AGING, HEARING COGNITION AND MUSIC

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Dr. Emily Bolt

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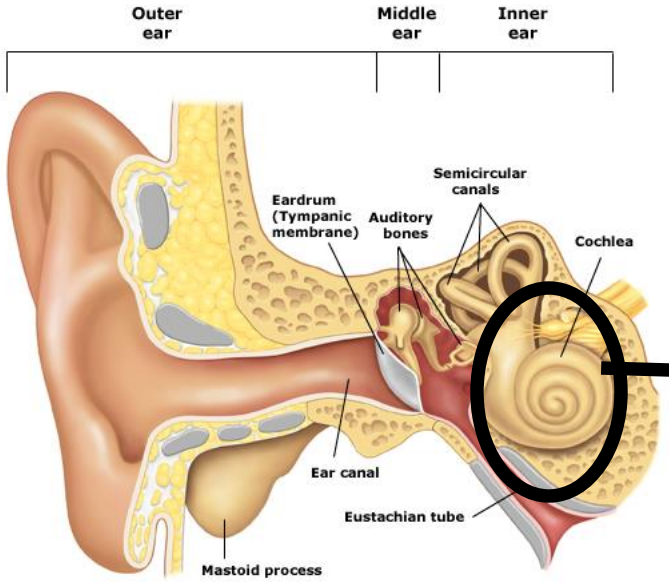
Dr. Marie-Elaine Lagrois

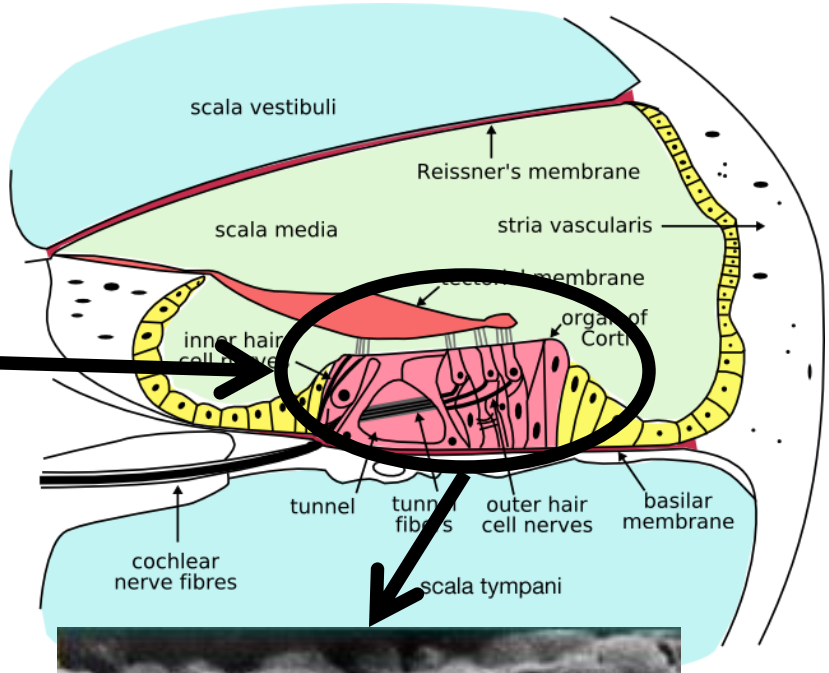
Auditory aging

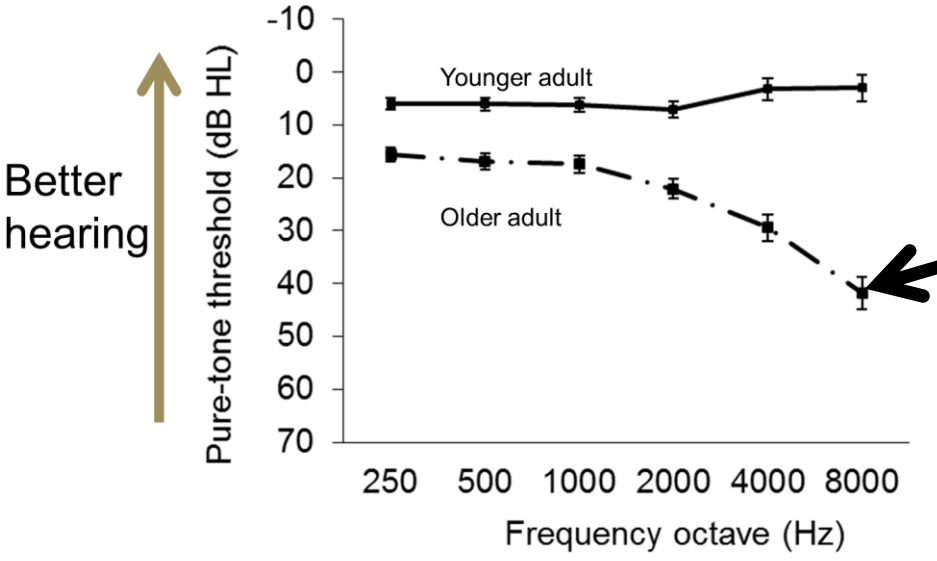
Loss of hearing abilities can lead to:

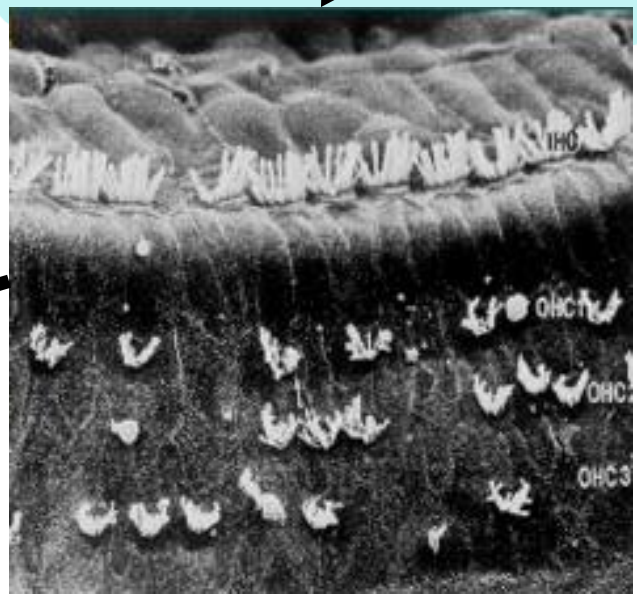
- Social isolation
- Depression
- Cognitive decline

Arlinger (2003) *International Journal of Audiology*;
Lin et al. (2013) *JAMA Internal Medicine*;
Mick, Kawachi & Lin (2014) *Otolaryngology – Head and Neck Surgery*

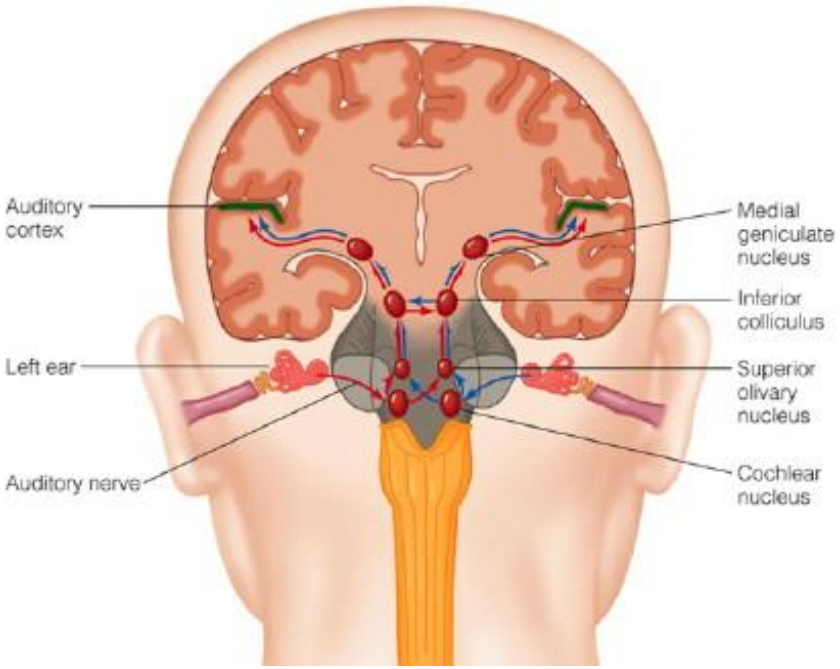

Outer ear
Middle ear
Inner ear
Eardrum (Tympanic membrane)
Auditory bones
Semicircular canals
Cochlea
Ear canal
Eustachian tube
Mastoid process


scala vestibuli
Reissner's membrane
scala media
stria vascularis
membrane
organ of Corti
inner hair cell nerve
tunnel
outer hair cell nerves
basilar membrane
cochlear nerve fibres
scala tympani


Better hearing
Pure-tone threshold (dB HL)
-10
0
10
20
30
40
50
60
70
Younger adult
Older adult
250
500
1000
2000
4000
8000
Frequency octave (Hz)


IHC
OHC1
OHC2
OHC3

Age-related decline - Central



Auditory information > brainstem > cortex

Sound is refined, processed, given meaning

- Neural timing is disrupted in older adults (Parbery-Clark et al. 2012)
- Leads to decreased ability to process acoustic information
  - Frequency discrimination (Raz et al. 1989)
  - Sound location detection (Abel et al. 2000)
  - Duration discrimination (Fitzgibbons, 1994)
  - Gap-detection (Gordon-Salant et al., 2006; Schneider et al., 1994)
  - Mistuned harmonic detection (Alain et al. 2001)
- Performance often not related to PT thresholds

Listening is a cognitive task

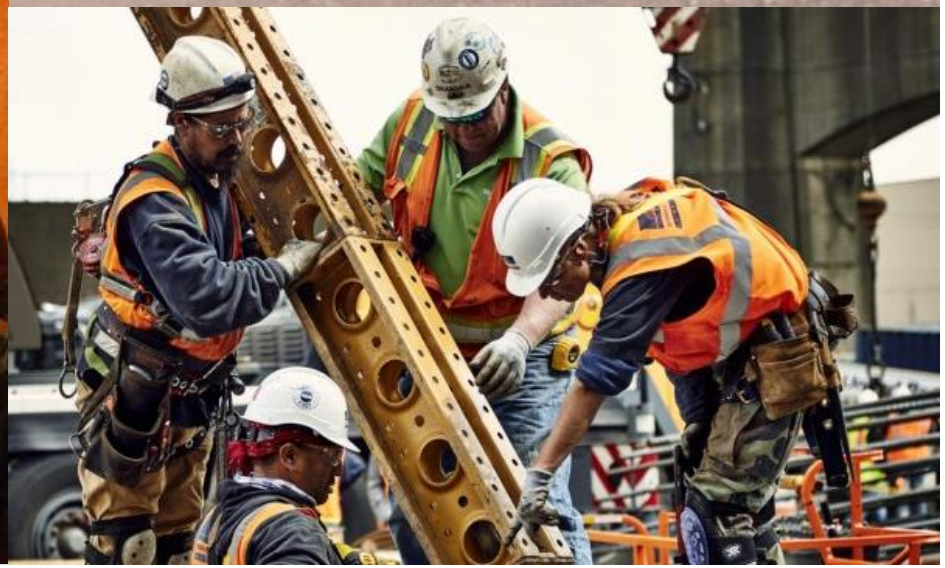
- Listening relies on multiple brain regions
- The brain is modifiable via neuroplasticity
- **Can we improve hearing by improving how the brain processes acoustic information?**

Two lines of research

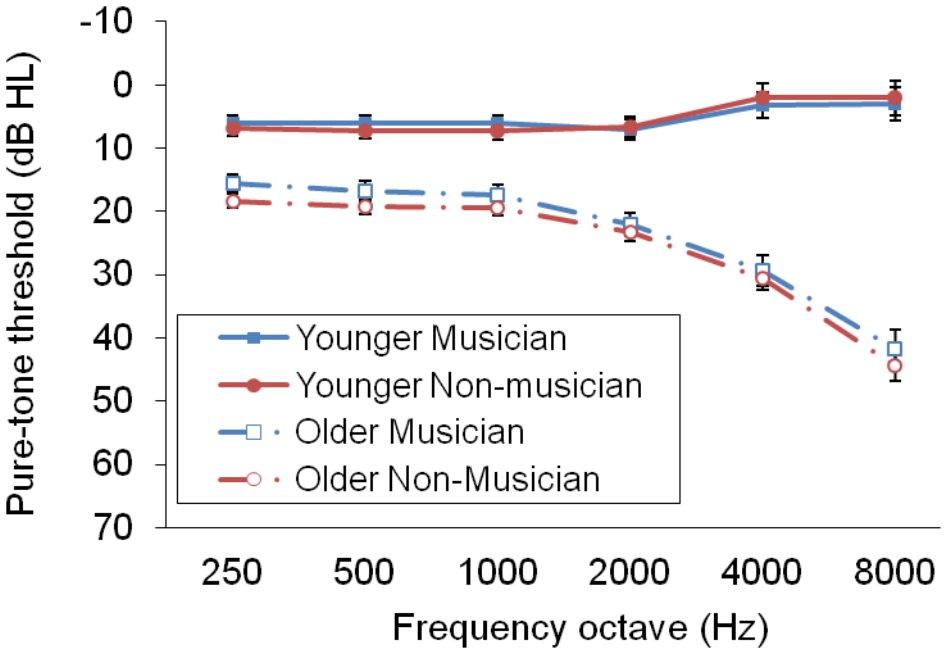
1. Impact of music training on hearing abilities in older adults

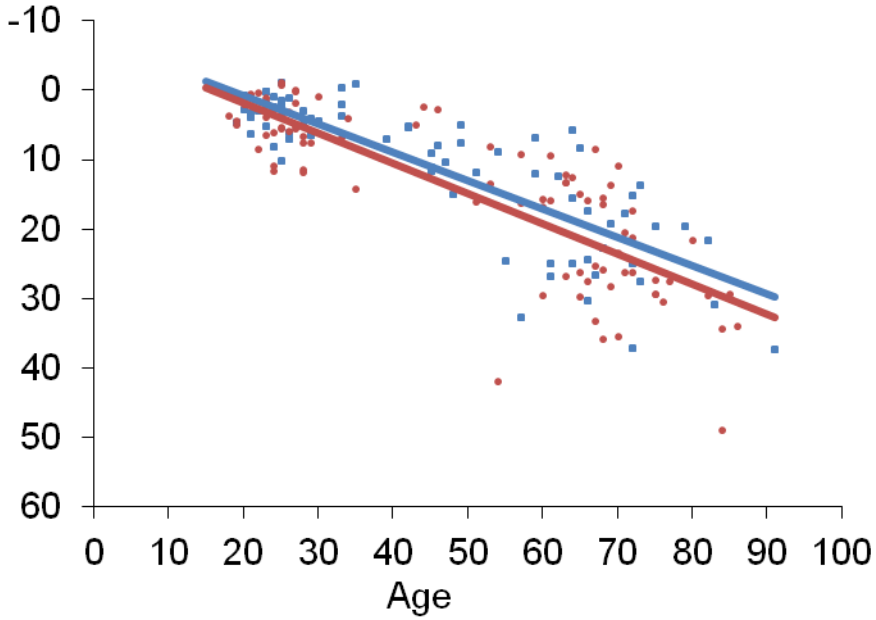
2. Impact of aging on music perception tasks

Music training and the ability to understand Speech in Noise



Pure-tone thresholds

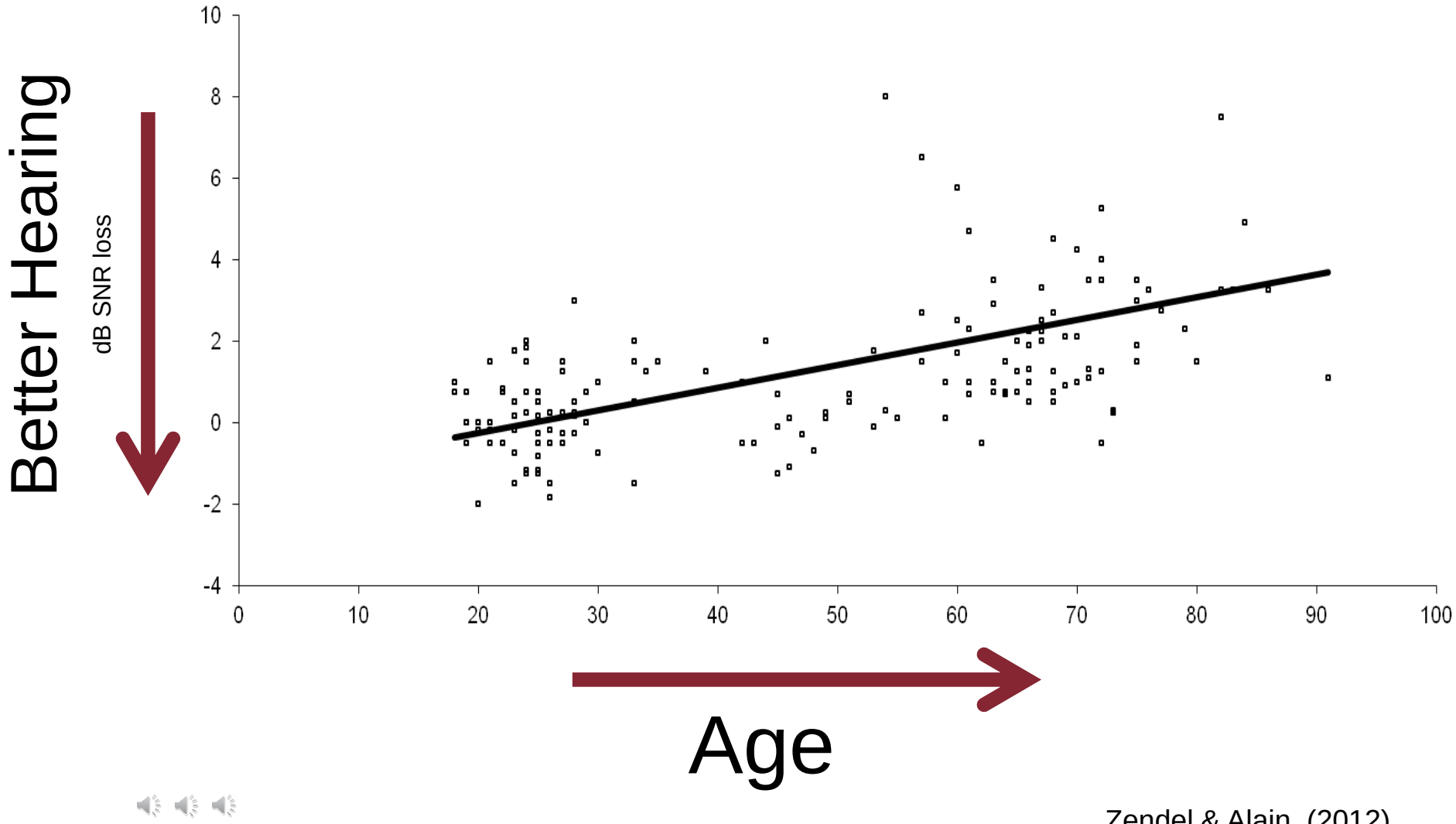




- N = 163 (74 Mus: 19-91yrs; 89 NonMus: 18-86 yrs)
- Increased thresholds in older adults
- No influence of musicianship

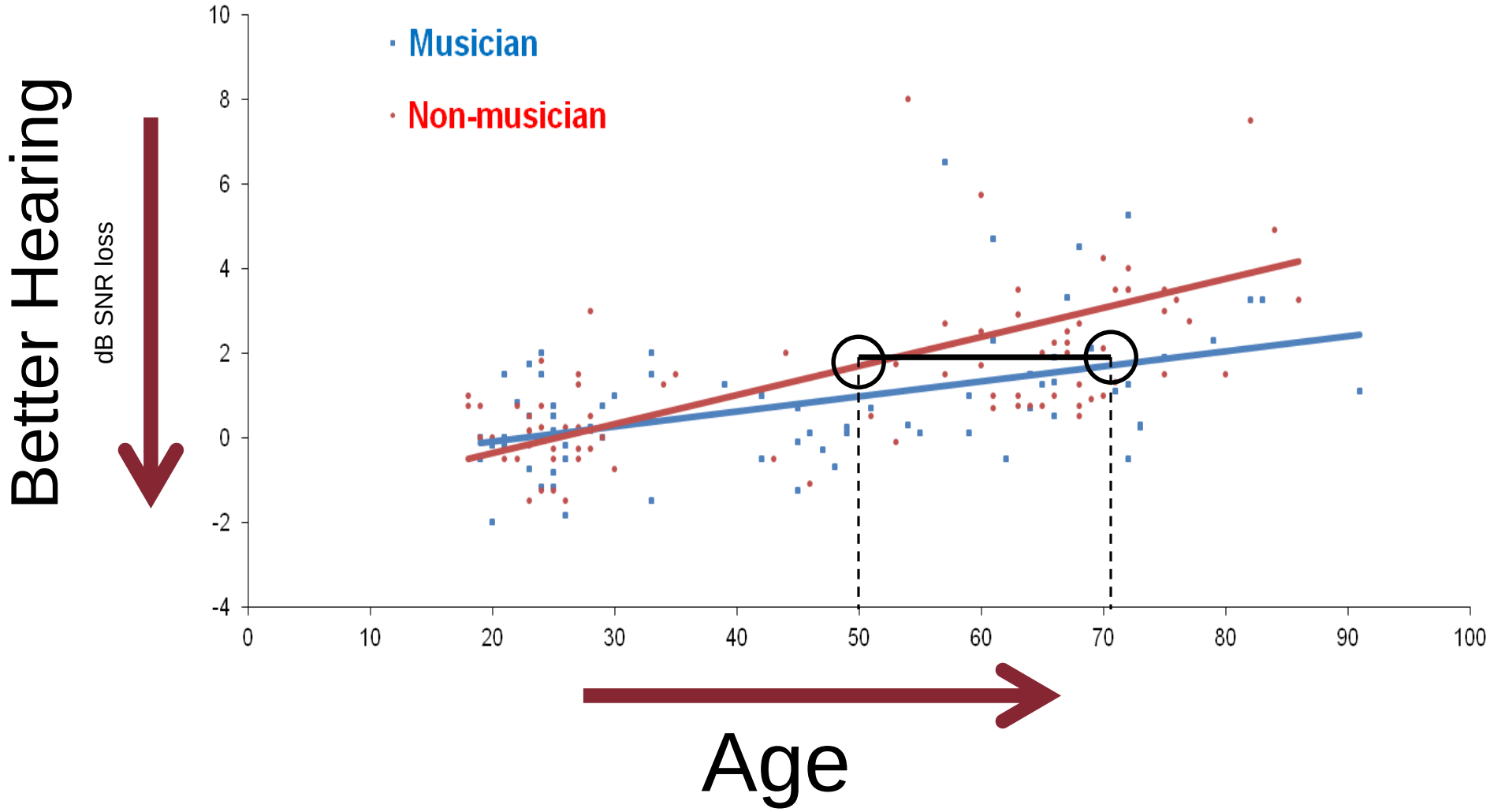
Zendel & Alain, (2012)
Psychology and Aging

Understanding speech in noise



Zendel & Alain, (2012)
Psychology and Aging

Understanding speech in noise

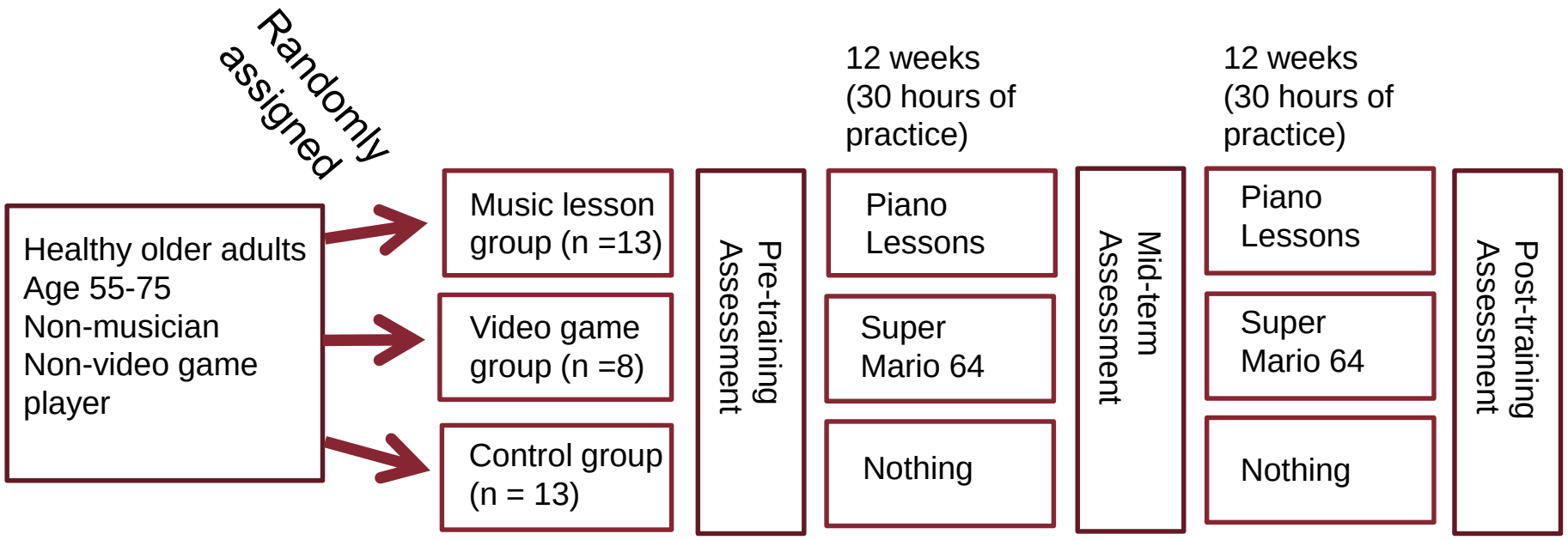


Zendel & Alain, (2012)
Psychology and Aging

Is it too late?

Can music training improve hearing in older adults?

Randomized Control Study Design:



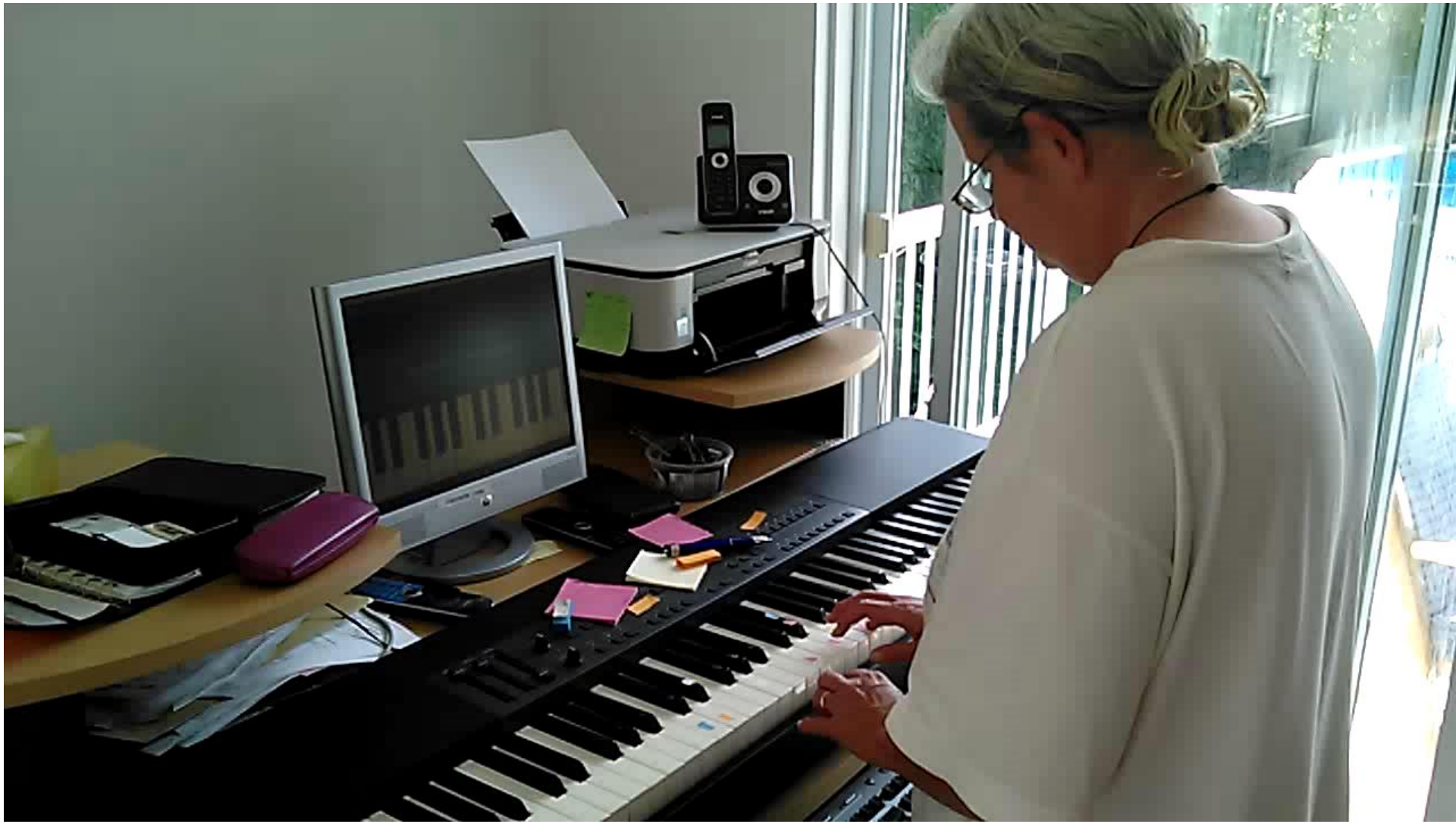
West, Zendel et al. (2017) *PLOS-One*;
Diarra, Zendel et al. (2019) *Exp. Brain Res.*
Zendel et al. (2019) *Neuro. Bio. Aging*;
Fleming, Zendel et al. (2019) *Brain and Cognition*

Participants

Group	Age (SD)	Gender	Yrs Education (SD)
Music (n = 13)	67.5 (4.2)	10 female; 3 male	14.5 (2.2)
Video (n = 8)	66.9 (3.9)	4 female; 4 male	17.5 (2.3)
No Contact (n = 13)	69.3 (5.7)	10 female; 3 male	15.2 (3.1)

1st Lesson

After 6 Months

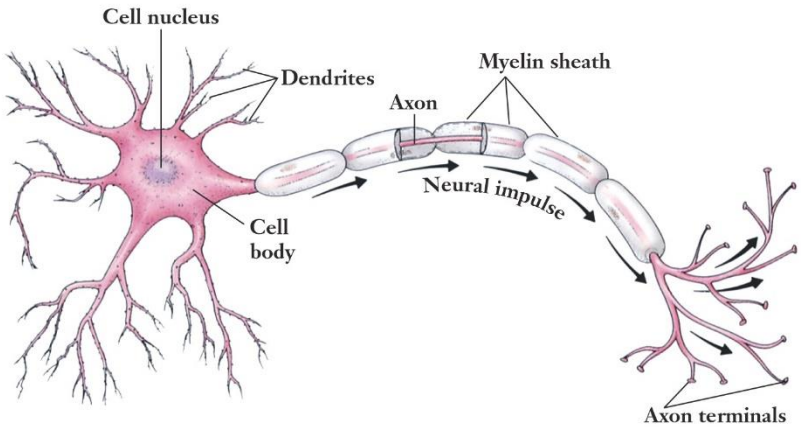


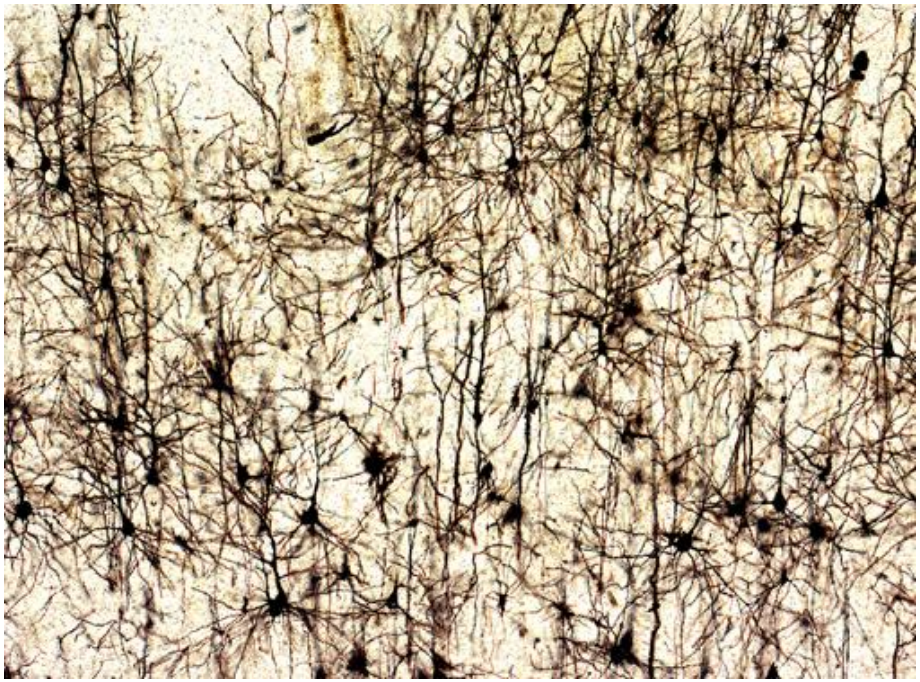
Tasks

1. Electroencephalography (EEG) word-in-noise task

2. Functional Magnetic Resonance Imaging (fMRI) sentence in noise task

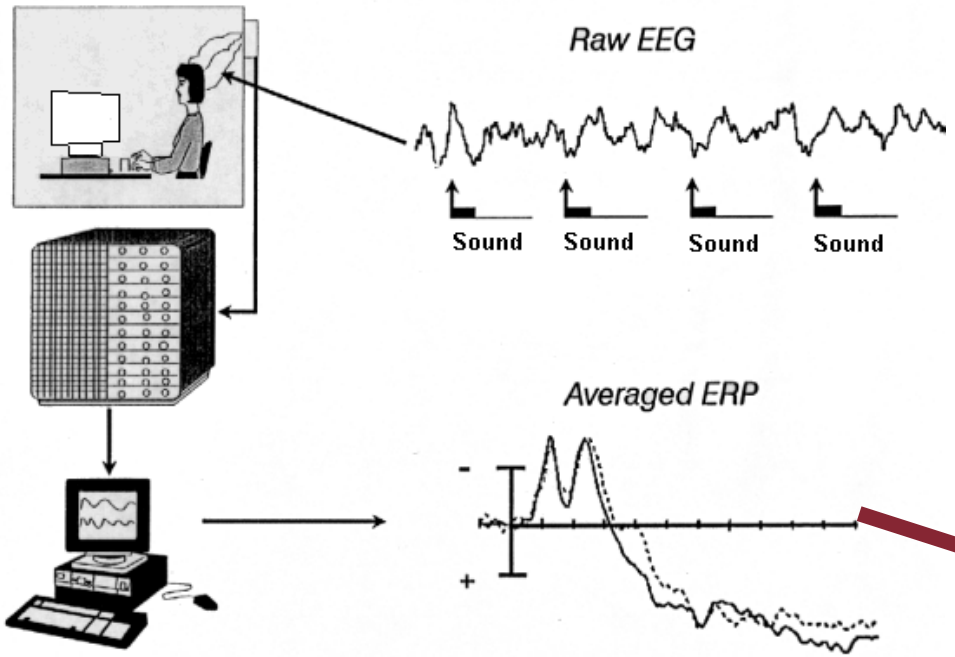
Electroencephalography - EEG

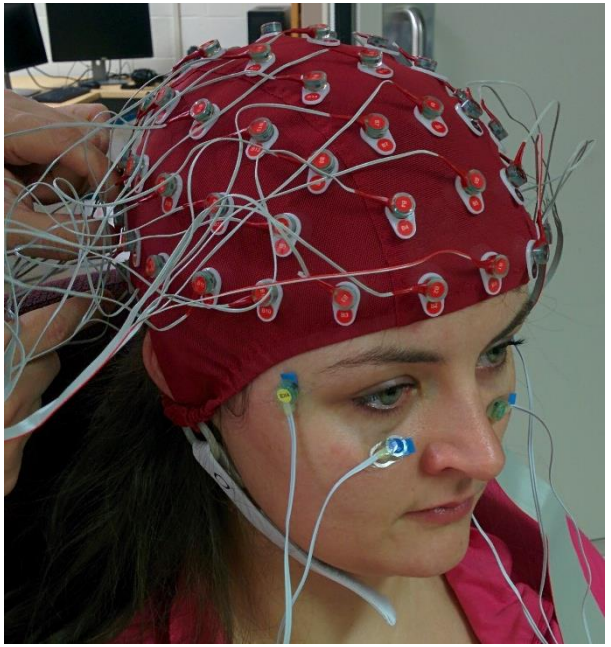


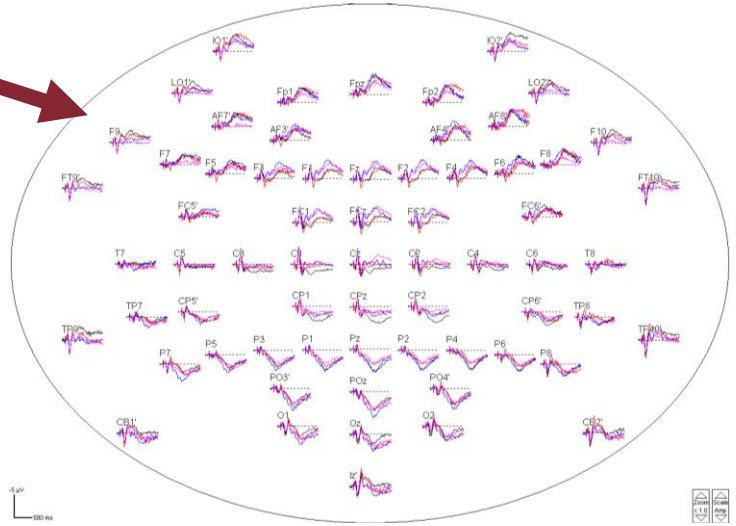


- Brain is made up of billions of neurons
- Each time one fires, it produces a small electrical field
- When groups of neurons fire together they produces an electrical field that can be measured at the surface of the scalp

Event-related potentials (ERPs)





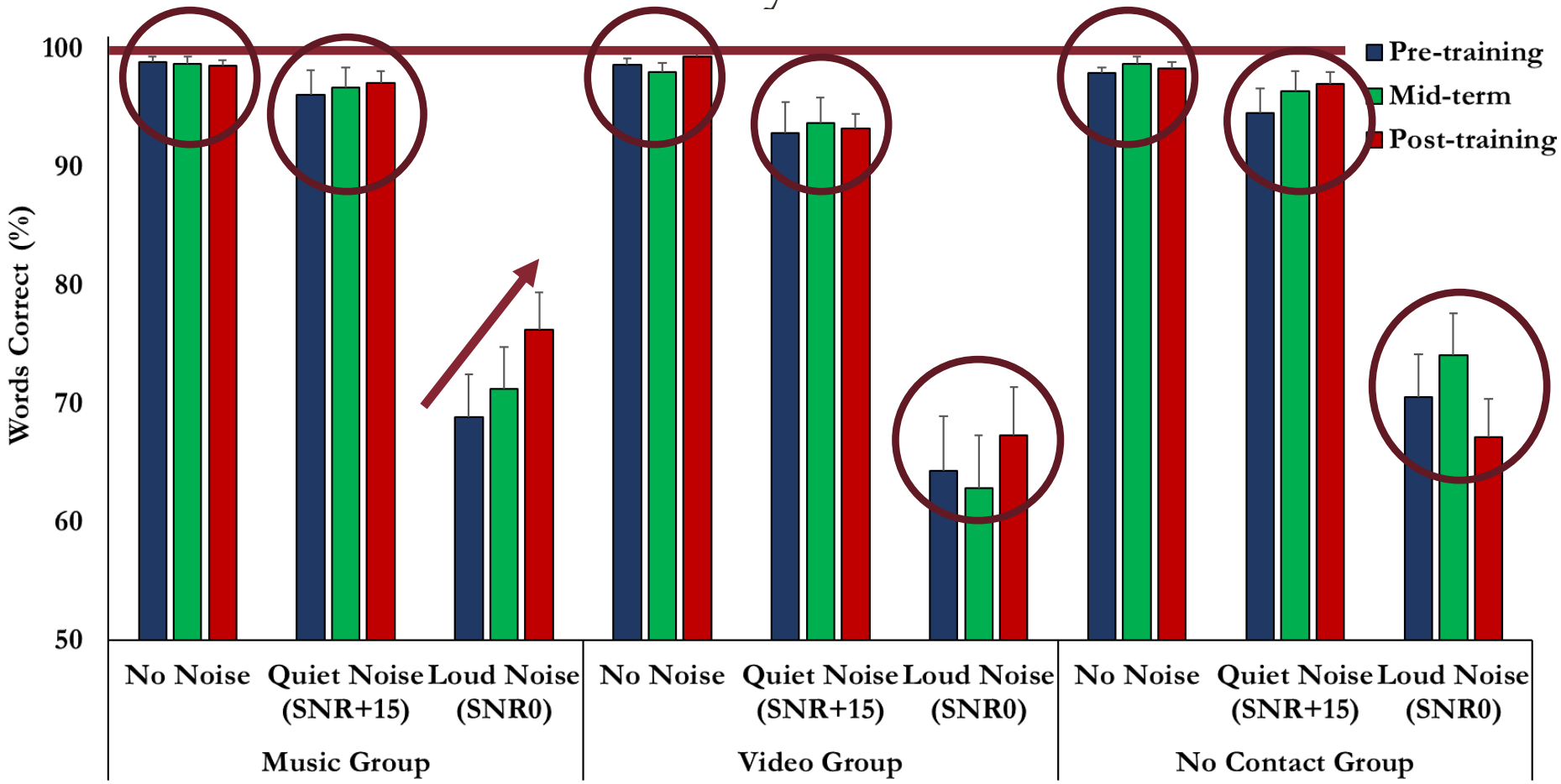


EEG Word in Noise task

- 3 Noise conditions:
  - No background noise
  - Quiet background noise (15 dB SNR)
  - Loud background noise (0 dB SNR)
- 2 Listening conditions:
  - Active Task: Repeat the word out loud
  - Passive Task: watch a subtitled film

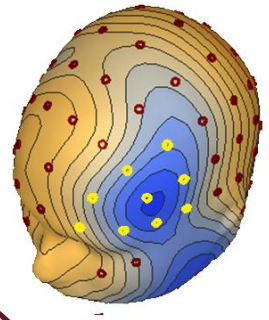
Zendel et al. (2019). Neurobiology of Aging

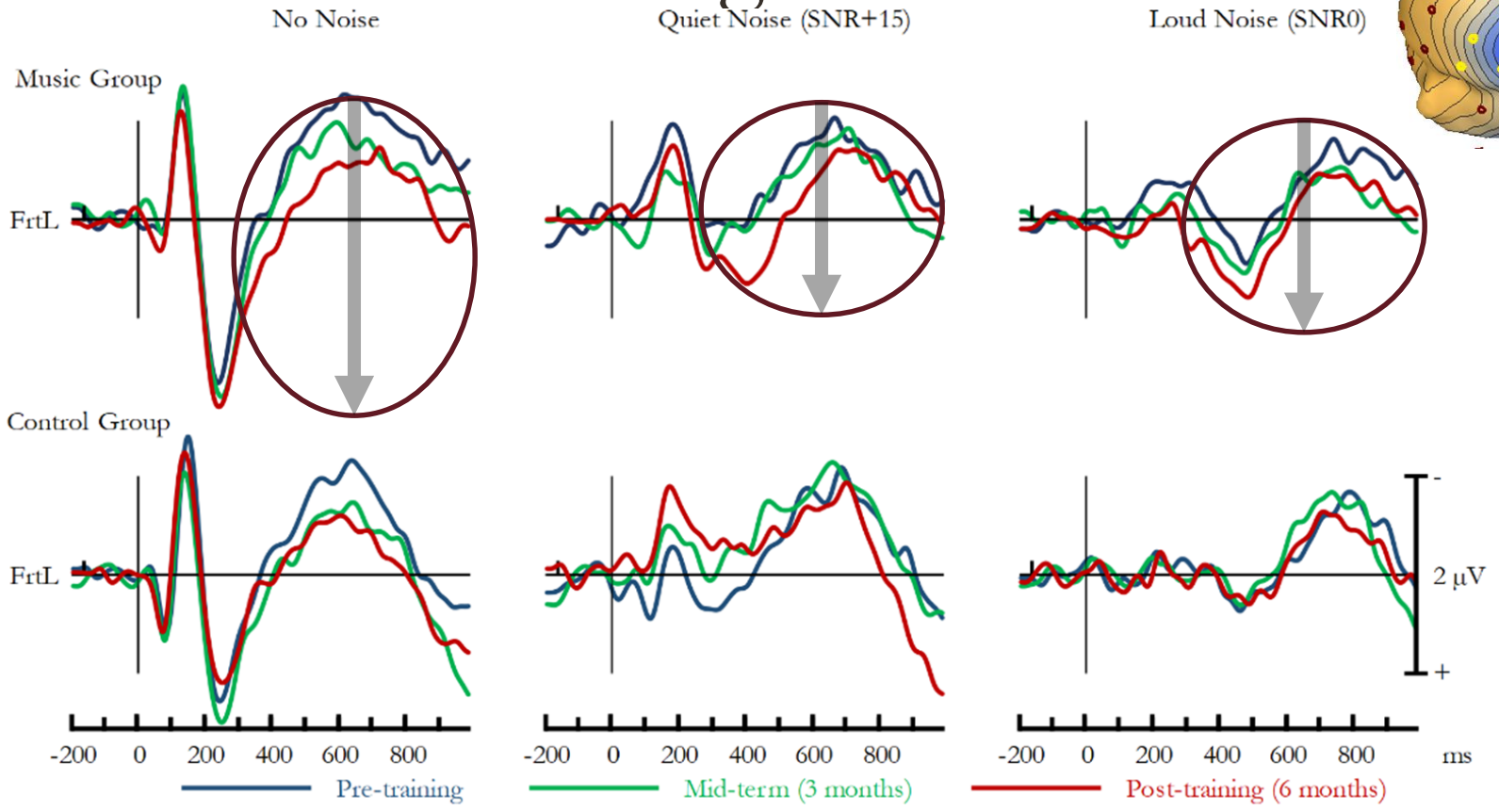
EEG: Word Accuracy



- Participants in the Music group improved in the most difficult listening situation (68.9% > 76.2%)

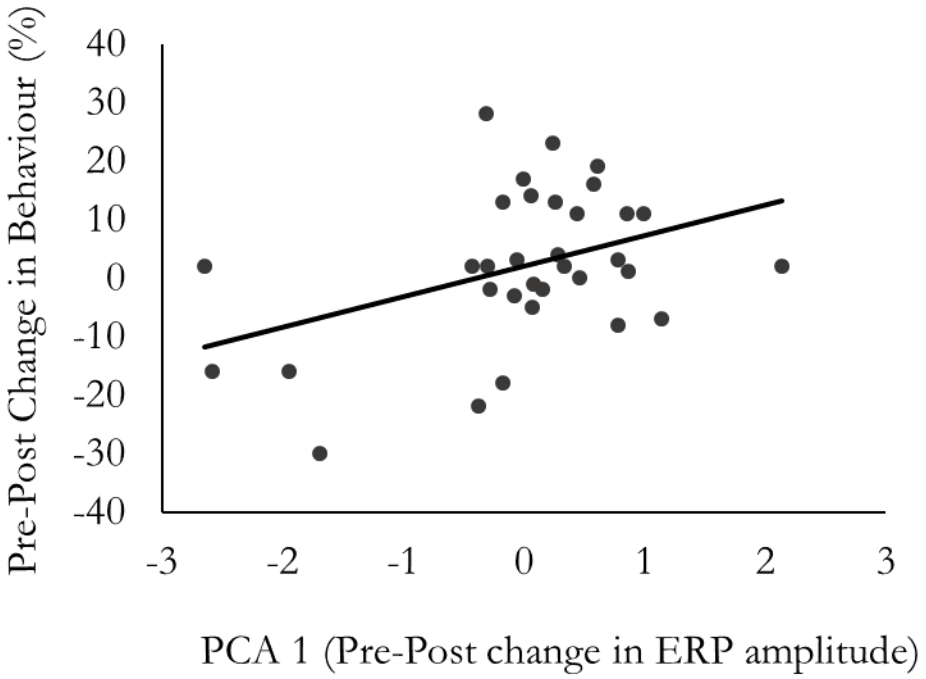
ERP: Active Listening





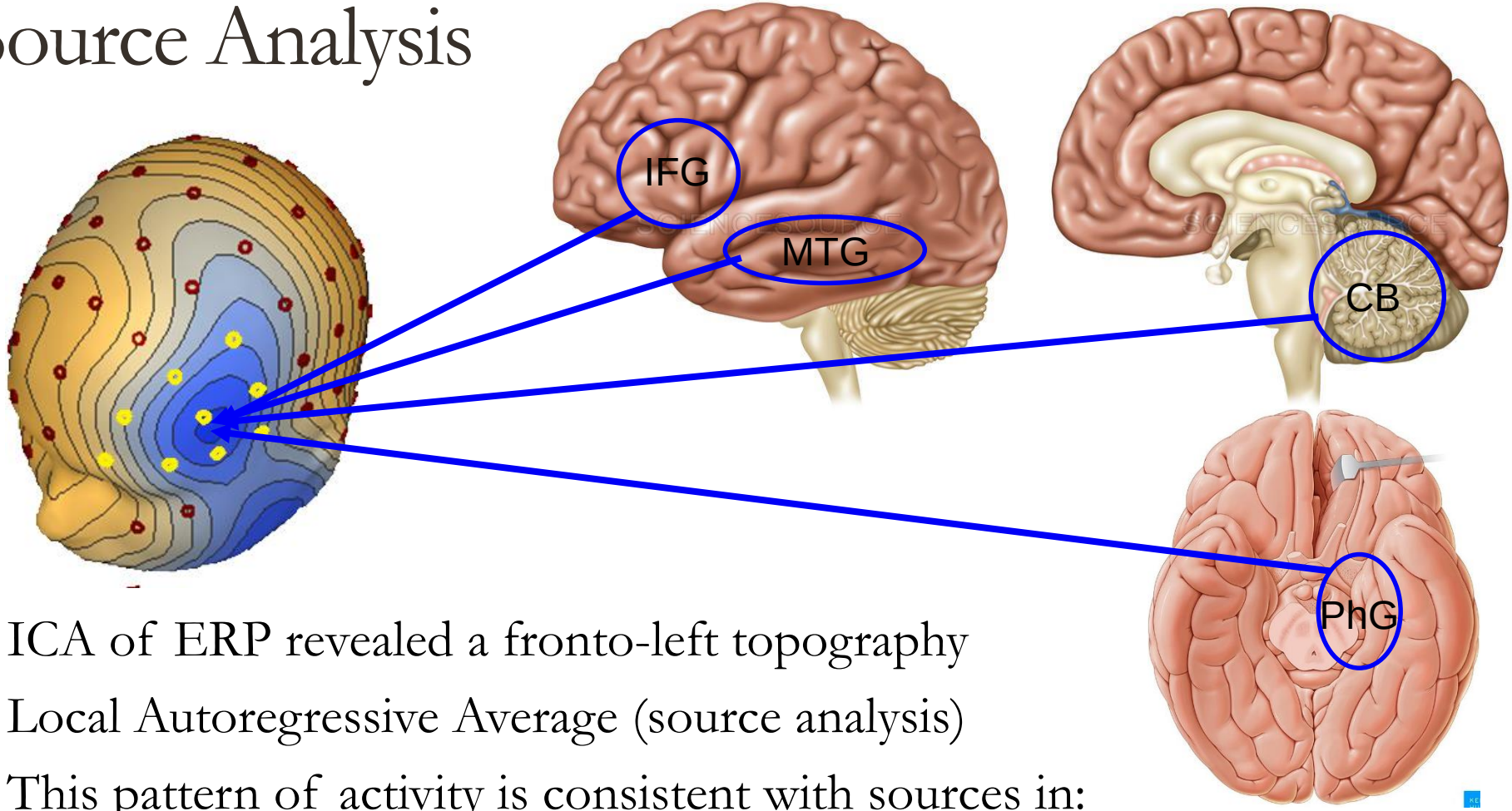
- Increase in positive going activity from 200-400, 400-700 & 700-1000 ms.

Brain-Behaviour Correlation



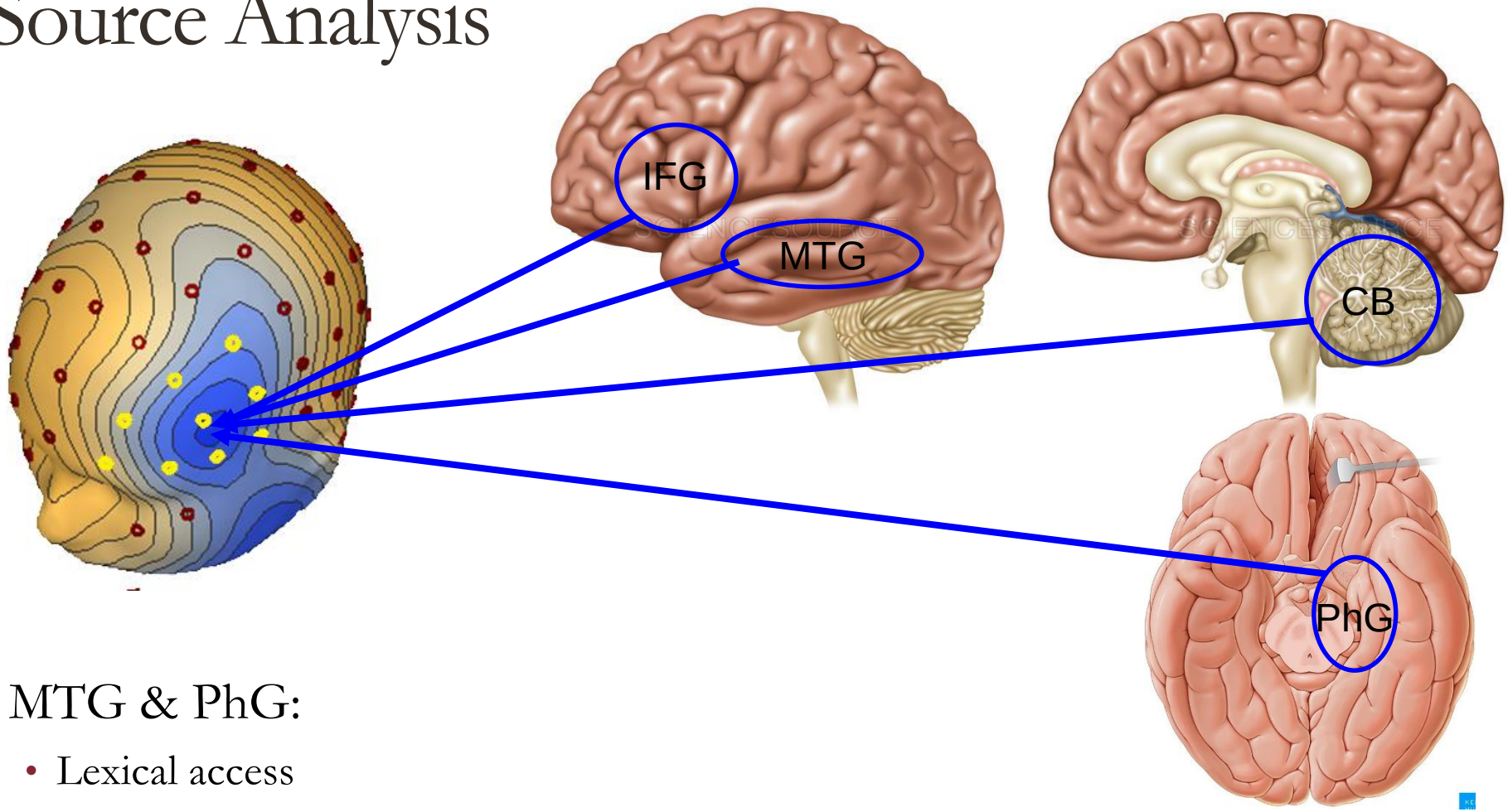
- Pre-post change in ERP amplitude during Active Listening predicted improvement for speech in noise (loud condition)
- PCA1 accounts for 77.7% of the variance in pre-post ERP data

Source Analysis



- ICA of ERP revealed a fronto-left topography
- Local Autoregressive Average (source analysis)
- This pattern of activity is consistent with sources in:
  - Left inferior frontal gyrus (IFG, BA45, Broca's area)
  - Left middle temporal gyrus (MTG, BA22)
  - Right parahippocampal gyrus (PhG, BA34)
  - Right Cerebellum (CB)

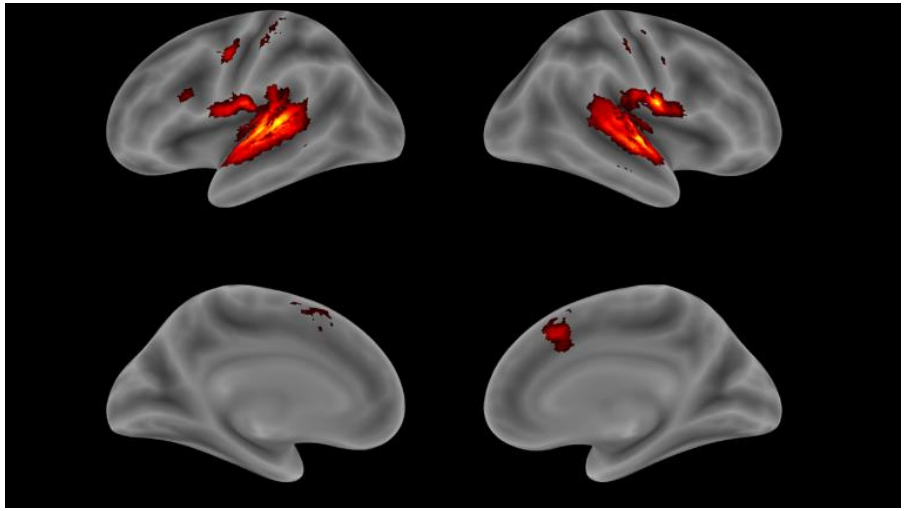
Source Analysis

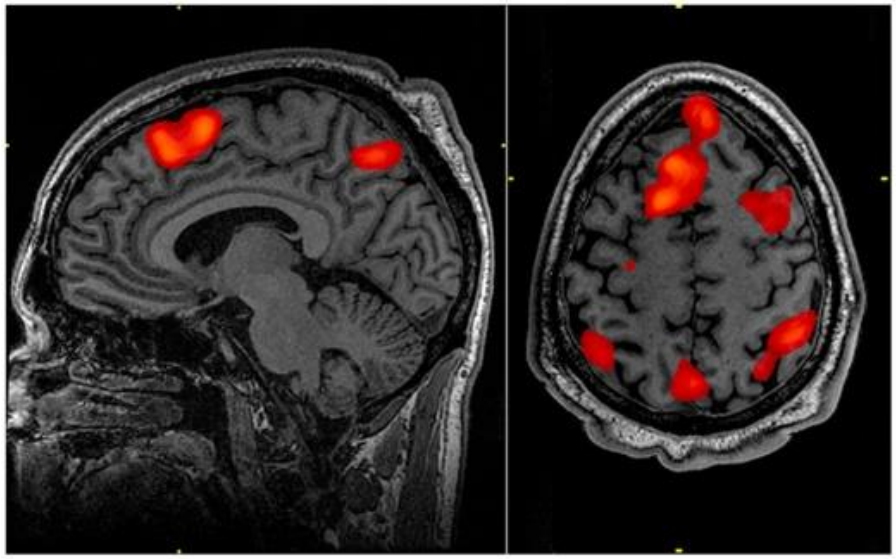


- MTG & PhG:
  - Lexical access
- IFG & CB:
  - pre-articulatory motor planning of speech

Functional magnetic resonance imaging (fMRI)

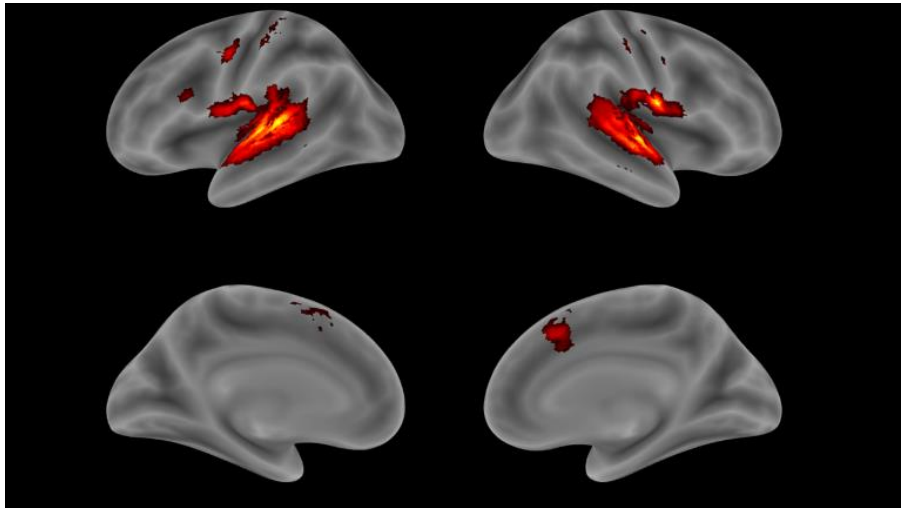
fMRI: measuring activity through blood oxygenation

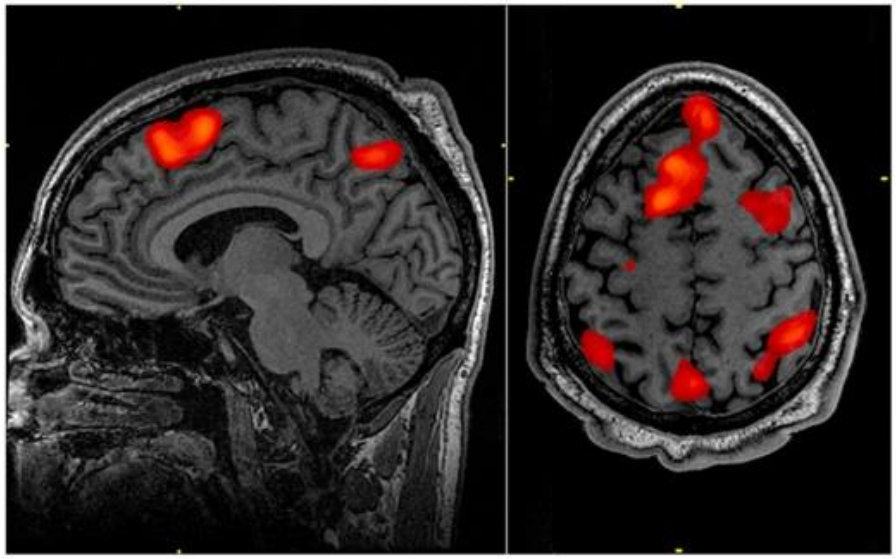




- When neurons are active, they require more oxygen
- A few seconds after a task, there will be an increase of oxygenated blood that flows to regions that were active
- BOLD (**B**lood-**O**xygen **L**evel **D**ependent) response

fMRI: measuring activity through blood oxygenation





- Good at measuring where in the brain activity is happening – we can analyse voxel-by-voxel (whole-brain approach), or select pre-defined regions of interest (ROI)
- Bad at measuring when the activity is occurring – opposite of EEG
- Indirect measure of brain activity, unlike electrophysiological techniques like EEG

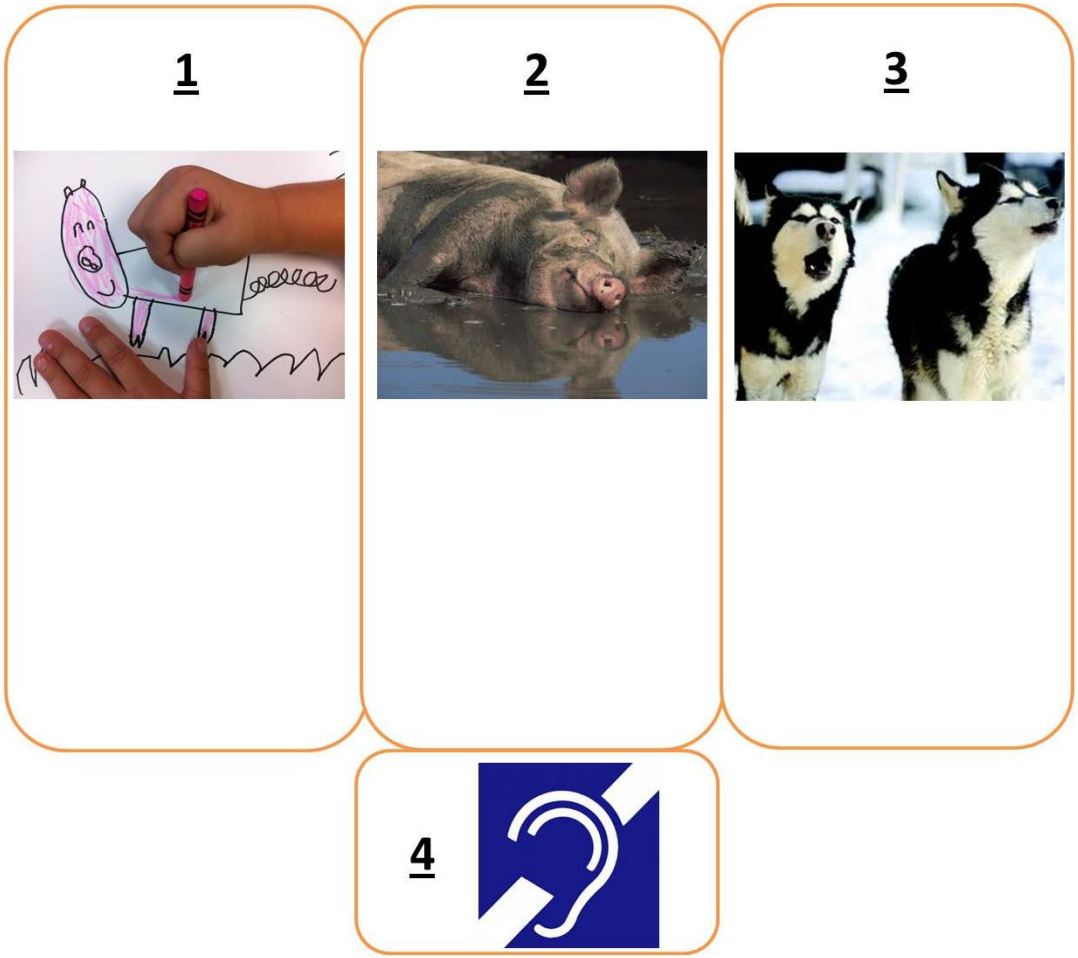
Functional Magnetic Resonance Imaging (fMRI) sentence in noise task

3 Noise Conditions:

Loud
5 dB SNR

Quiet
20 dB SNR

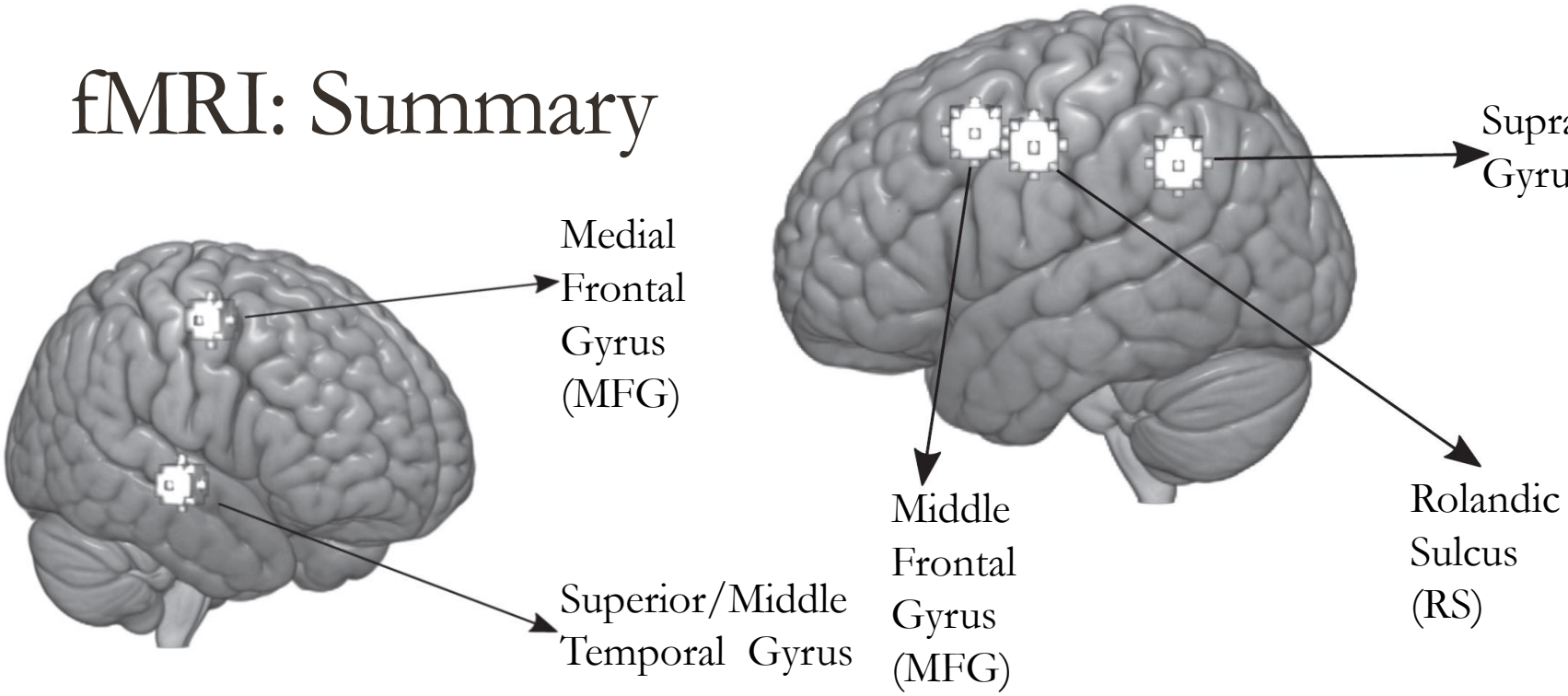
None



Participants select a picture that matched the sentence

Fleming, et al., Zendel (2019). Brain and Cognition

fMRI: Summary



- MFG, RS and SmG are part of the motor system
- The task for this study did not involve saying anything

Summary

- Two pathways to processing incoming speech
  - Acoustic
  - Motor
- Motor system is involved in mapping acoustic input into a phonemic code
  - Your brain 'sounds' out the speech input to aid in comprehension
  - This mode of perception is more effective for understanding speech when there is background noise
- Music lessons may aid this system as learning music requires mapping motor movements that connect perception and production

Music training: Summary

- **6 months of music training improved the ability to understand speech-in-noise**

- **Music training could be used to develop auditory rehabilitation programs for older adults**

- Suggests:
  - music training improves the ability orient attention to critical components of the incoming auditory code
  - This enhanced attentional focus is related to mapping the acoustic input to phonemic code
  - Involvement of the motor system is critical

From Training to Listening…

- How does music perception change with age?
- Aging is associated with worse hearing, and slower processing of information
- Prediction: Music requires rapid processing of acoustic information, so music perception abilities should decline in older adults
- However: music enjoyment seems to persist in older adults, even those with significant cognitive decline

Aging and Music perception

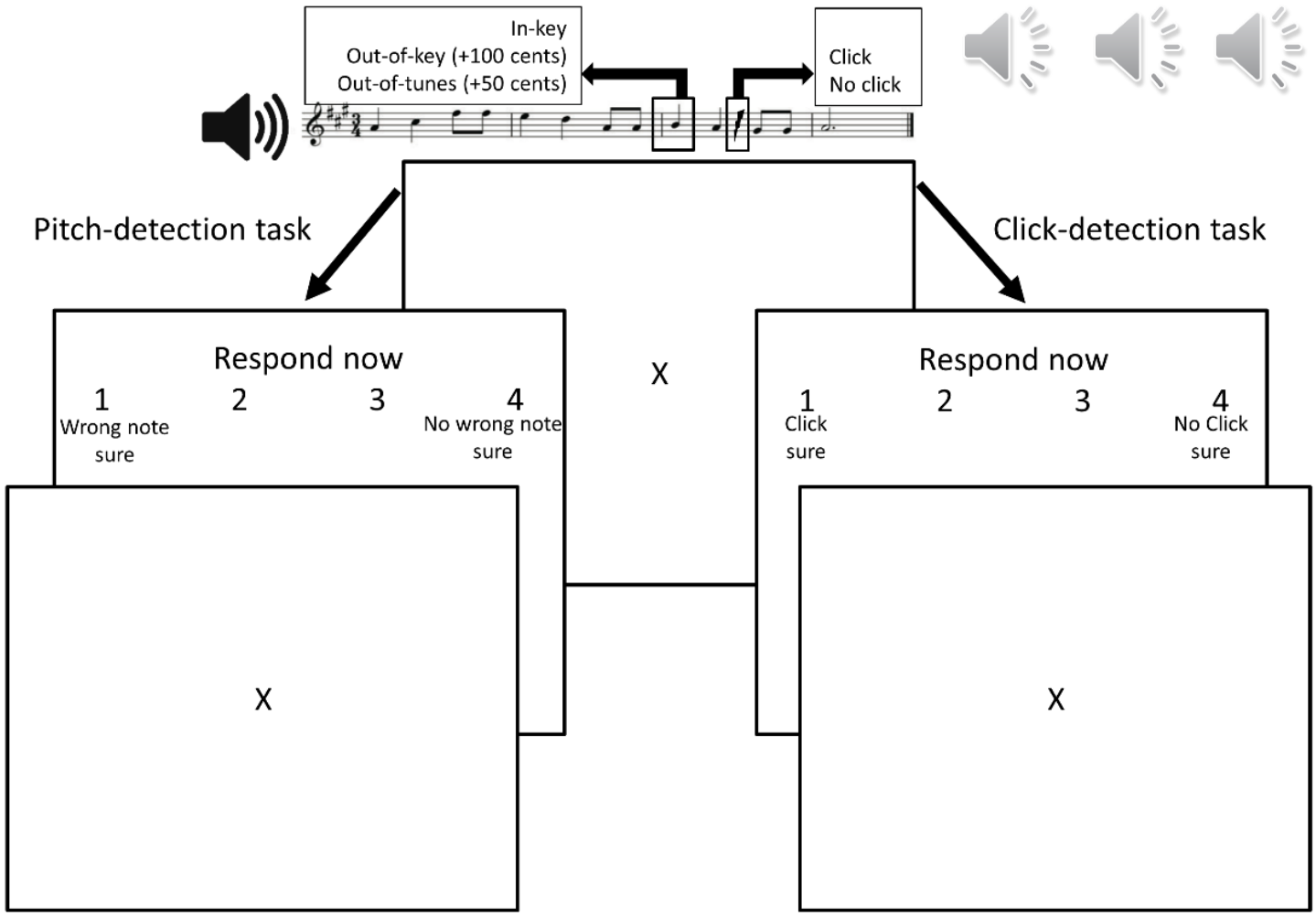
- Two important aspects of music perception are:
  - Tonality: the hierarchical relationship between different notes
    - Examined brain responses to bad notes
  - Rhythm: the temporal organization of notes into beats
    - Examined the strength of neural entrainment to the 'beat'

Tonality

- Examined the ability to detect bad notes in a melody and monitored EEG
- The ability to detect bad notes in a melody is learned implicitly and requires no formal training

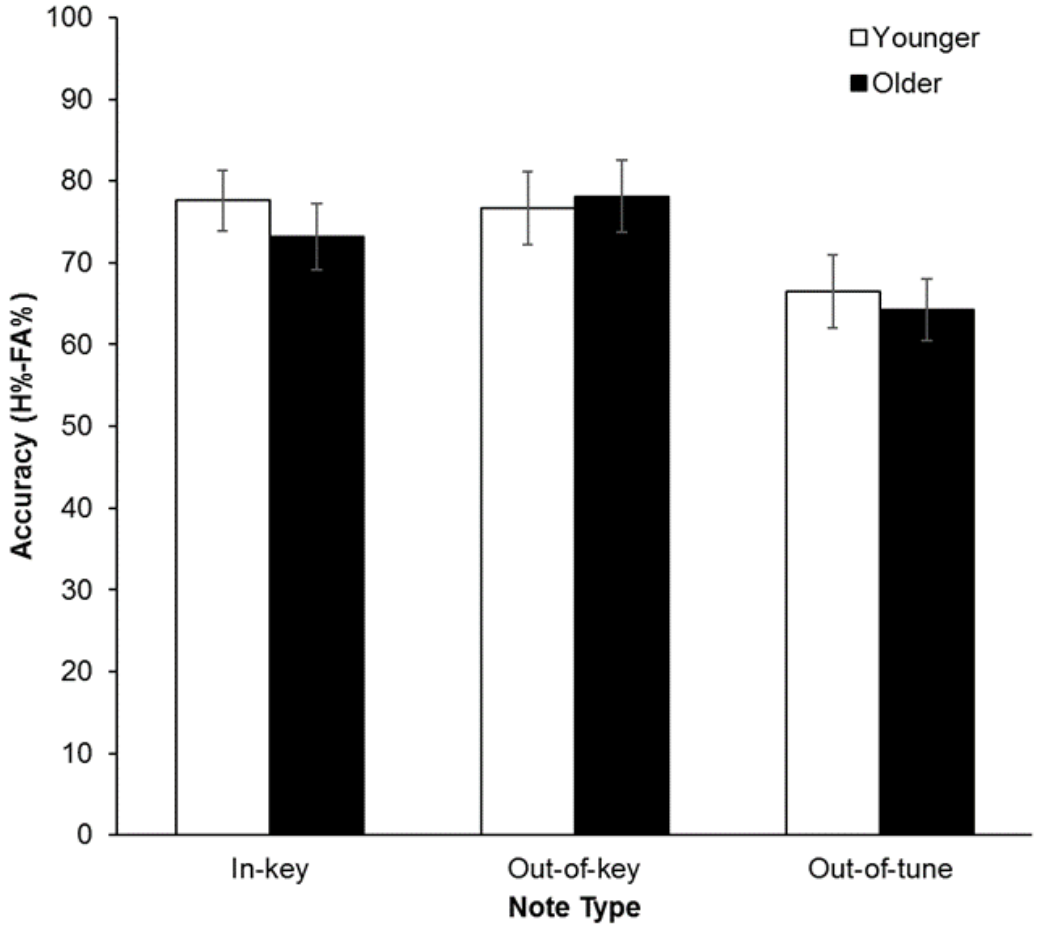
- Participants:
  - Younger Adults
    - N = 12 (Age 18-35 [Mean 25.7, SD 6.3, 6 female]
  - Older Adults
    - N=11 (Age 59-73 [Mean 64.3, SD 4.3, 8 female]
- Groups were matched on
  - Years of education [15.8 vs 15.5, p = .74]
  - Years of Music training [0.1 vs. 0.7, p = .15]

Experimental Design



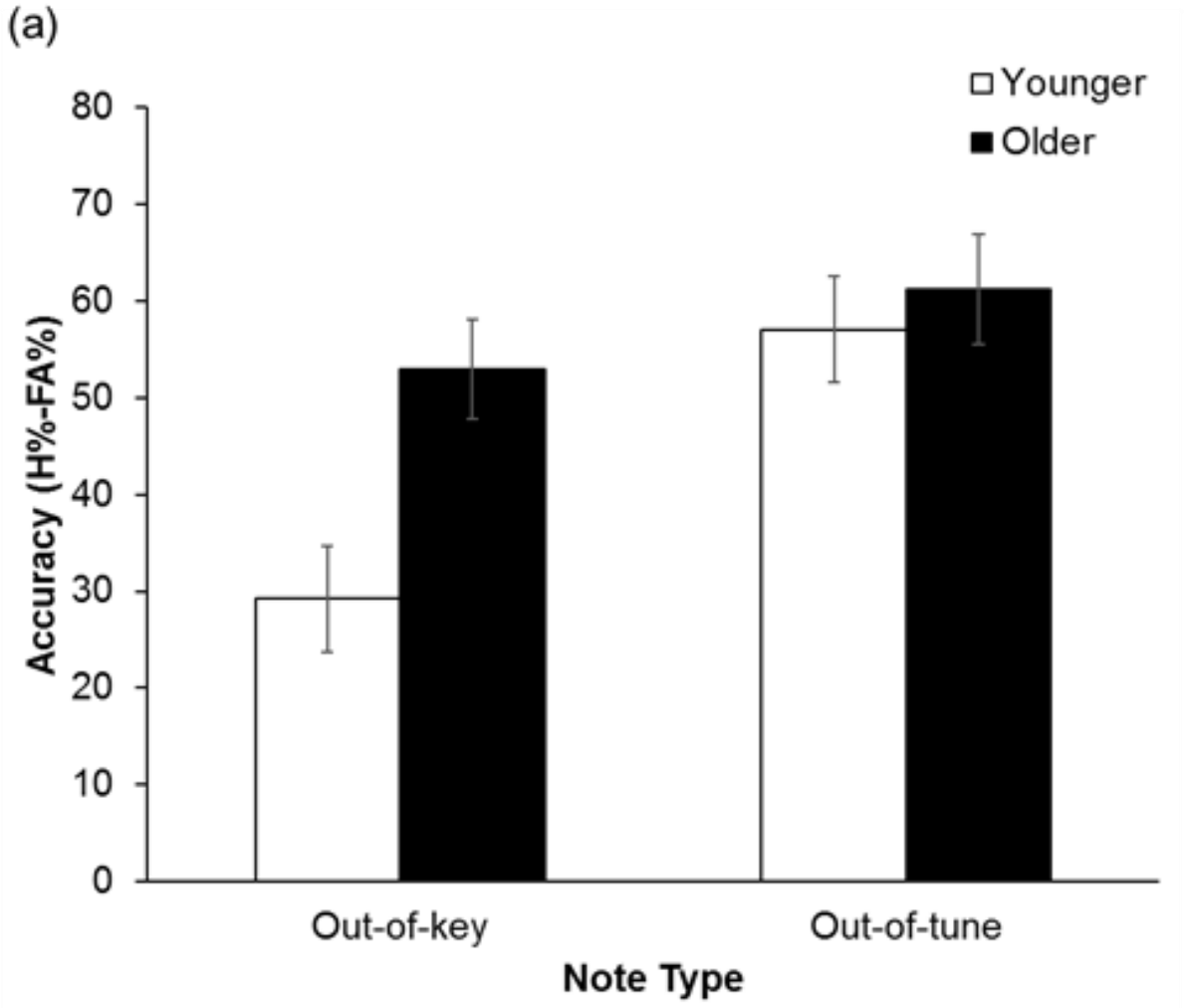
Lagrois, Peretz & Zendel (2018) Frontiers in Neuroscience

Click Detection Task



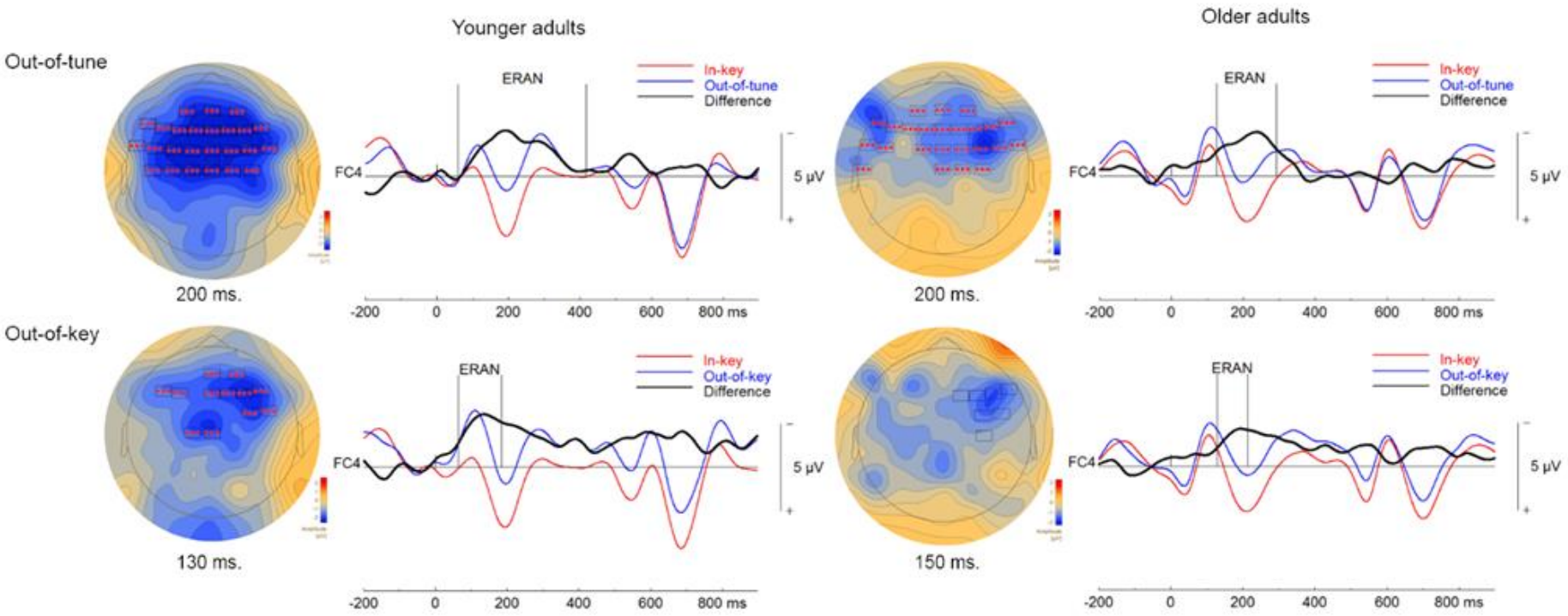
- No difference between groups for the ability to detect a near threshold click
- Harder to detect a click after an out-of-tune note

Pitch Detection Task



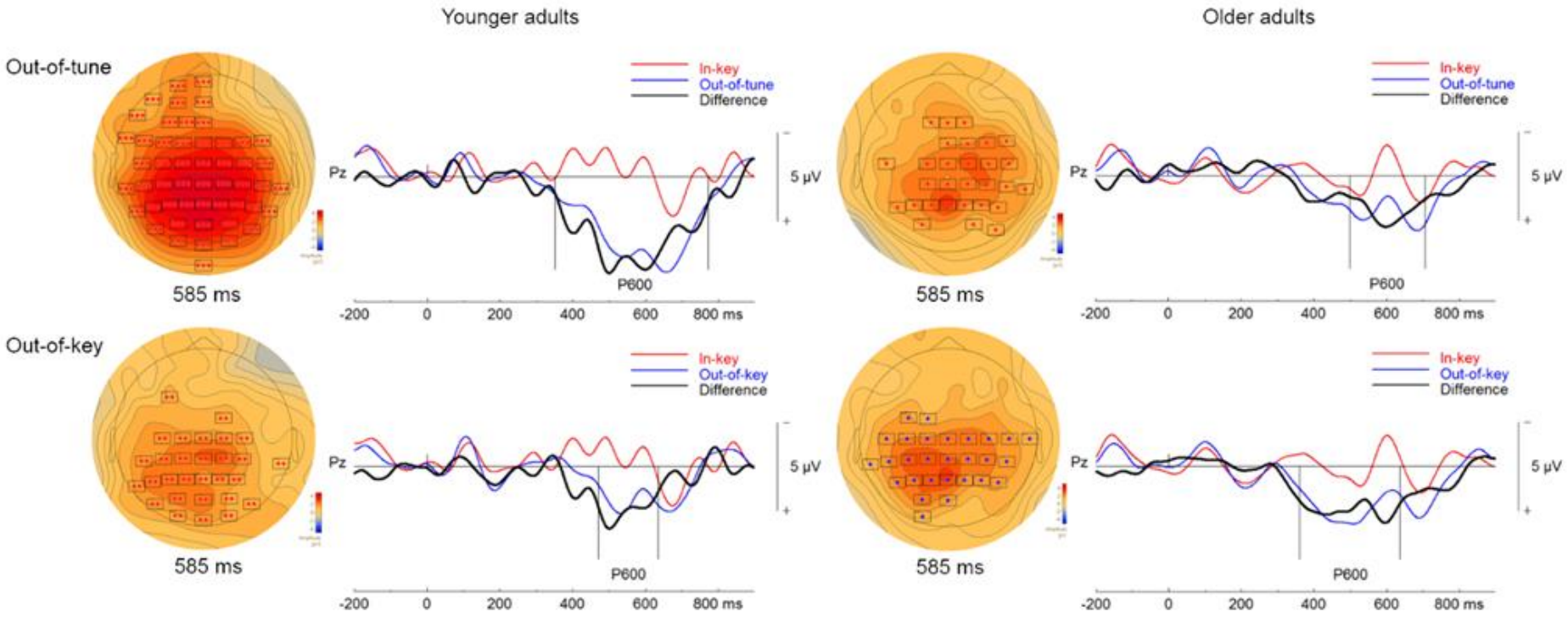
- Older adults were better at detecting an out-of-key note
- Out-of-tune notes were easier to detect

ERAN: Early Right Anterior Negativity



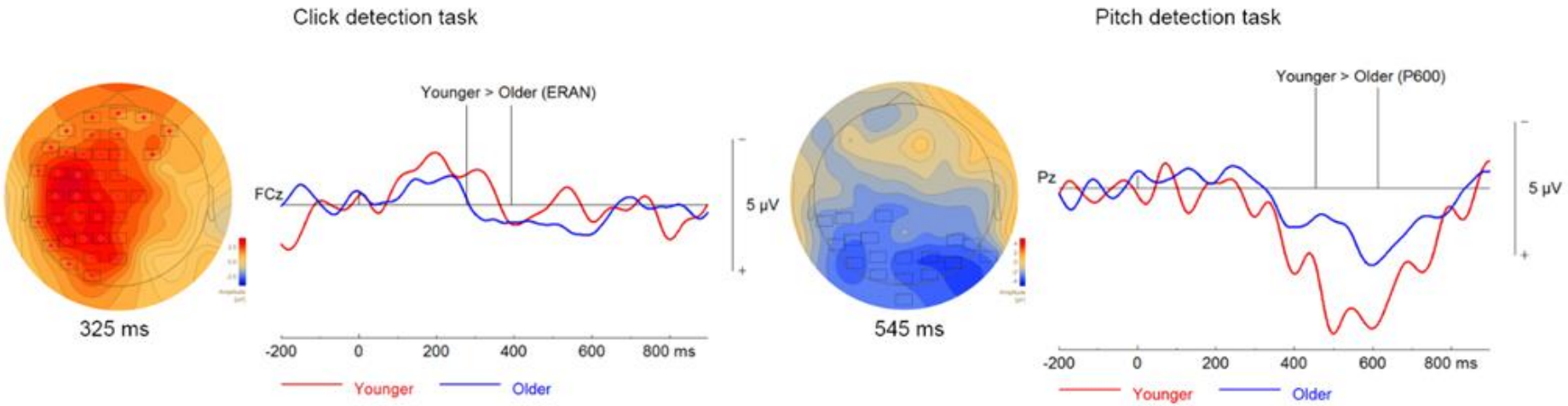
- ERAN: Automatic response to tonal violation
- Evoked in both click- and pitch-detection tasks

P600: Positive wave at 600 ms



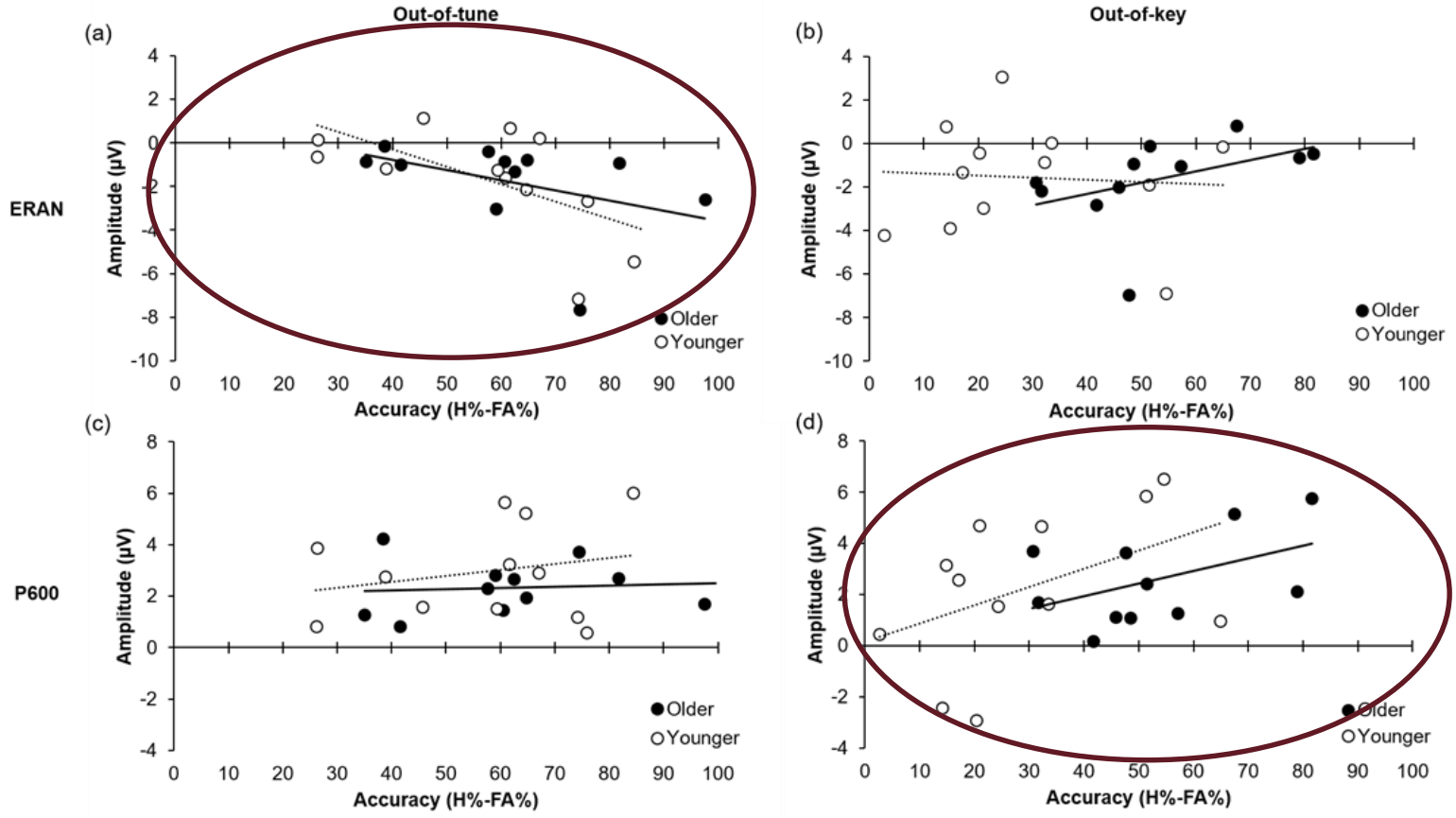
- P600: Conscious integration of the tonal violation into the current melodic context
- Evoked only in pitch-detection task

Younger vs Older adults



- ERAN and P600 were larger in Younger adults compared to Older adults
  - Smaller ERAN in Older Adults: decrease in automatic processing of incoming acoustic information
  - Smaller P600 in Older Adults: mainly at posterior sites, suggesting increased reliance on frontal mechanisms to perform the task

Brain-Behaviour Relationships



- ERAN amplitude best predicted Accuracy for Out-of-Tune notes
- P600 Amplitude best predicted Accuracy for Out-of-Key notes

Tonality - Summary

- **Increased accuracy in Older Adults** for detecting violations of musical key
- **Reduced ERAN in Older Adults** supports previous work highlighting a decrease in automatic processing of incoming acoustic information
- **Reduced P600 in Older Adults** at posterior sites suggests an increase reliance on frontal mechanisms
- **Weaker brain-behaviour correlations in older adults**

- Suggests: older adults use a more distributed neurophysiology to make tonality judgements

Rhythm Perception

- Rhythmic entrainment is a core component of music perception
- The ability to detect and synchronize movements to a beat is learned implicitly, and does not require formal training

- Participants:
  - Younger Adults
    - N = 14 (Age 18-25 [Mean 20.3, SD 1.84, 7 female]
  - Older Adults
    - N=15 (Age 60-73 [Mean 63.4, SD 3.68, 10 female]
- Groups were matched on
  - Years of education [14.6 vs 12.9, p = .15]

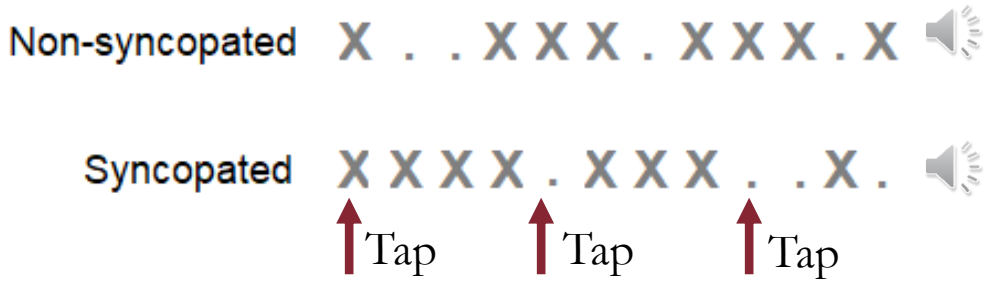
Sauvé, Bolt, Fleming & Zendel (2019) *NeuroReport;*
Sauvé, Bolt, Nozaradan & Zendel (2022) *Frontiers in Aging Neuroscience*

Frequency Tagging

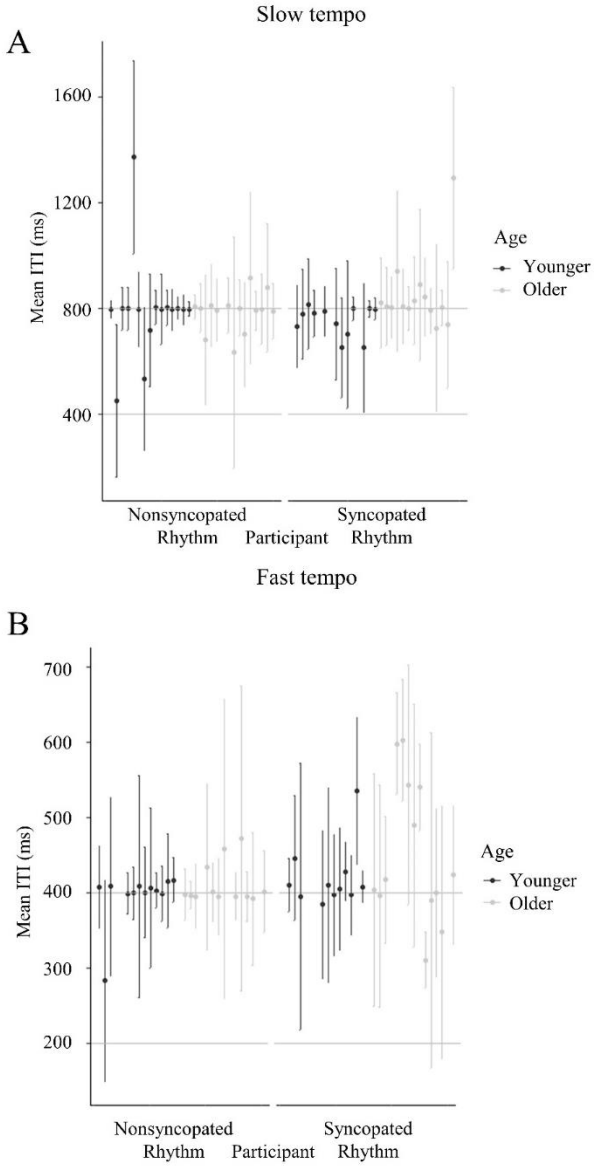
- When playing a rhythmic stimulus, the brain entrains to the frequency
  - Play a metronome click 120 BPM (120 BPM = 2 beats/second = 2 Hz)
    - Some neurons in the brain will oscillate at 2 Hz
  - Ask someone to mentally 'metricize' the metronome
    - March: so that every second click is a 'strong' beat.
      - Some neurons will still oscillate at 2 Hz, and others will oscillate at 1 Hz
    - Waltz: so that every third click is a 'strong' beat
      - Some neurons will oscillate at 2 Hz, others at 0.667 Hz [2 Hz/ 3]
  - Strength of the response at targeted frequencies can be used to identify how well the brain entrains to that frequency in music

Task

- Attend to the rhythm by alternating between tapping/resting
  - Rest: 48 seconds, Tap: 12 seconds; 8 tap-rest cycles/condition
- Stimuli:
  - 2 rhythms (Syncopated, Non-syncopated)
  - 2 Tempo
    - Slow [2400 ms/cycle; beat: 1.25 Hz, 800 ms];
    - Fast [1200 ms/cycle; beat 2.5 Hz, 400 ms]

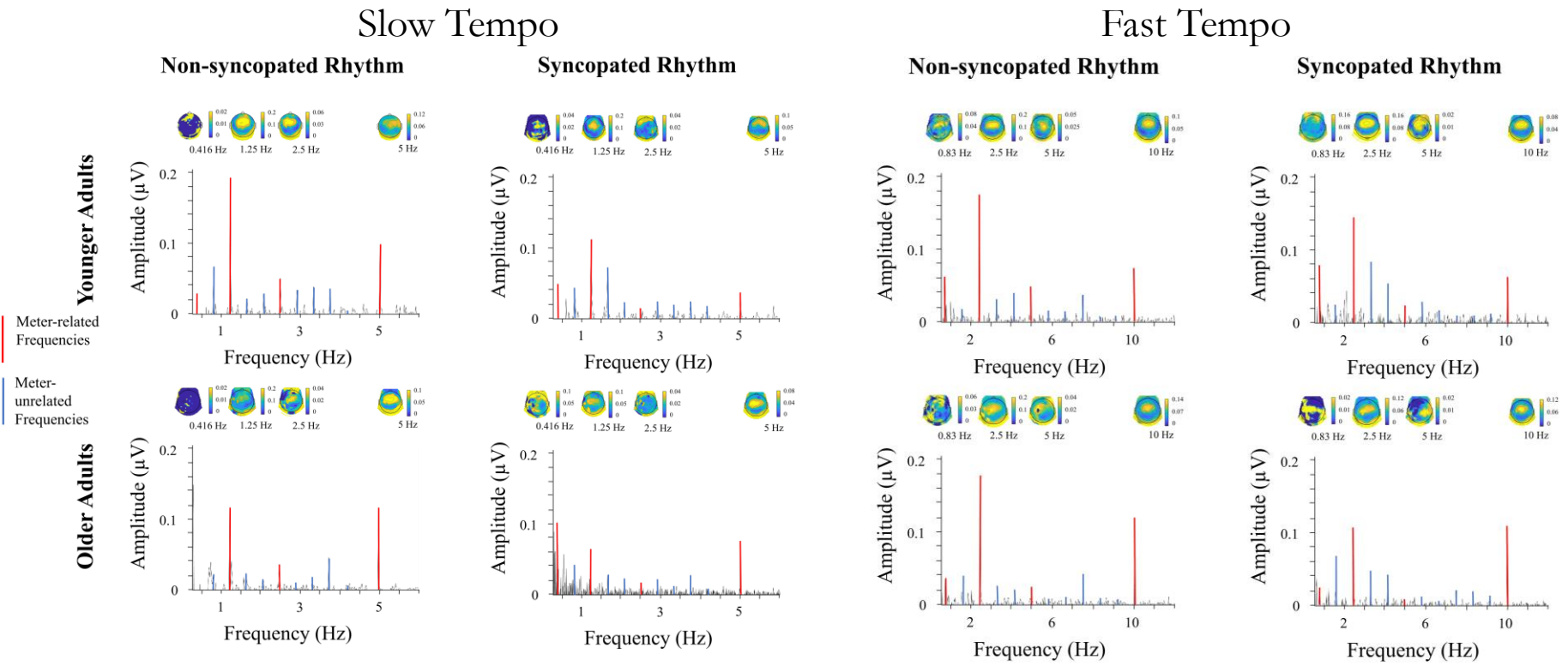


Tapping performance



- Designed to maintain attention for EEG, not for comprehensive analysis
- Inter-tap interval: time between taps
  - Mean indicates the tapped beat
  - Error bars indicate variability
- Tapping performance was similar between older and younger adults
  - Variability and ITI

Frequency Tagging



- Overall: Minimal impact of age on brain responses

Rhythm Summary

- Tapping performance: similar in older and younger adults
- Frequency tagging: similar in older and younger adults
- Suggests processing rhythm is little impacted by age

Music perception Summary

- Music perception seems to be relatively preserved

- The functional neurophysiology of music perception is different in older adults when processing tonality, but not rhythm
  - Rhythm perception engages multiple brain regions known to be involved in the motor system

- Neural architecture that supports music perception could be used as a cognitive scaffold to develop rehabilitation programs
  - For example: Melodic Intonation Therapy

Overall Summary

- Music training can be used to improve hearing abilities in older adults
- Music perception is relatively stable in older adults, particularly rhythm
- Rhythmic perception relies heavily on the motor system
- Music-based forms of auditory rehabilitation should focus on:
  - Integrating auditory-motor systems with a focus on rhythm
  - Connecting music to speech, in order to scaffold impaired speech perception with preserved music perception

Questions?

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