Neuroplasticity following bone conduction amplification

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University of Alberta

Land Acknowledgement

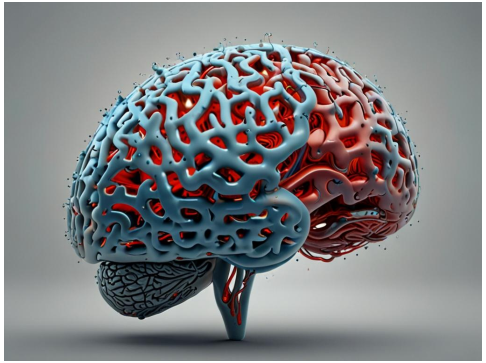
"I would like to acknowledge that the location that I work and live is Treaty 6 territory, the traditional lands of many First Nations, including the Cree, Saulteaux, Nakota Sioux, Blackfoot, and Métis peoples. This land has been a place of gathering, storytelling, and healing for thousands of years, and today we honor the deep connection that Indigenous peoples have with this land. I am committed to learning, honoring, and respecting the rich histories, languages, and cultures of those who have cared for and continue to care for this land. Let us all strive to be respectful stewards of this land as we move forward together."

Positionality Statement

-How I approach the concepts of neuroplasticity are shaped and influenced by my training and personal experiences.

Training - I am a cognitive neuroscientist who works in a Department of Communication Sciences and Disorders

-Tools - fMRI, DTI, fNIRS, sMRI - in humans



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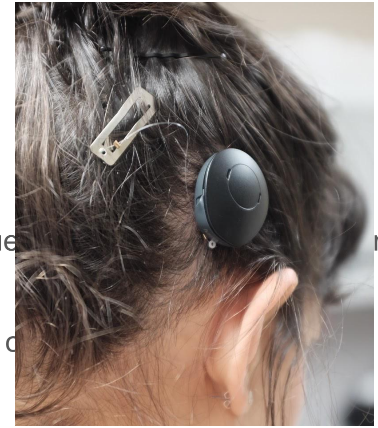

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Training - I am a cognitive neuroscientist who works in a Department o and Di

-Tools - fMRI, DTI, fNIRS, sMRI - in humans

Personal Experiences - I have bilateral conductive hearing loss with a mixed component on the left (or so says my audiologist)

- A VERY long history of fluctuating hearing loss, psychosocial impacts, speech therapy, and only recently (i.e., within the last 10 years) have I been aided.
- Ponto on the left
- Bonebridge on the right
- I have A LOT to say about how my brain changed as a function of this history and treatment.

Learning Objectives

1. By the end of this talk, individuals will be able to explain the underlying mechanisms of neuroplasticity related to treatment interventions such as hearing aids and aural rehabilitation in adults.

2. We will discuss the time frames in which brains respond to changes in input (i.e., hearing amplification).

3. We will identify several avenues where neuroplasticity research can be brought into the clinical conversation.

What is Neuroplasticity?

Refers to the brain's ability to reorganize itself by forming new neural connections throughout life. This adaptability allows the brain to compensate for injury, adapt to new experiences, and support learning and memory.

Objective 1: What is neuroplasticity? Let's break it down.

Synaptic Plasticity

Structural Plasticity

Compensation

Learning

Changes in the strength of connections/amplitude of activity between neurons, which can either become stronger (long-term potentiation) or weaker (long-term depression) in response to repeated activity.

Neuroplasticity

What is neuroplasticity? Let’s break it down.

Synaptic Plasticity

Structural Plasticity

Compensation

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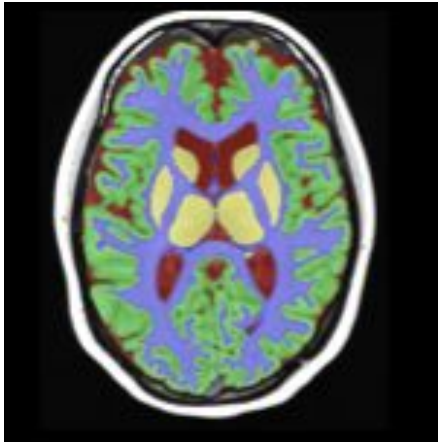
Physical changes in structure by forming new connections or eliminating unused ones.



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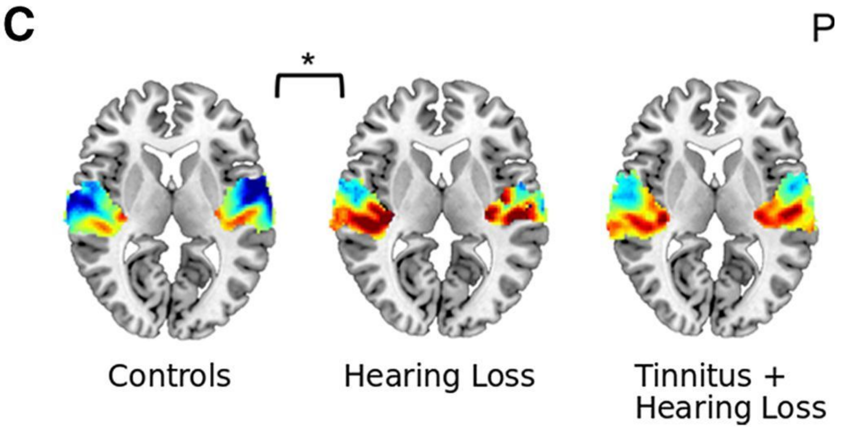

Nearby healthy regions of the brain can take over the functions of damaged/deprived areas through neuroplasticity, allowing recovery of abilities such as movement or language.

Neuroplasticity

Koops et al., 2020, J of Neuroscience

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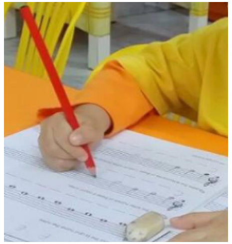


New skills or acquiring new knowledge leads to the rewiring of neural circuits, reflecting the brain’s adaptability.

Neuroplasticity

How can we measure neuroplasticity?

Connectivity	Changes in the strength/amplitude of activity of connections between neurons, which can either become stronger (long-term potentiation) or weaker (long-term depression) in response to repeated activity.
Volume, Thickness, Density, Diffusion	Physical changes in structure by forming new connections or eliminating unused ones.
Activity	Nearby healthy regions of the brain can take over the functions of damaged areas through neuroplasticity, allowing recovery of abilities such as movement or language.
Activity and/or connectivity	New skills or acquiring new knowledge leads to the rewiring of neural circuits, reflecting the brain's adaptability.

Neuroplasticity

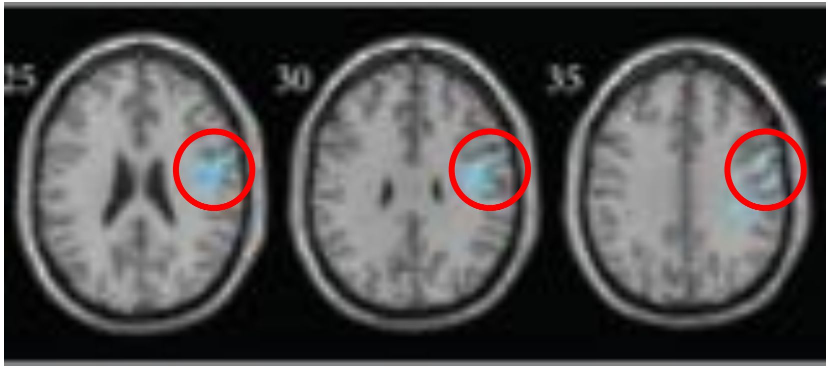
How can we measure neuroplasticity?

Connectivity

Volumetric, Density, Diffusion

Activity

Activity and/or connectivity



Decreased amplitudes for adults with sudden sensorineural hearing loss compared to age matched controls without hearing loss (Chen et al., 2020; https://doi.org/10.1155/2020/9460364)

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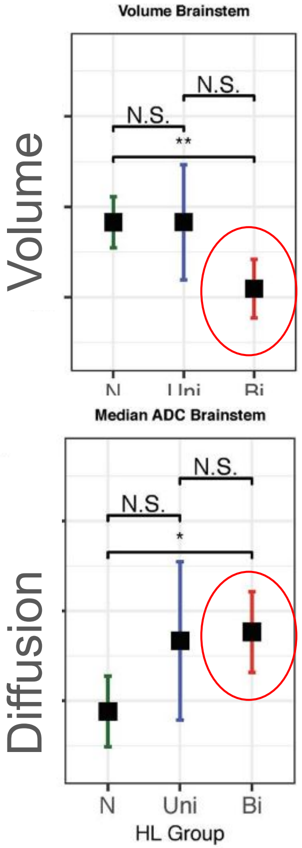

Children with bilateral sensorineural hearing loss have reduced volume and increased mean diffusion in the brainstem compared to non-hearing impaired children (Moon et al., 2020; https://doi.org/10.1016/j.nicl.2020.102328.

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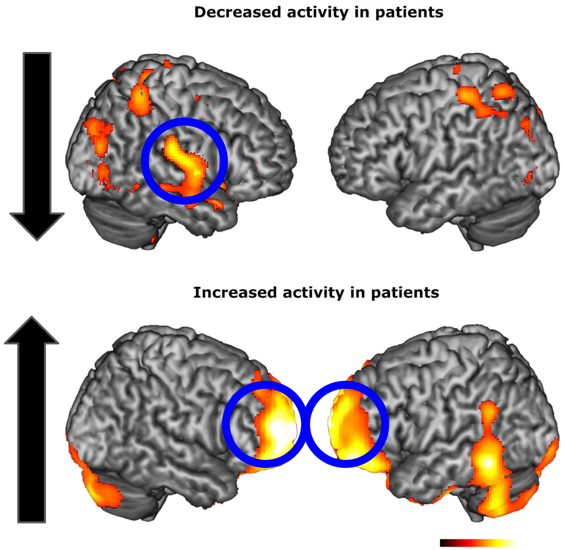


Cochlear implant users - Decreased activity in auditory cortex and increased activity in frontal cortices in comparison to age matched controls (Strelnikov et al., 2024; https://doi.org/10.1016/j.heares.2024.10907)

Neuroplasticity

How can we measure neuroplasticity?

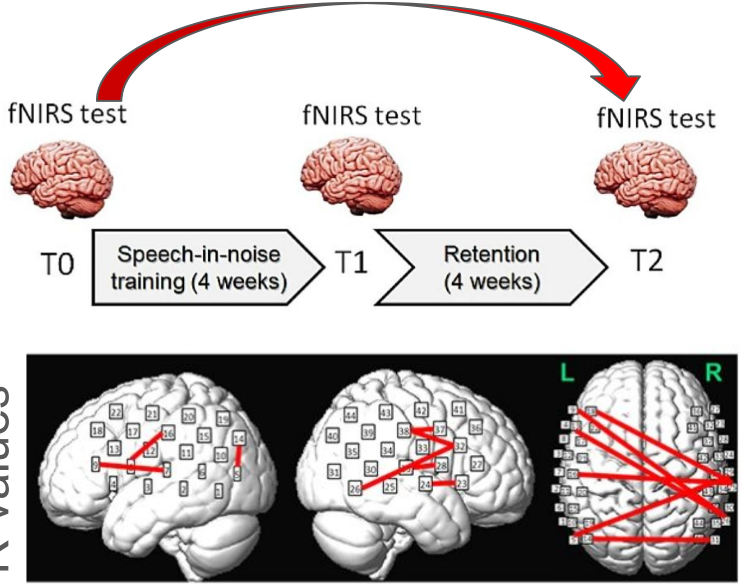
Connectivity

Volumetric, Density, Diffusion

Activity

Activity and/or connectivity

Older adults with mild hearing loss show increases in connectivity within and across hemispheres (Mai et al., 2024; https://doi.org/10.1007/s10548-024-01070-2)



R-values

Neuroplasticity

Objective 1: Summary

Many mechanisms of neuroplasticity associated with hearing aid treatment and rehabilitation

Neuroplasticity associated with treatment intervention effects span:

Device: CI, air conduction, bone conduction

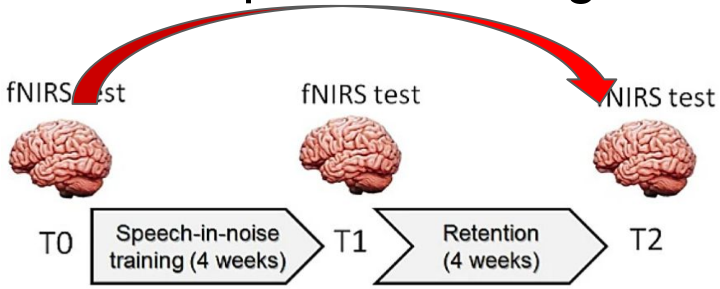
Population: Children through adults

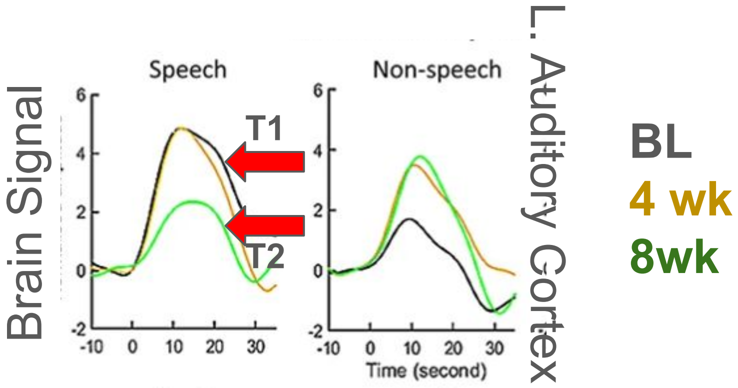
Etiologies: Congenital, middle ear, inner ear, etc.

Duration: Longterm vs. sudden onset

Objective 2: Time frames in which brains respond to changes in input

Older adults (N = 10) with mild-to-moderate hearing loss show significant decrease in speech related brain activity pre-post training in the auditory cortex. (Mai et al., 2024; https://doi.org/10.1007/s10548-024-01070-2)





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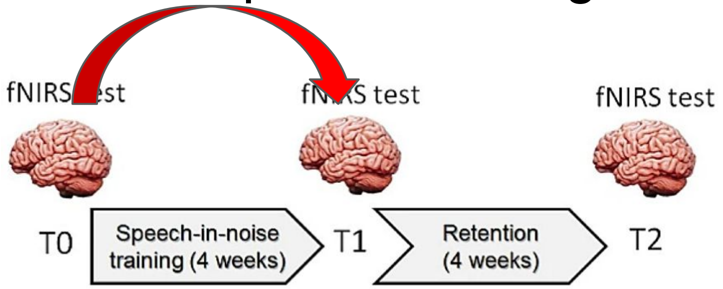

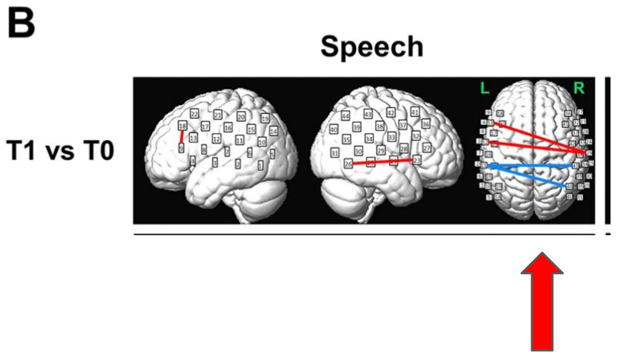

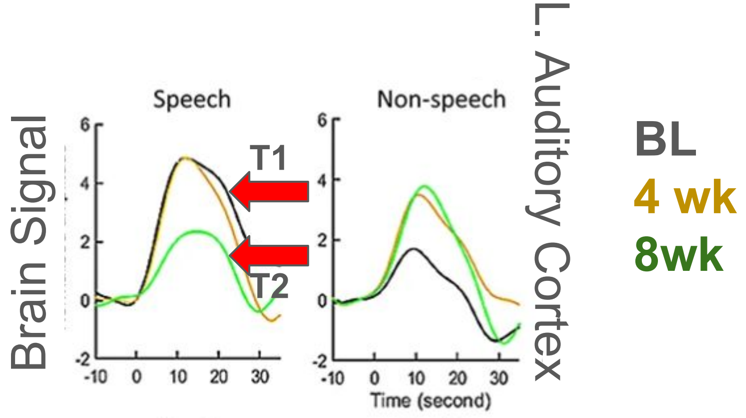

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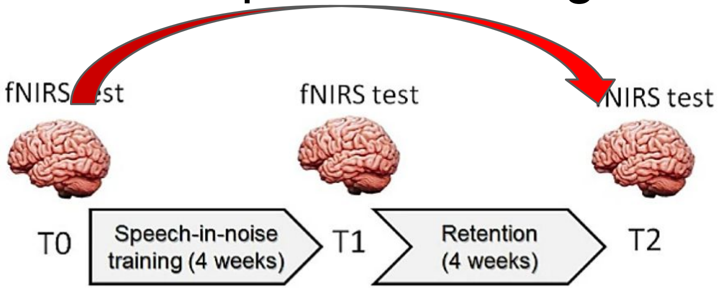

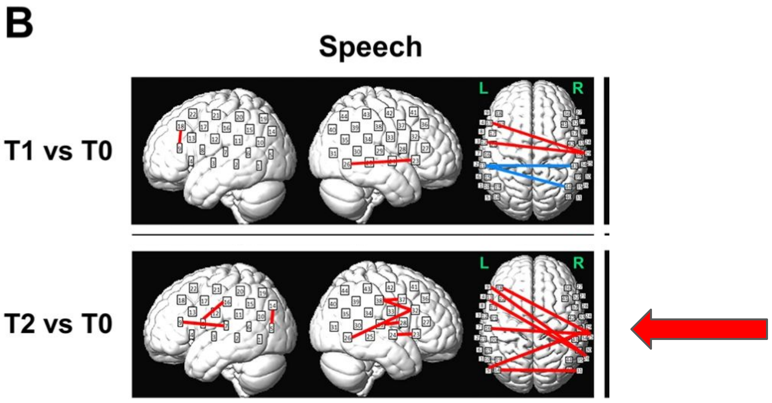

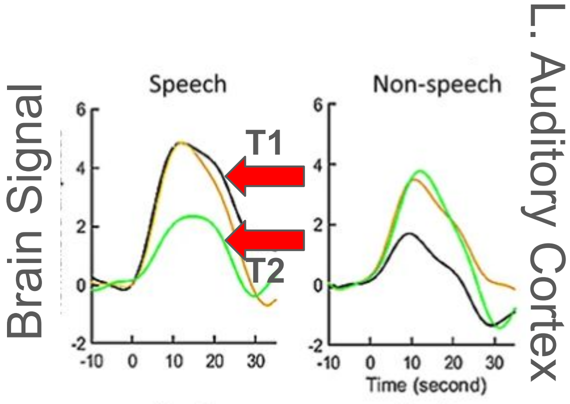

BL
4 wk
8wk

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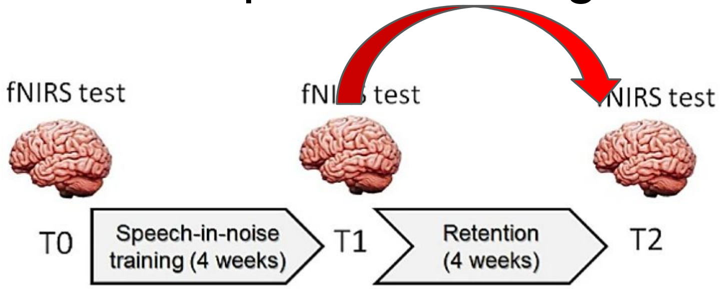
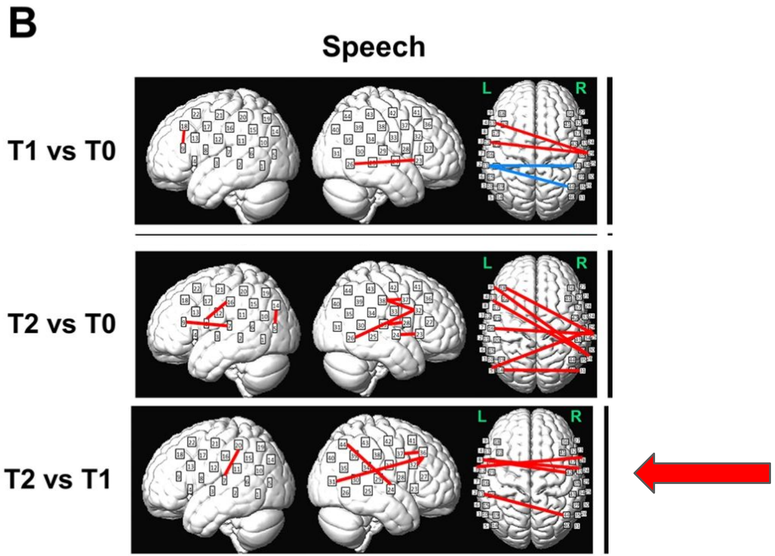
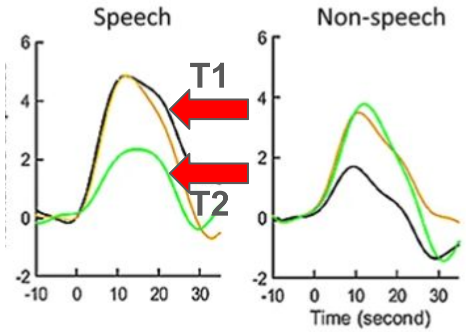






L. Auditory Cortex

BL
4 wk
8wk

Objective 2: Time frames in which brains respond to changes in input

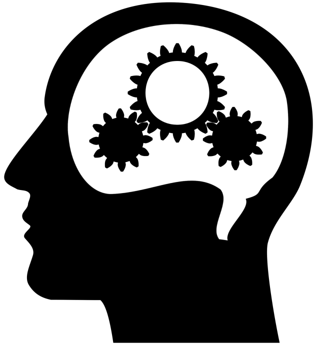
Do not know the short and long-term trajectory of change of hearing related treatment!

Study Design: Multiple Single Case Experimental Approach

Measured Brain Responses using functional near infrared spectroscopy (fNIRS):

1) Effortful listening task

2) Resting state



Baseline Measurements

B1 → B2 → B3 → B4 → B5

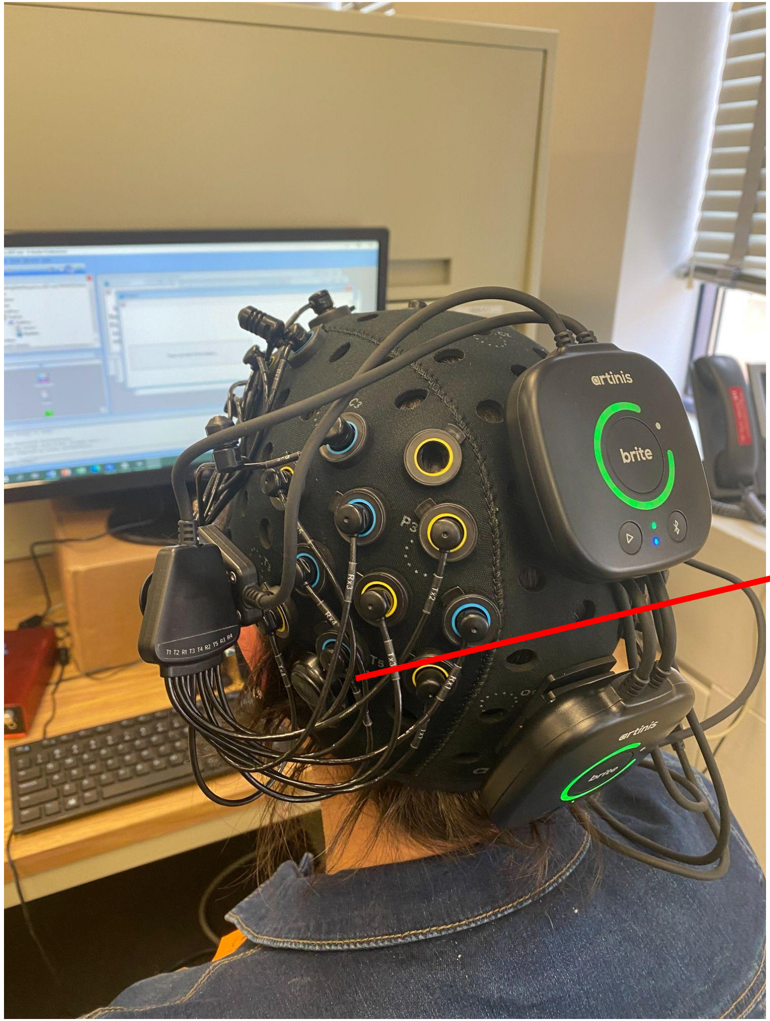
Hearing Aid

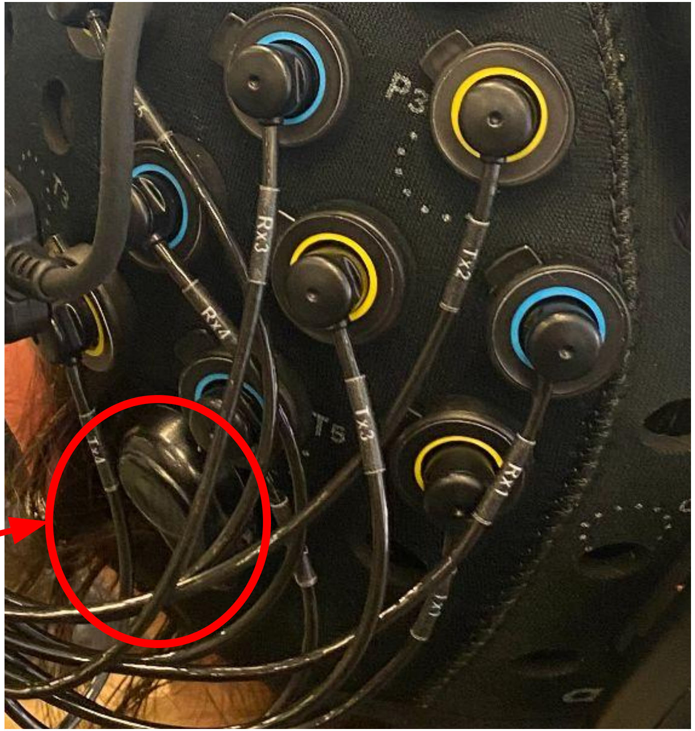
Treatment Measurements

T1 → T2 → T3 → T4

1 week, 1 month, 2 months, 3 months

Note: 9 timepoints/measures @ approx 3 hours each covering audiological, cognitive, & brain domains for each human





Non-invasive brain imaging technique that utilizes light absorption to indirectly infer brain activity. Standardized preprocessing applied. Dependent measures associated with oxygenated blood are extracted.

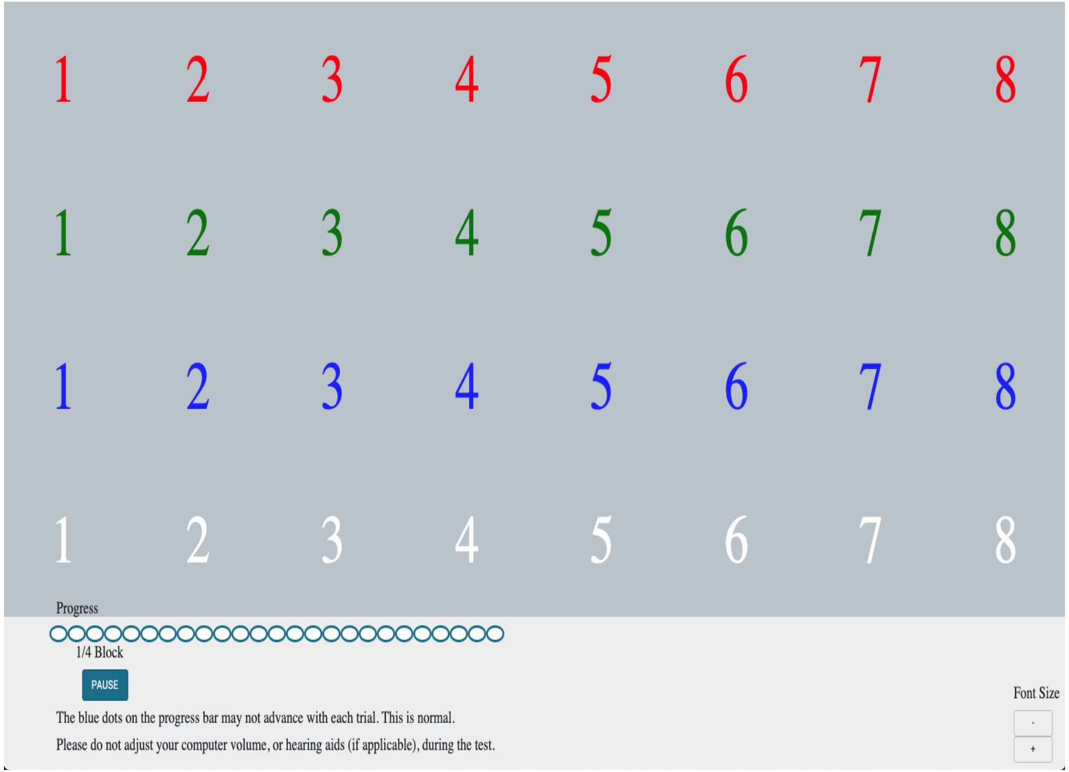
Effortful Listening Task

-Approx. 20 mins over two blocks.

‘Ready Baron go to blue 3 now’

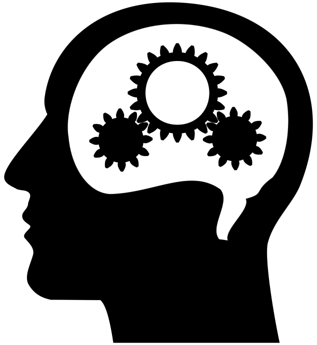
Background noise: Multitalker Babble

Adaptive procedure to maintain 75% accuracy (✅ - SNR goes down by 1; ❎ - SNR goes up by 3)



Resting State Measurements

Rest with your eyes closed (8 mins).



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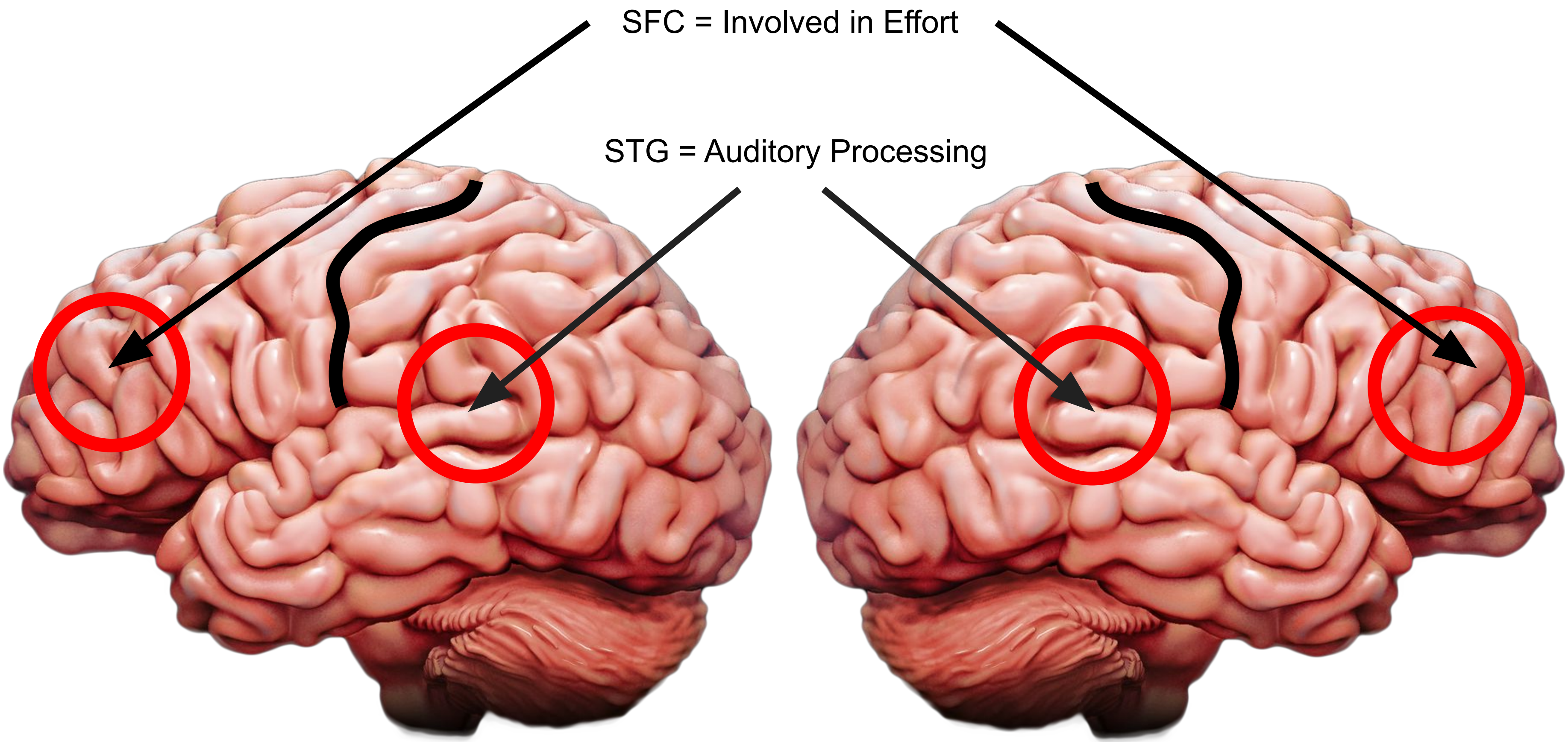
No task - blank screen

Brain Regions Of Interest



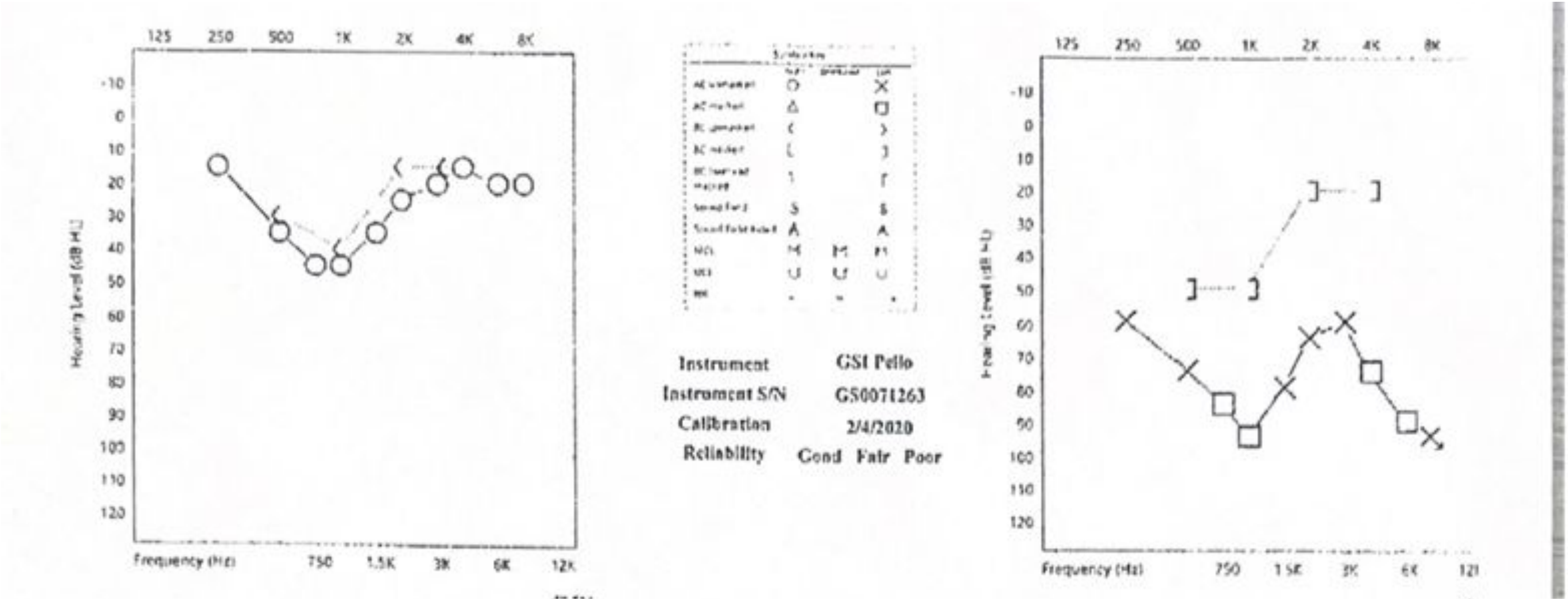
Case - Male (Age 41)

Hearing loss: Right mild to moderate sensorineural hearing loss; moderately-severe to severe mixed hearing loss on the left (25 to 55 dB air bone gap) with two previous stapedotomies on the left side

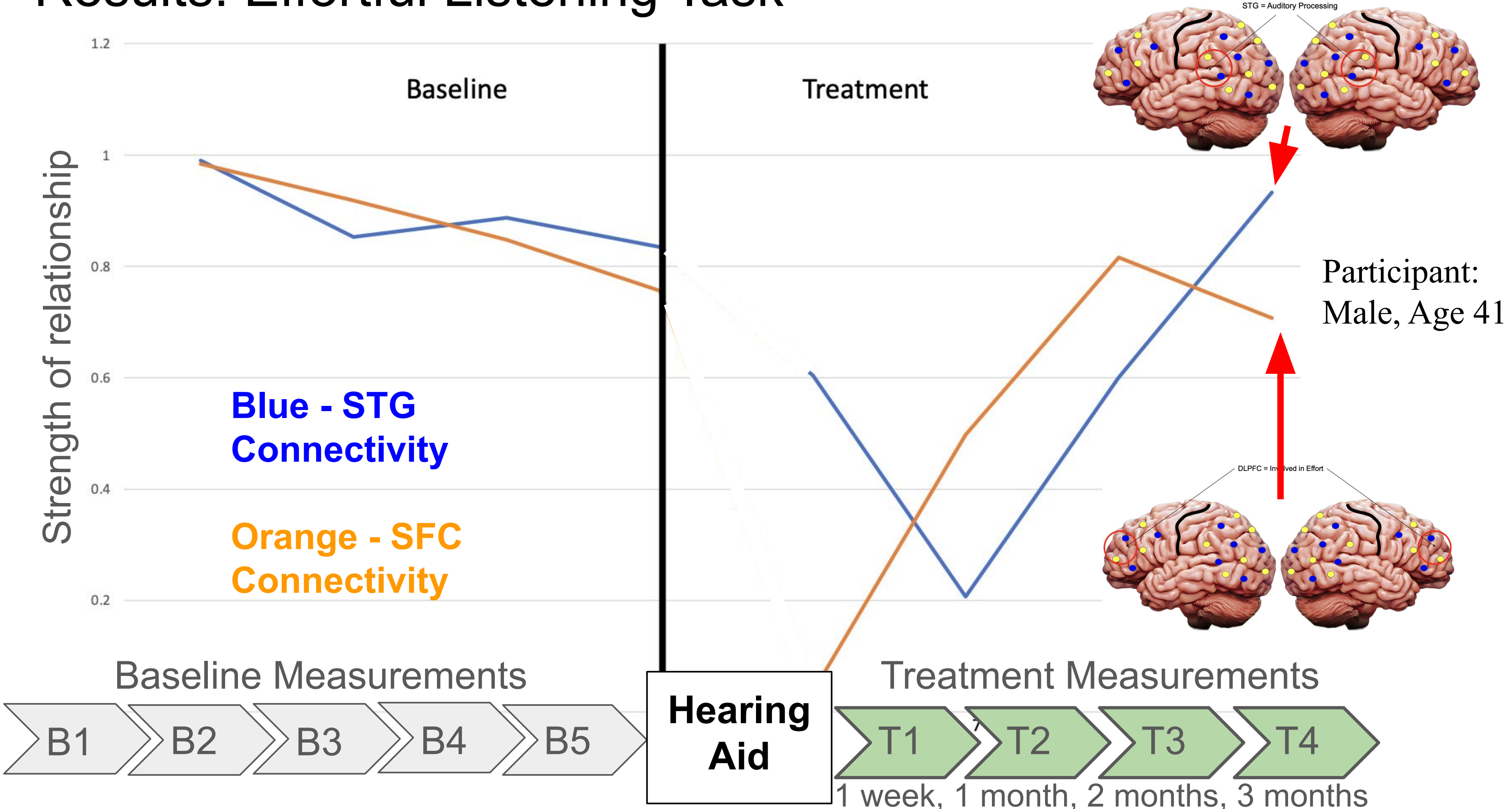
Previous treatment: Aided with air conduction hearing aids in the right ear for 8 years; aided with air conduction hearing aids in the left ear for 10 years

BCD information: Left side surgery 28 Feb; Fit 31 May with a left Ponto 3 SP

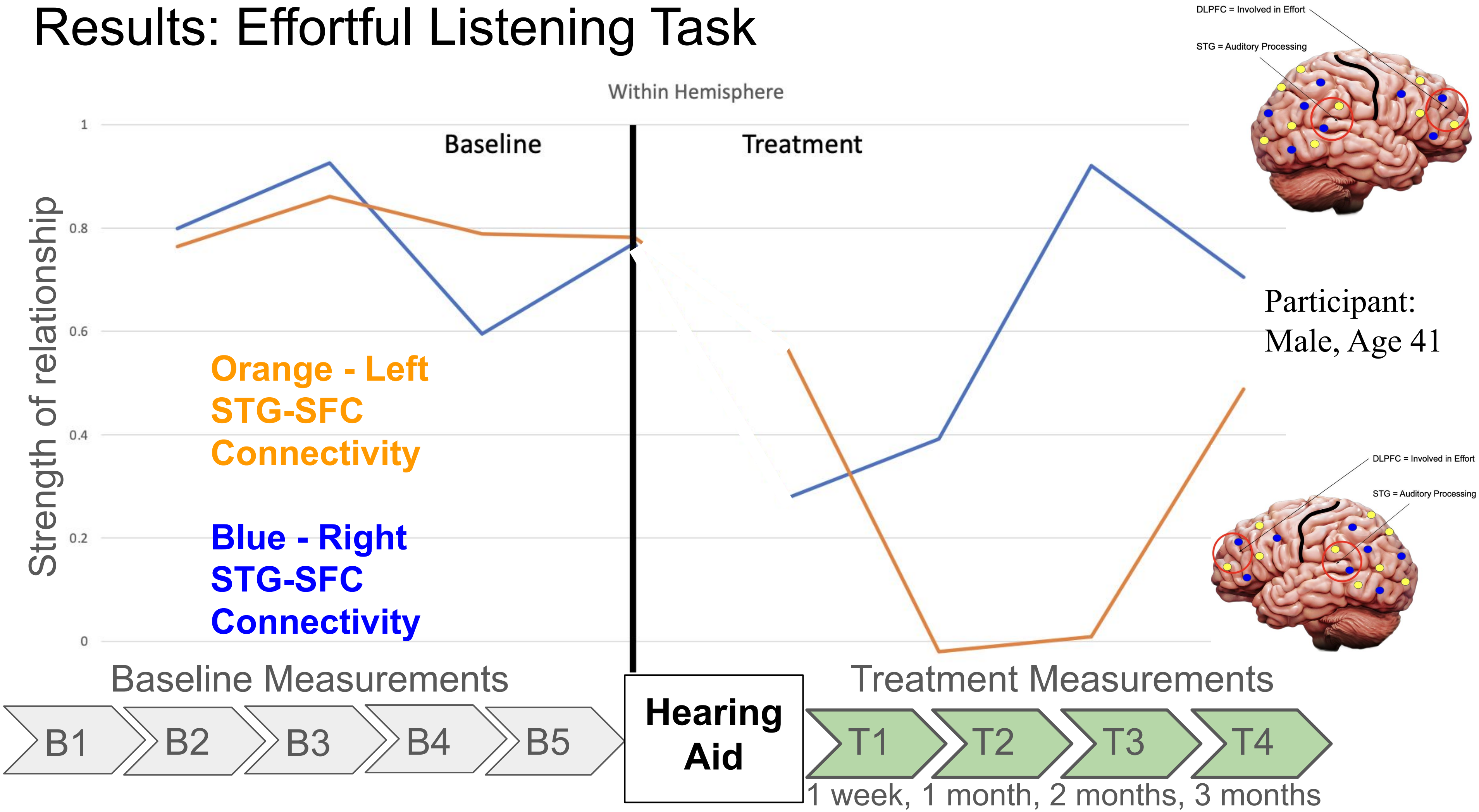
Audiogram


125 250 500 1K 2K 4K 8K
-10 0 10 20 30 40 50 60 70 80 90 100 110 120
Frequency (Hz) 750 1.5K 3K 6K 12K
Instrument GSI Pello
Instrument S/N G50071263
Calibration 2/4/2020
Reliability Good Fair Poor

Results: Effortful Listening Task



Results: Effortful Listening Task



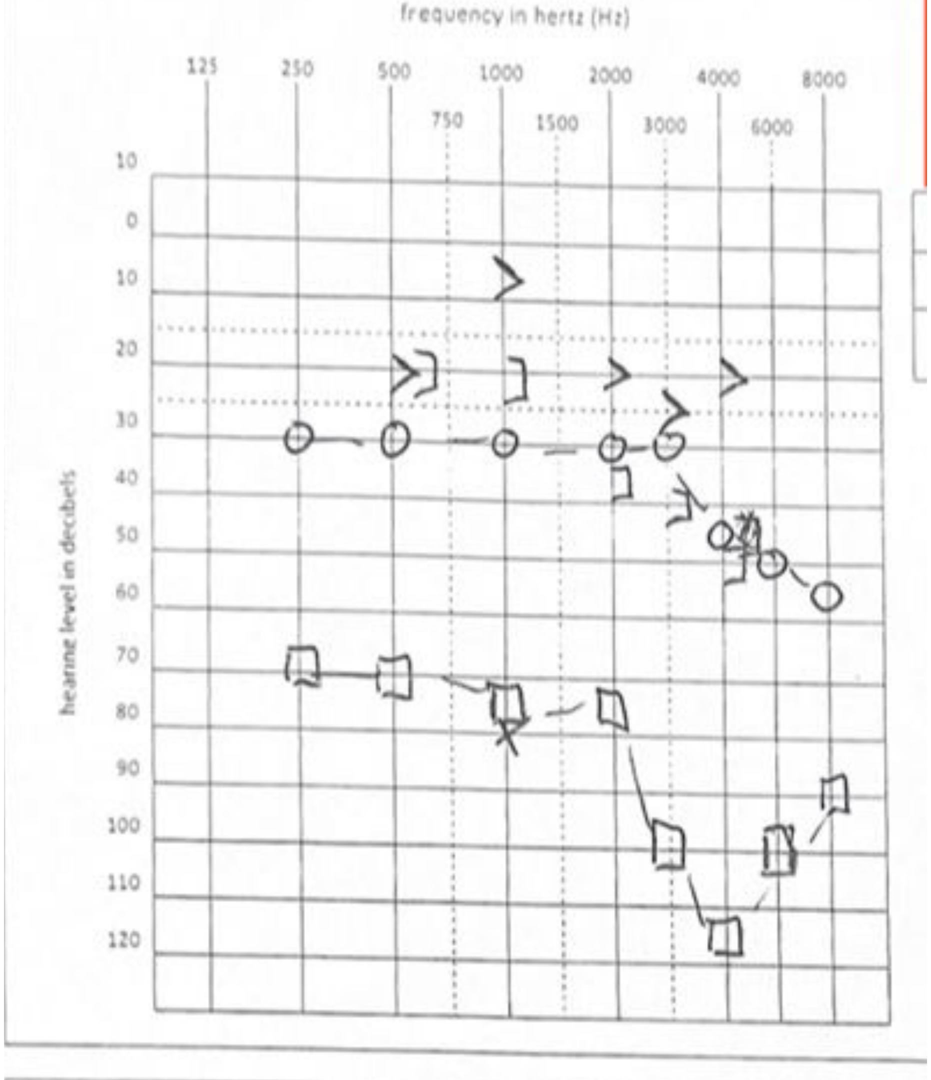
Case - Female (Age 54)

Hearing loss: Mild sloping to moderately-severe sensorineural hearing loss on the right; severe to profound mixed hearing loss on the left with a 40 to 60 dB air-bone gap from chronic otitis media

Previous treatment: Never aided

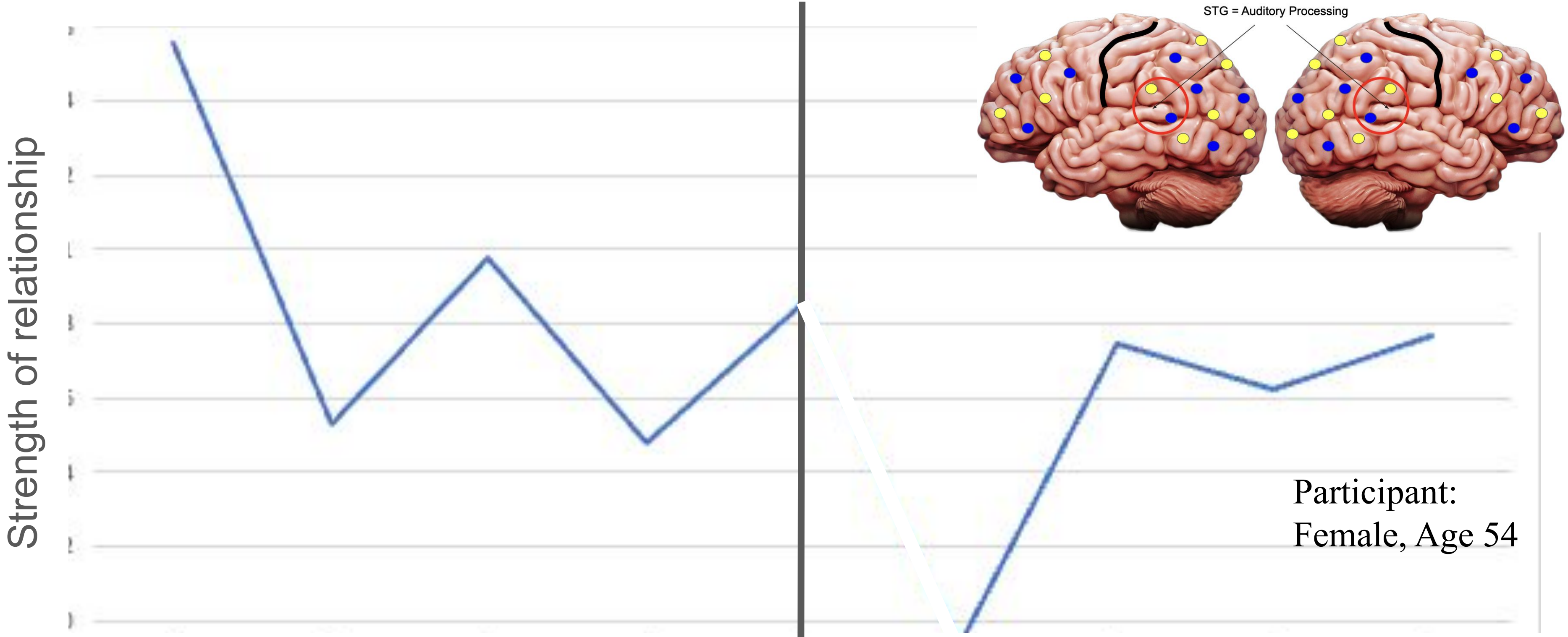
BCD information: Left side surgery 23 April; Fit July 29 with a left Ponto 3 SP

Audiogram


frequency in hertz (Hz)
125
250
500
750
1000
1500
2000
3000
4000
6000
8000
hearing level in decibels
10
0
10
20
30
40
50
60
70
80
90
100
110
120

Results: Resting State Analysis

Across Hemisphere Auditory Cortices



Baseline Measurements

B1 B2 B3 B4 B5

Hearing Aid

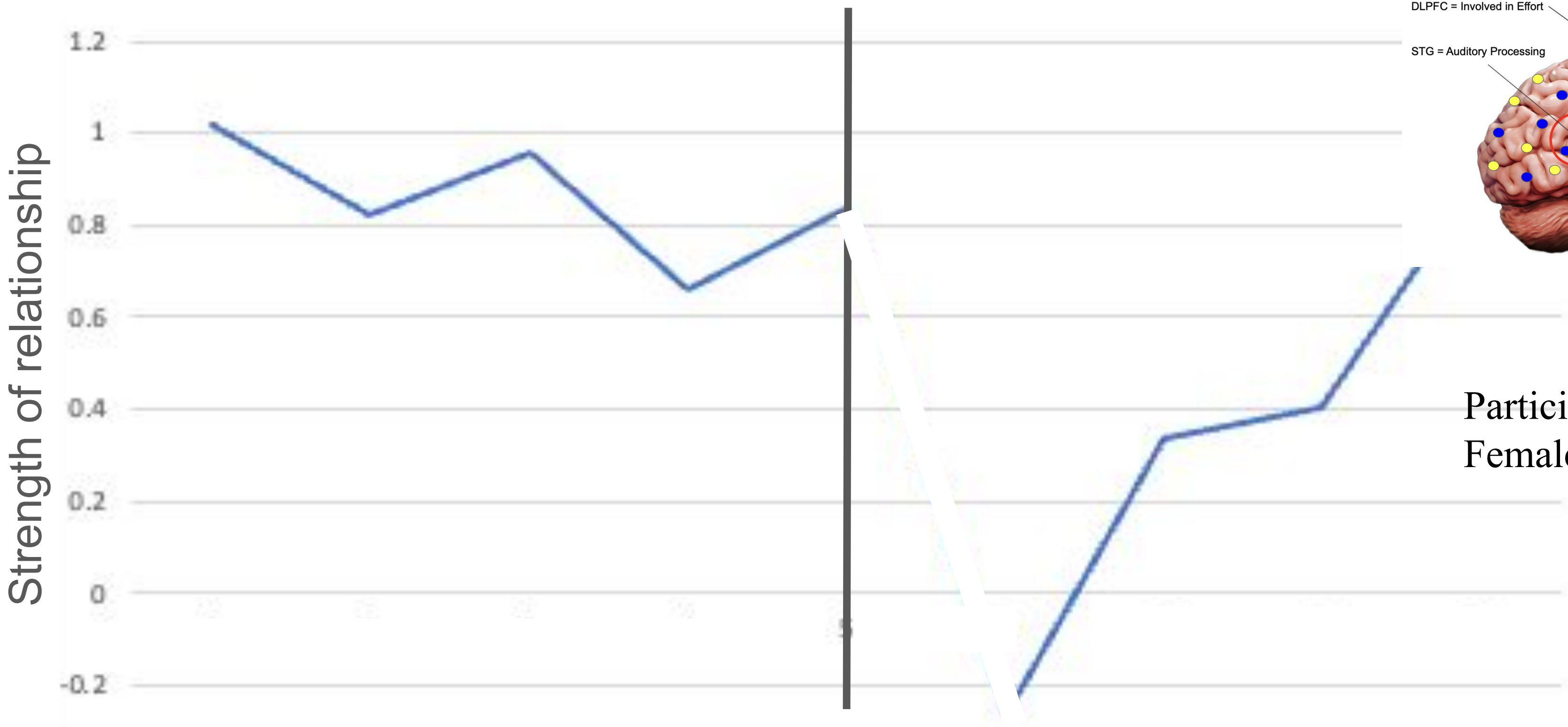
Treatment Measurements

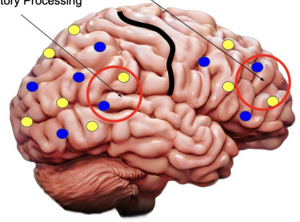
T1 T2 T3 T4

1 week, 1 month, 2 months, 3 months

Results: Resting State Analysis

Within Hemisphere STG - SFC





Participant:
Female, Age 54

Baseline Measurements

B1 B2 B3 B4 B5

Hearing Aid

Treatment Measurements

T1 T2 T3 T4

1 week, 1 month, 2 months, 3 months

Objective 1

Neuroplasticity

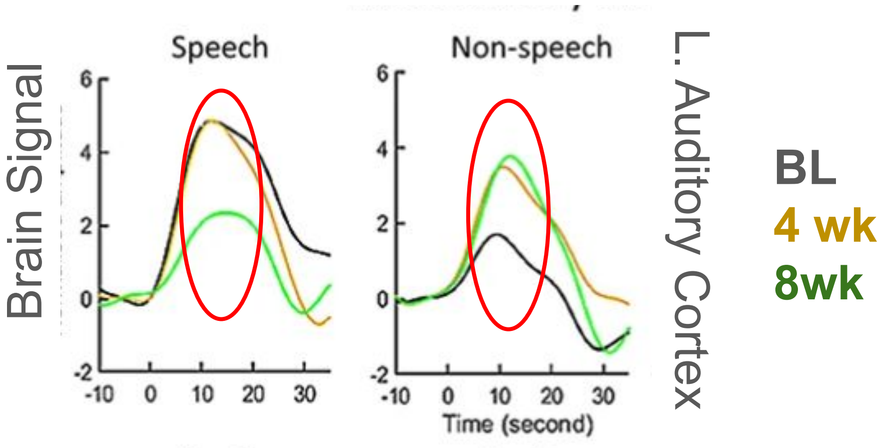
Objective 2

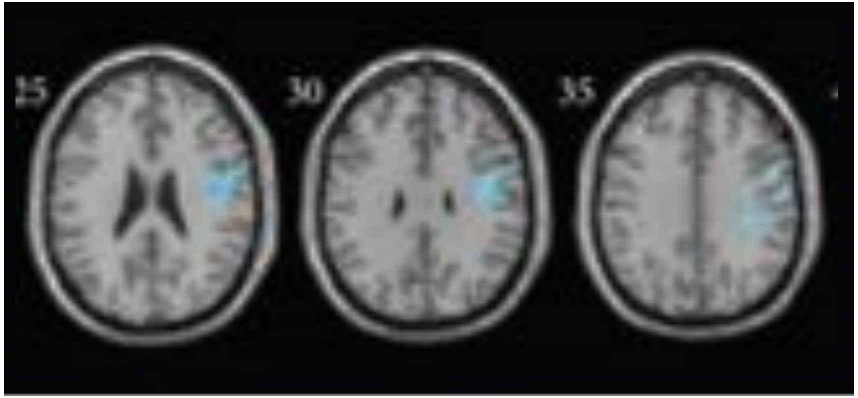
Time Frame

Objective 1		Objective 2	
Synaptic Plasticity	✓	Connectivity	Changes in connectivity immediately following HA treatment in auditory task, in absence of auditory task, & across humans
~~Structural Plasticity~~		~~Volume, Thickness,~~ Density, Diffusion	
Compensation	✓	Activity	LSTG-RSTG - Changes as late as 3 months and as early as 1 months.
Learning	✓	Activity and/or connectivity	STG-SFG - Changes happen along more variable time scales.

Side Bar: Is Activity/Thickness/Connectivity Good or Bad??

-It depends ….. What does the behaviour tell you?





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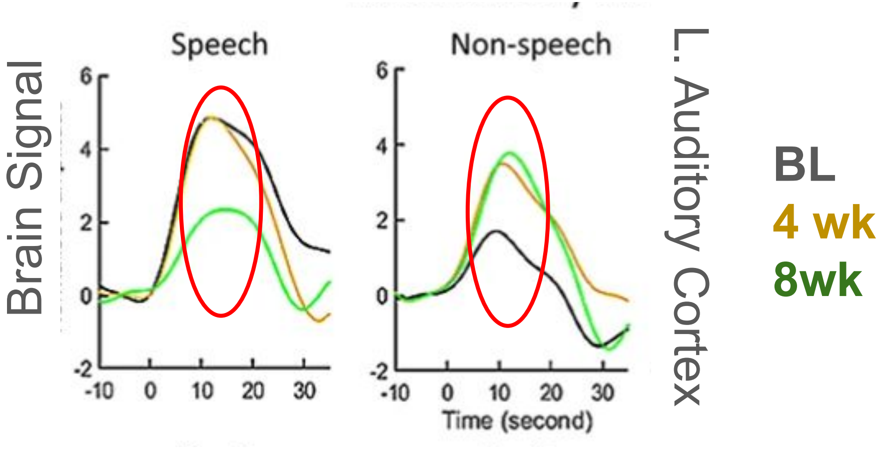

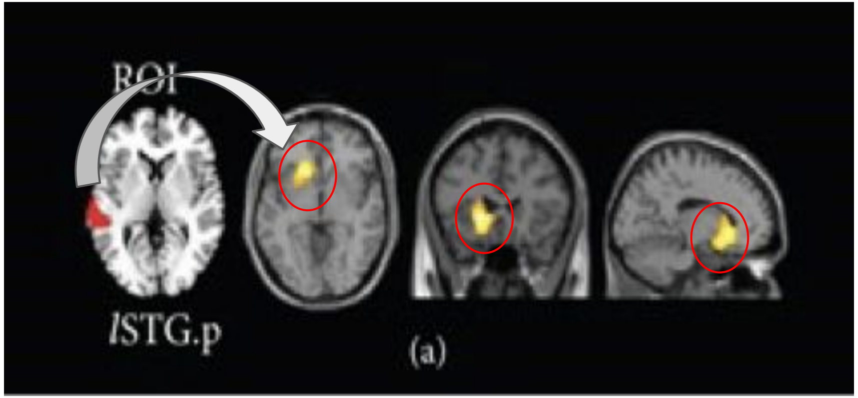

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Objective 3: Neuroplasticity in the clinical conversation

10 Principles of Neuroplasticity:

1. Use It or Lose It. Neural circuits that are not actively engaged will degrade over time. If specific skills or functions are not practiced or utilized, the brain may lose the ability to perform them effectively.

2. Use It and Improve It. Conversely, when neural circuits are actively engaged, they become stronger. Regular practice of a skill can enhance its associated neural networks, making the function more efficient.

3. Specificity. The changes that occur in the brain are specific to the activity being practiced. The brain adapts to the exact type of practice or learning experience, so targeted exercises are essential for improving specific skills.

4. Repetition Matters. Repetition of a skill or activity is crucial for inducing lasting changes in the brain. Repeated practice helps solidify new neural connections and increases the likelihood of long-term retention of the skill.

5. Intensity Matters. The intensity or level of engagement in a task influences the degree of neuroplastic changes. High-intensity practice can lead to more significant brain adaptations compared to low-intensity practice.

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3. Specificity. The changes that occur in the brain are specific to the activity being practiced. The brain adapts to the exact type of practice or learning experience, so targeted exercises are essential for improving specific skills.

4. Repetition Matters. Repetition of a skill or activity is crucial for inducing lasting changes in the brain. Repeated practice helps solidify new neural connections and increases the likelihood of long-term retention of the skill.

5. Intensity Matters. The intensity or level of engagement in a task influences the degree of neuroplastic changes. High-intensity practice can lead to more significant brain adaptations compared to low-intensity practice.

Objective 3: Neuroplasticity in the clinical conversation

10 Principles of Neuroplasticity (cont):

6. Time Matters. Neuroplastic changes often occur over time. Different forms of neuroplasticity may appear at different stages of training or recovery, so the timing of interventions is important.

7. Salience Matters. The brain is more likely to adapt and change when the activity is meaningful or has relevance to the individual. Motivation and attention play critical roles in driving neuroplasticity.

8. Age Matters. While neuroplasticity occurs throughout life, it tends to be more robust in younger individuals. The brain's capacity to reorganize diminishes with age, though older brains can still adapt with proper training.

9. Transference. Neuroplasticity in one area or function can enhance related functions. For example, improving motor skills in one area may facilitate improvement in similar skills.

10. Interference. Conversely, the acquisition of one skill may interfere with the ability to acquire another. Competing neural processes can limit the effectiveness of new learning if they conflict with established behaviors.

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Objective 3: Neuroplasticity in the clinical conversation

Encourage and educate individuals about the brain's ability to adapt and reorganize in response to auditory interventions

1) When introducing new aids/technology - the brain needs time to adapt to new auditory input
2) During aural rehabilitation - consistent practice helps strengthen neural pathways for sound processing
3) For challenging/complex conditions - retrain the brain to ignore or deprioritize the perception of tinnitus
4) Brain injury rehabilitation - highlight the brain's ability to rewire itself
5) For pediatric patients - early intervention takes advantage of heightened neuroplasticity in childhood

Learning Objectives

1. Underlying mechanisms of neuroplasticity related to treatment interventions such as hearing aids and aural rehabilitation in adults - synaptic, structural, activity, and connection-based changes.

2. The time frames in which brains respond to changes in input (i.e., hearing amplification) - varying considerably across individuals.

3. Avenues where neuroplasticity research can be brought into the clinical conversation - brains are plastic and highly dynamic that change in response to the environment.

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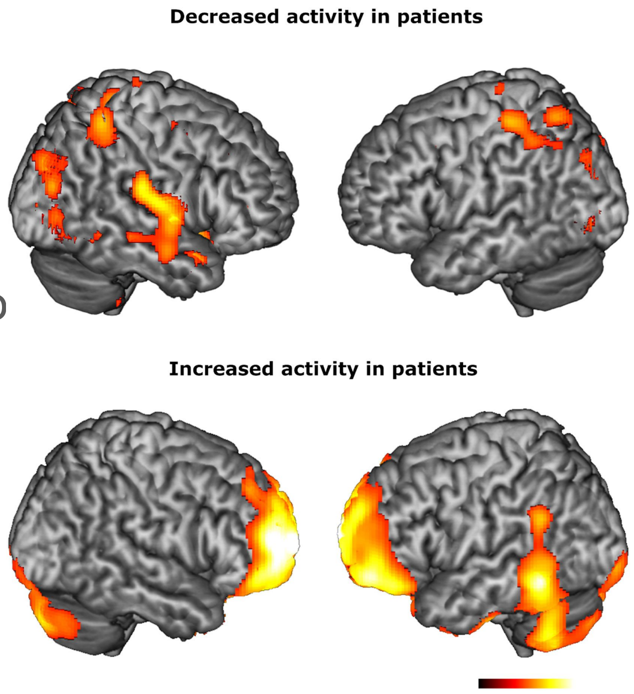
Questions?

Does device type influence brain changes?

1. Cochlear Implants - most work here
    a. Genesis of a lot of the neuroplasticity work

2. Air conduction hearing aids - next amount of wo

3. Bone conduction hearing aids - least amount of



How can we measure neuroplasticity?

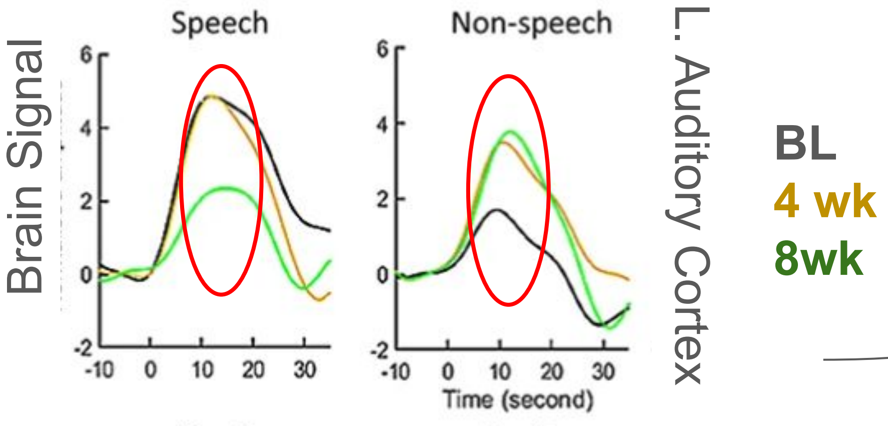
Connectivity

Volumetric, Density, Diffusion

Activity

Activity and/or connectivity

Older adults (N = 10) with mild-to-moderate hearing loss show significant decrease in speech related brain activity pre-post training in the auditory cortex. (Mai et al., 2024; https://doi.org/10.1007/s10548-024-01070-2)



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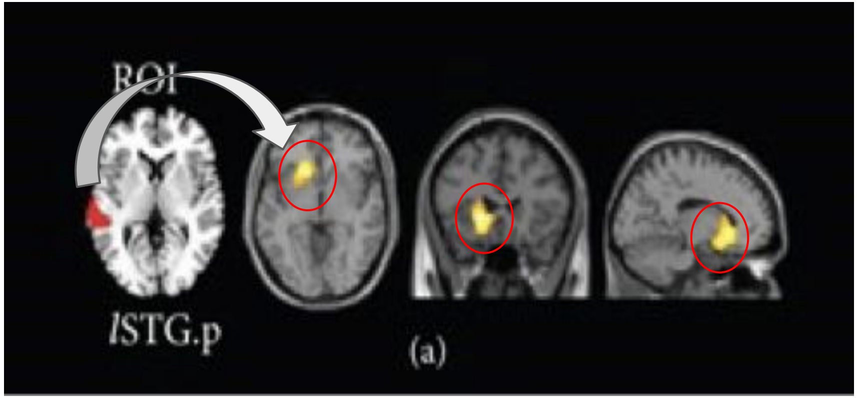

Increased connectivity for individuals with sudden sensorineural hearing loss compared to age matched controls without hearing loss (Chen et al., 2020; https://doi.org/10.1155/2020/9460364)

Neuroplasticity

What happens in the absence of sound input?

Sensory deprivation studies - tons of animal work

1. Cross-modal plasticity - visual to auditory and auditory to visual.

2. Compensatory plasticity - homologue regions

3. Adaptive plasticity - peripheral regions - somatosensory recruitment

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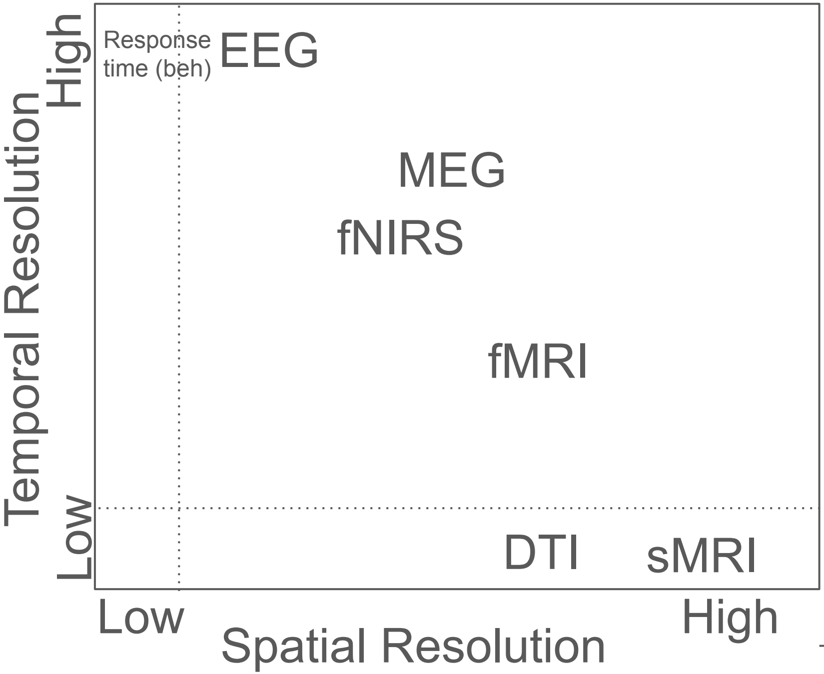

Neuroplasticity