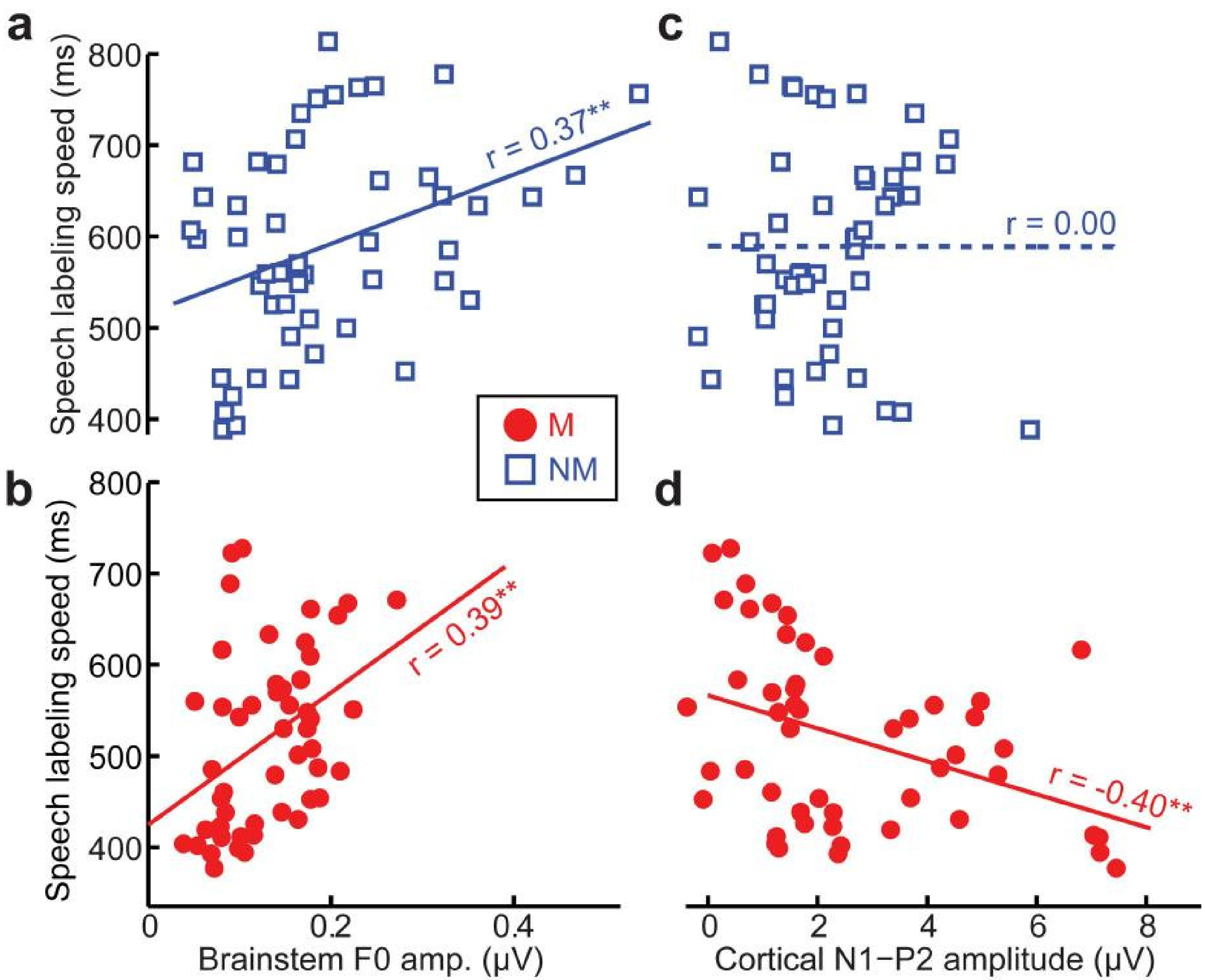
Cortical speech encoding is enhanced in older adults with musical experience



Cortical ERPs for older (**a**) nonmusicians and (**b**) musicians. (**c**) Cortical N1-P2 amplitudes do not differ between groups but are modulated by vowel stimulus. **(d-e)** Older musicians show earlier N1 and P2 responses compared to older nonmusicians. Older musicians show larger P3 responses that better differentiate speech sounds compared to nonmusicians (**a**, insets).

Bidelman & Alain (2015) *Journal of Neuroscience*

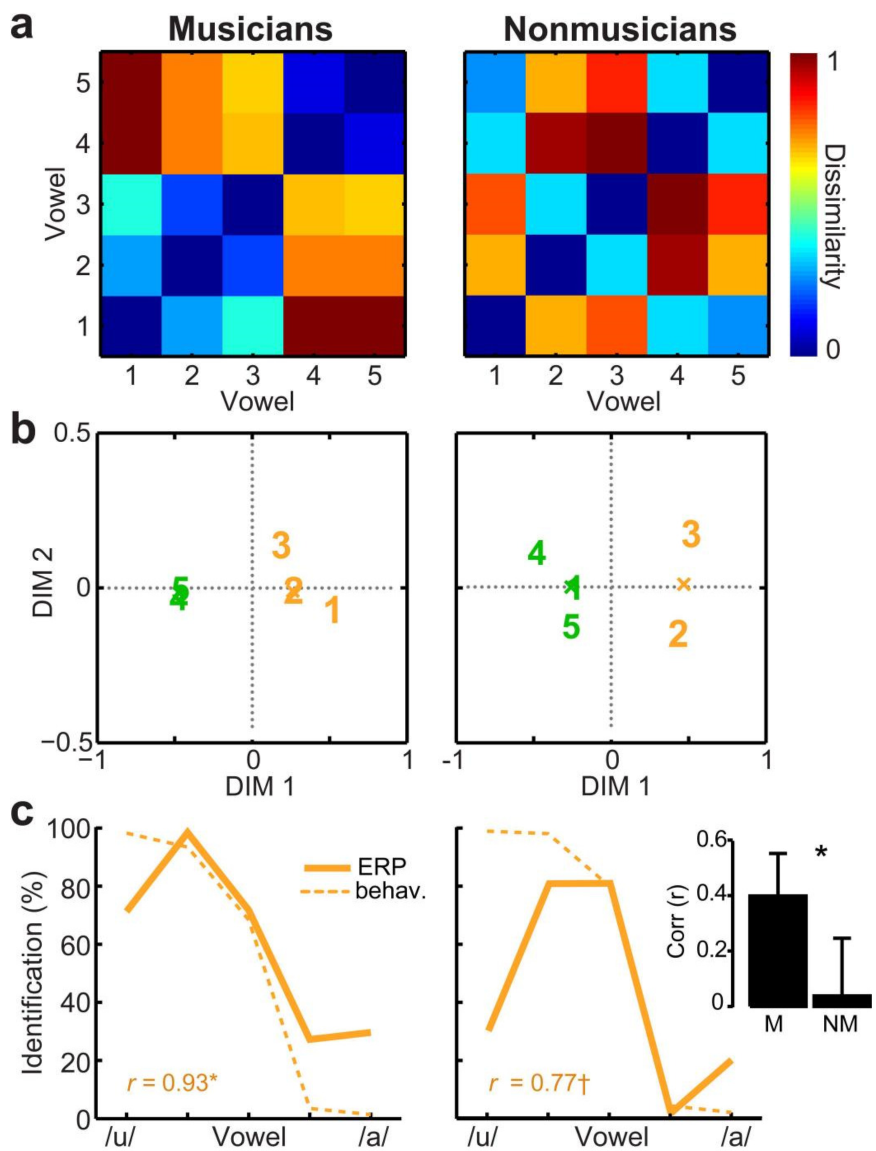
Musical experience improves coordination between brain and behavioral speech processing in the aged brain



Bidelman & Alain (2015) *Journal of Neuroscience*

Neural organization for speech is more categorical in older musicians

(**a**) Dissimilarity matrices of brain responses. (**b**) Multidi-mensional scaling (MDS) solution quantify the Euclidean distance between ERPs across the vowel continuum. (**c**) Neurometric (solid) and psychometric (dotted) categorical identification functions. Neural functions closely mirror behavior in older musicians but are much less faithful in non-musicians. (inset) Brain-behavior correlations for older musician and non-musician group.



Bidelman & Alain (2015) *Journal of Neuroscience*

Summary: Musical training enhances brainstem and cortical speech representation in older listeners

- Older adults with musical training show improved (i.e., faster more robust neural encoding of speech sound at both subcortical and cortical levels of auditory systems. ***Musical training does mitigate age-related changes in sensory encoding.***

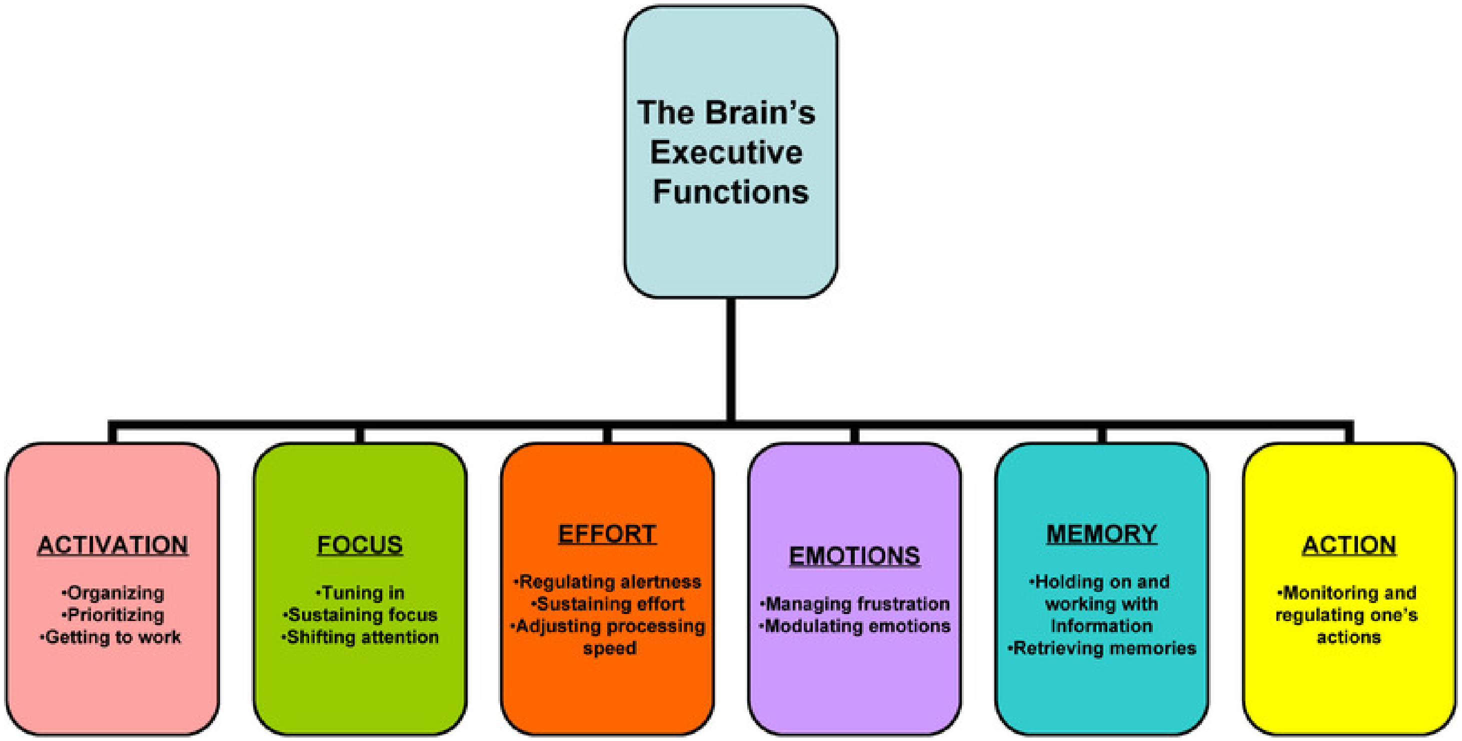
- Older musicians also showed neural representations that are more coupled to perception.

- Attention-related effects (i.e., P3b) were larger in older musicians than non-musician. ***Musical training does mitigate age-related changes in neural indices of top-down controlled processes.***

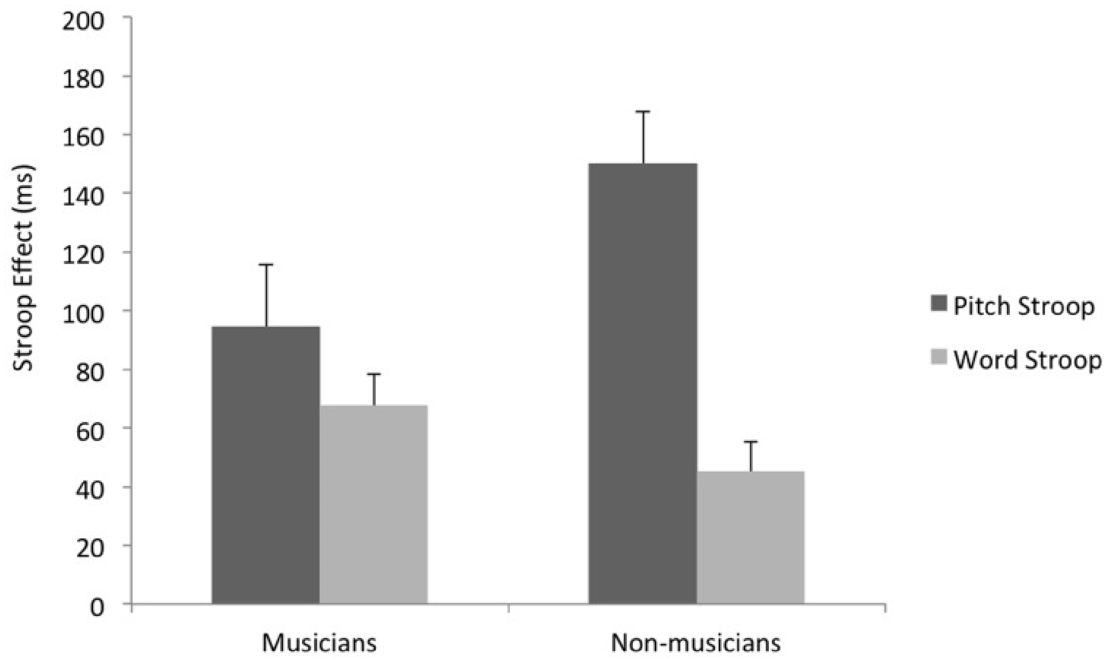
Lifelong musicianship makes older adults better listeners

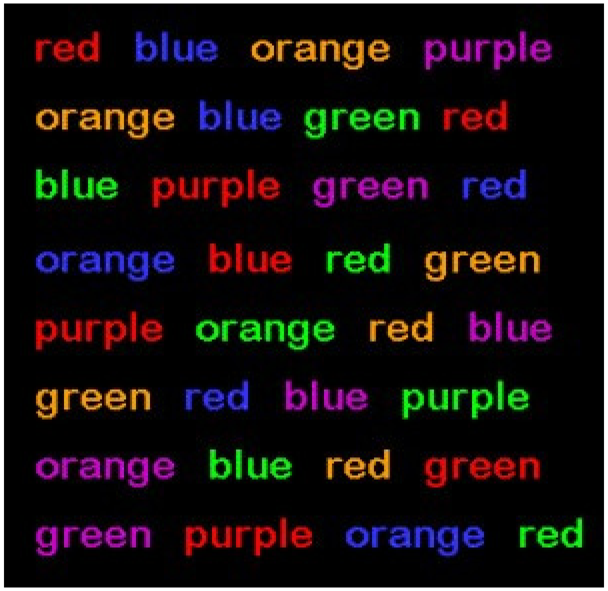
Musical training, aging and executive functions

- **Executive functions** (also known as cognitive control and supervisory attentional system) refers to the management (regulation, control) of cognitive processes, including working memory, reasoning, task flexibility, and problem solving as well as planning and execution.



Cognitive control: Stroop task



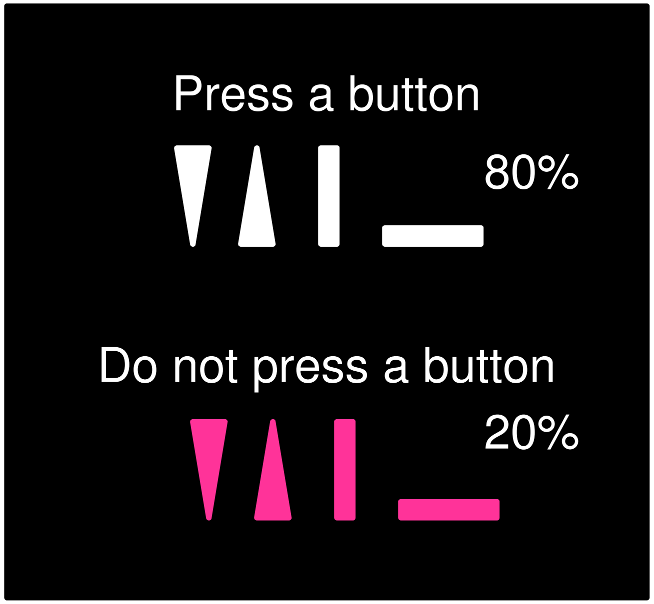


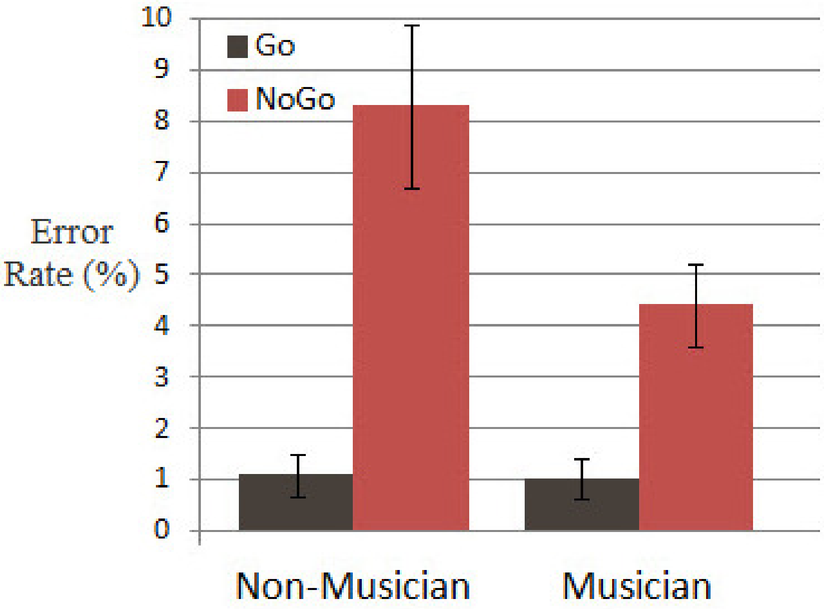
Musicians showed similar Stroop effects for the pitch and word conflict conditions, but non-musicians showed a significantly larger Stroop effect for the pitch condition compared to the word condition. Error bars are standard errors.

Amer et al. (2013) *PLoS ONE*

Cognitive control: Go/no task

Go/no-go task





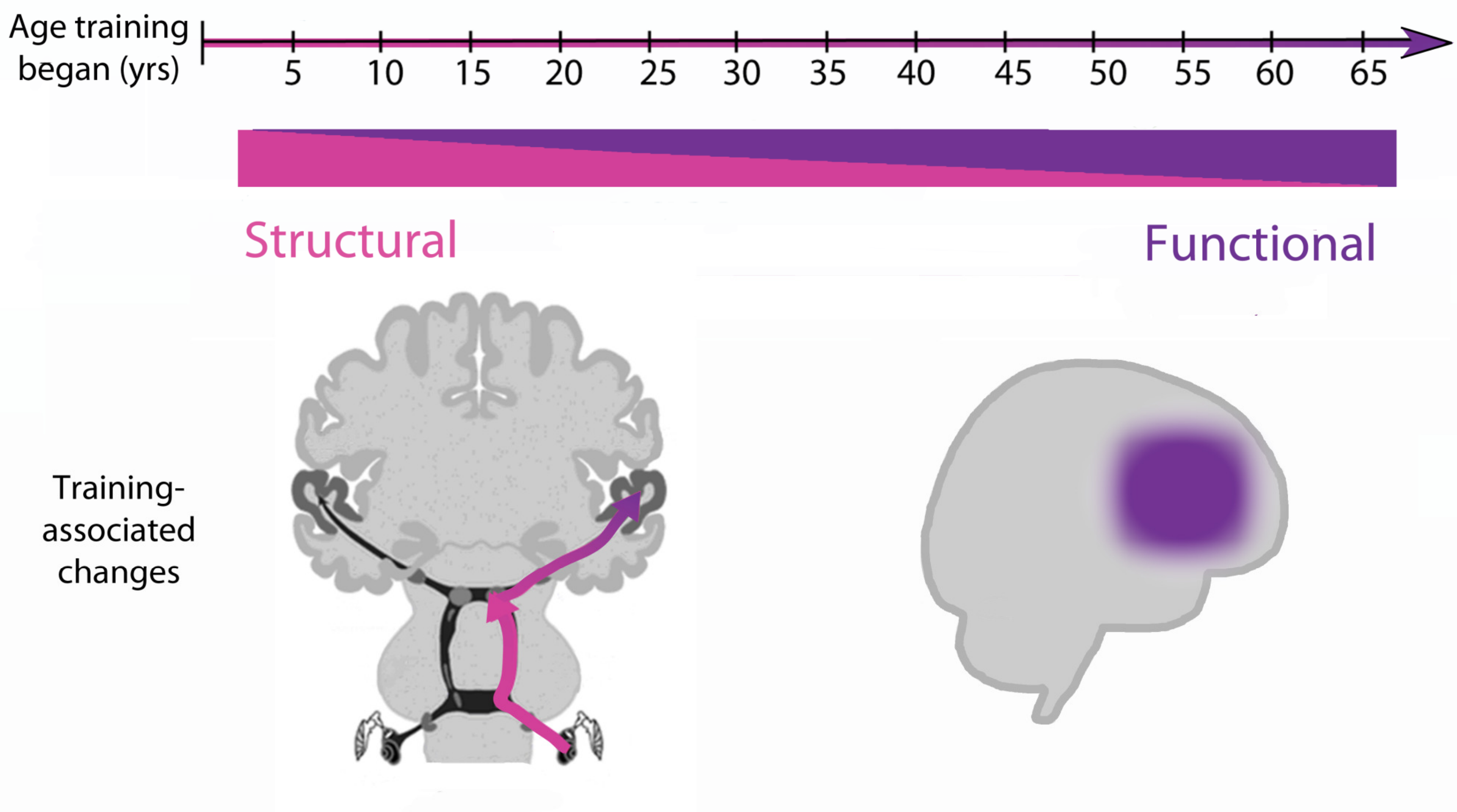
Older musicians (N = 17, Mean age 69.9, 59-80 yrs) are better able to inhibit response than their non-musicians counterparts (N = 17, Mean age 69.2, 59-80 yrs). Error bars are standard errors.

Moussard , Tays, Alain, & Moreno (Submitted)

Ongoing and Future directions

- Nature vs nurture: Longitudinal studies.
- Could listening to music be enough to enhance listening skill?
- What about other auditory ‘expertise’ (e.g., sound engineers)?
- How much training is enough?

How much training is enough



Clinical Implications

- Audiological examinations in musicians.

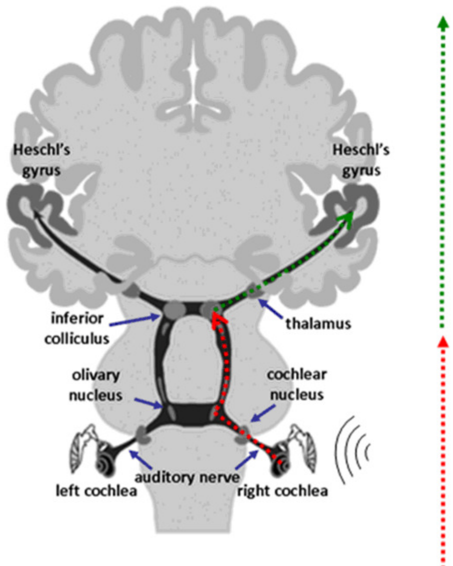
- Music lesson in adulthood as a way to mitigate age-related decline in auditory cognition.

- For patients who already have dementia, music can be used in a different way to help the mind.

- Trends emerging from research show that music exposure -- whether through casual listening or more formalized music therapy -- can help reduce the incidences of behavioral issues and generally calm dementia patients.

Concluding remarks

- Hearing diminish with age – peripheral as well as central auditory processes



- Musical training does enhance auditory skills beyond music performance

- Lifelong musical activities mitigate age-related decline in hearing ability by enhance/preserving listening skills

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