EEG-Based Neurofeedback Training Offers a Novel Treatment Option for Auditory Deficits in Noise

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Service-Connected Hearing Loss Is a Big Problem

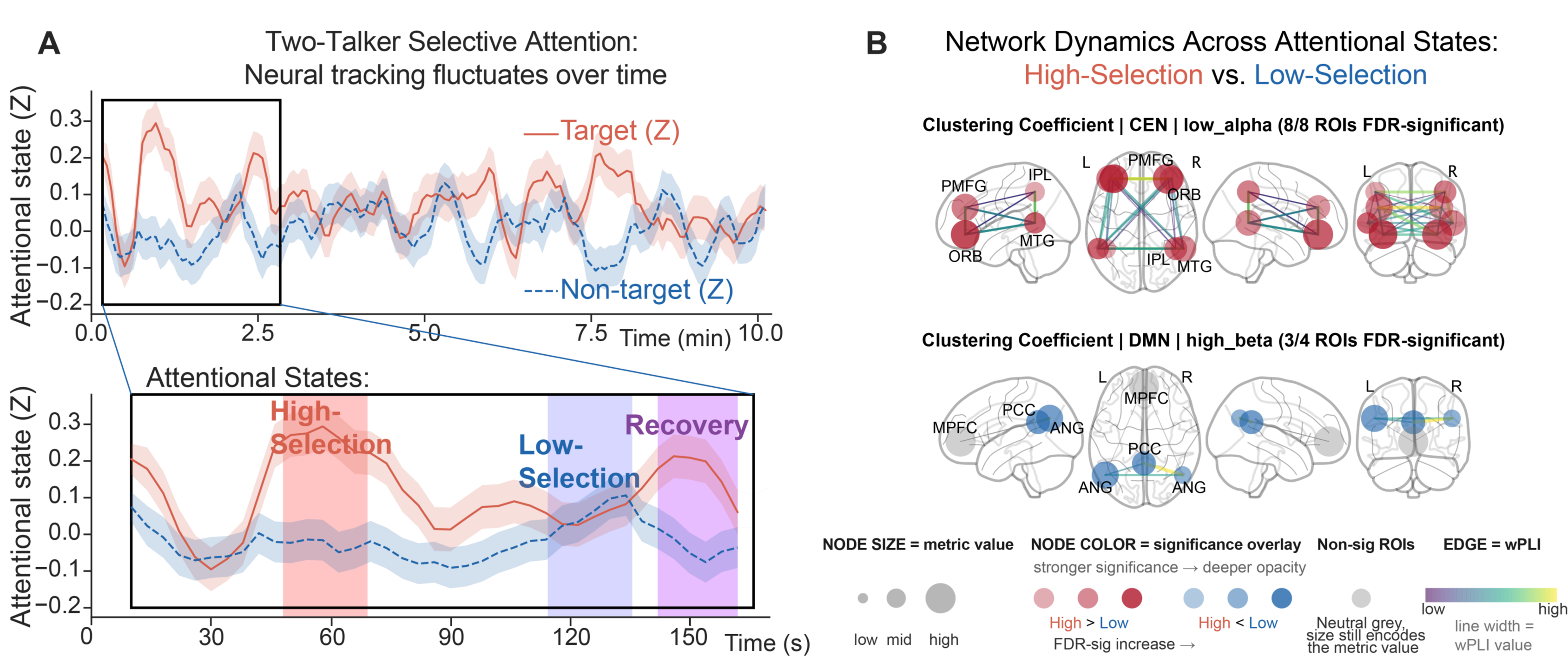
Veterans face a **30% higher risk** of **severe hearing loss** compared to civilian populations.[1]

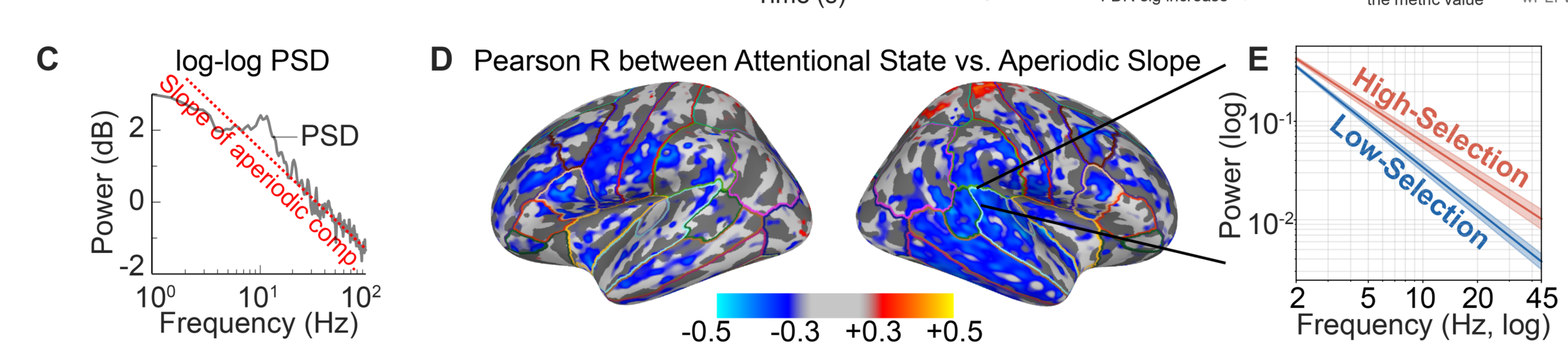
Post-2001 combat veterans show **significantly elevated rates**, driven heavily by **high-intensity blast exposures** and **traumatic brain injuries** (TBI).[2]

U.S. Marines fire an M120 Mortar during a mission in southwest Asia, Dec. 5, 2018. (U.S. Army photo/Matthew Crane)

Consequence of noise-induced hearing loss: Failure of Selective Listening

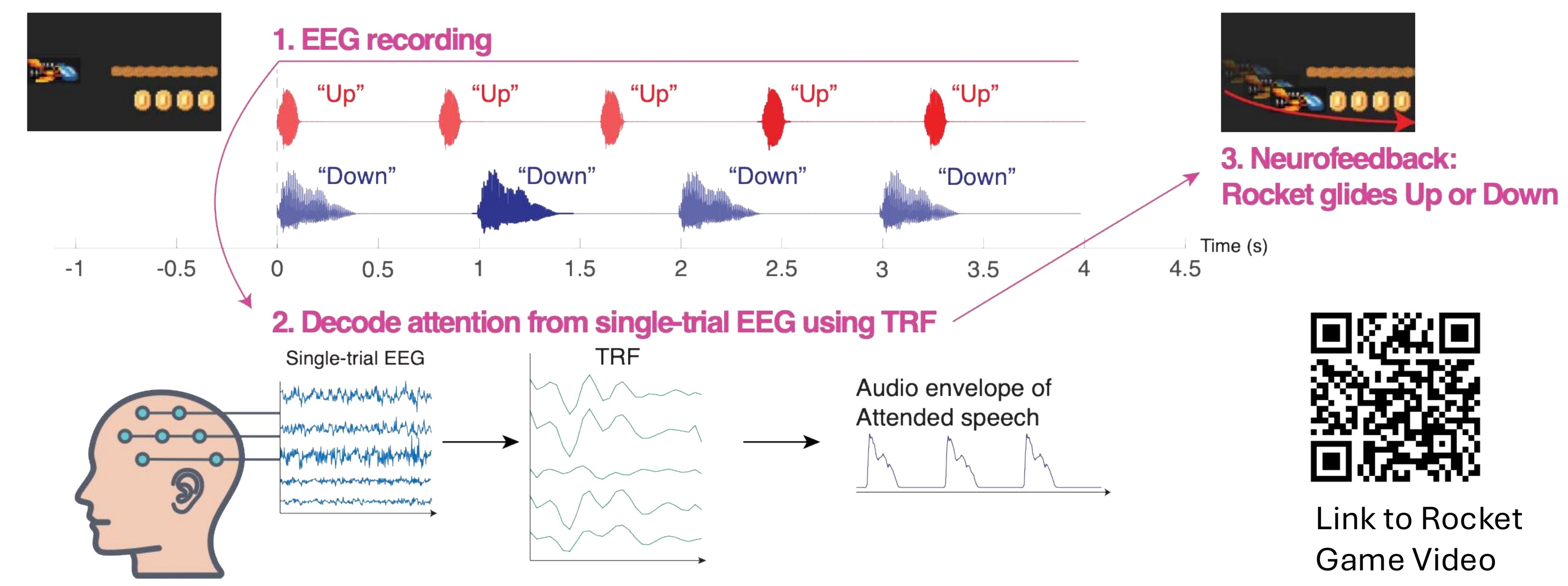
Noise exposure → Sensitivity damage
→ Increased central gain / internal noise
→ Over representation of external noise / tinnitus[3,4]





Our evidence that **selective listening fluctuates over time** and is **accompanied by systematic network reconfiguration**. **A.** Backward speech reconstruction was used to estimate correlations between EEG-reconstructed speech and the actual target and non-target speech envelopes. High-Selection windows indicate sustained target-dominant tracking, Low-Selection windows indicate weak or absent target dominance. Here, **auditory selective attention fluctuates over minutes** rather than remaining fixed across a listening block. **B.** Source-level band-limited connectivity was estimated using wPLI among predefined tri-network and attention-control ROIs, and graph-theoretic metrics were computed from the resulting adjacency matrices. Clustering Coefficient (CC) indexes local segregation / local neighborhood cohesion. Our results indicate that **low-alpha CEN and DAN CC is stronger during High-Selection windows**, whereas **high-beta DMN CC is stronger during Low-Selection windows**, supporting a **frequency-dissociated control architecture for distraction-resilient listening. C.** Aperiodic spectral slope explained: It is the exponent of the aperiodic 1/f power spectrum, indexing local excitability (flatter slope à more excitatory). **D.** Cortical maps of the correlation between the time course of spectral slope (of each vertex) and the time course of attentional state. **E.** PSDs from the right pSTG show a flatter slope in the High-Selection time windows, suggesting **increased excitability during the High-Selection state.**

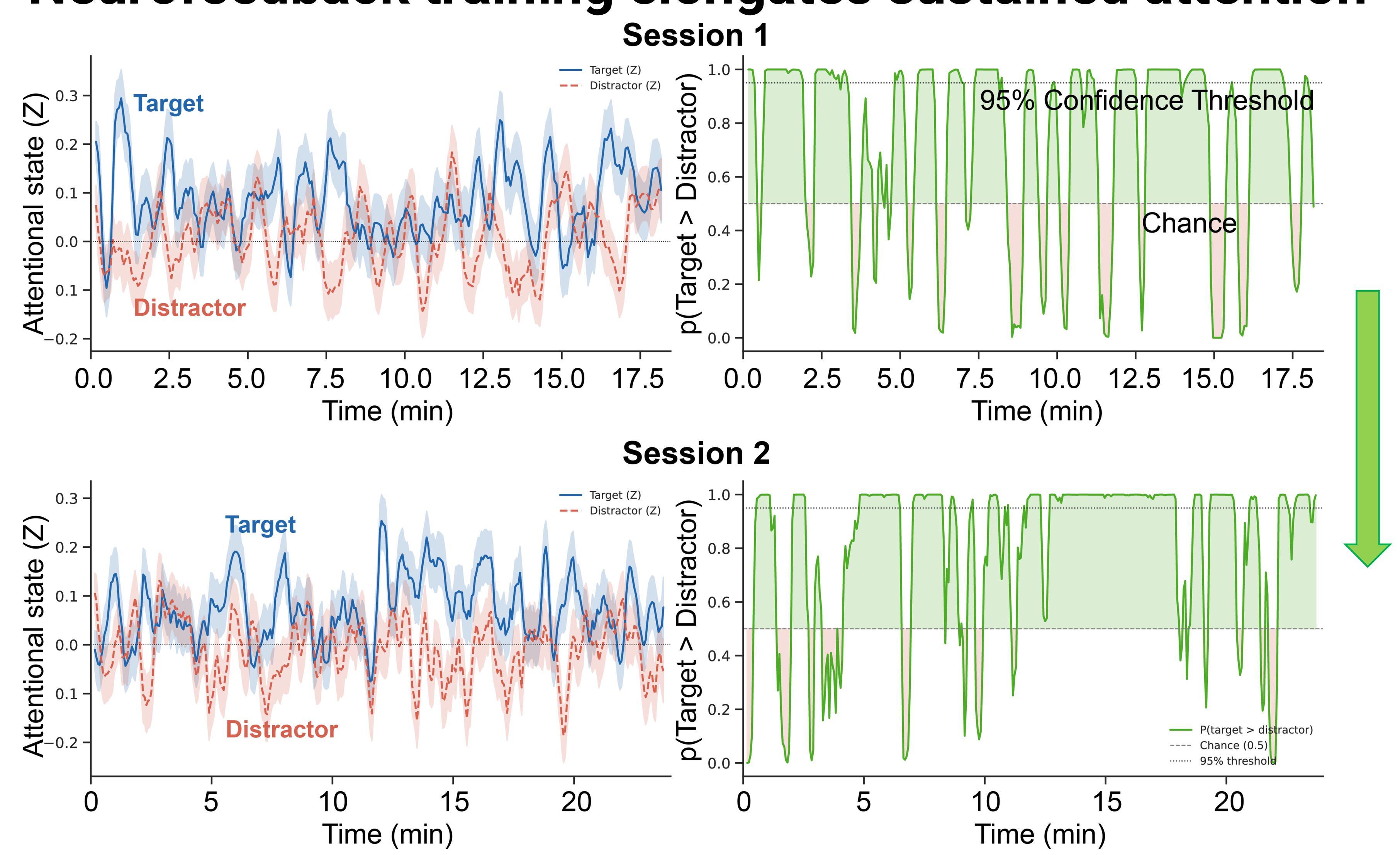
Neurofeedback Training of Selective Listening with a Gamified BCI

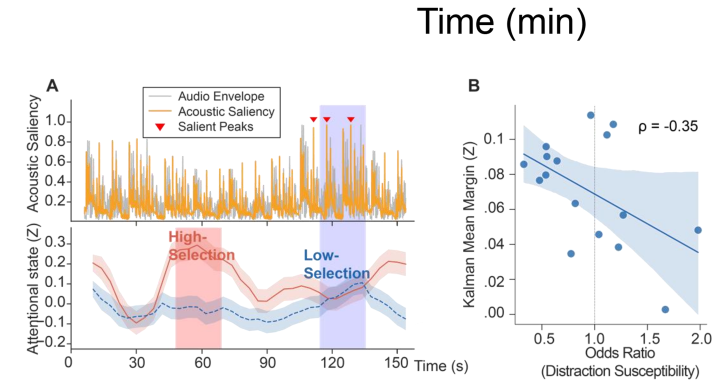


Link to Rocket Game Video

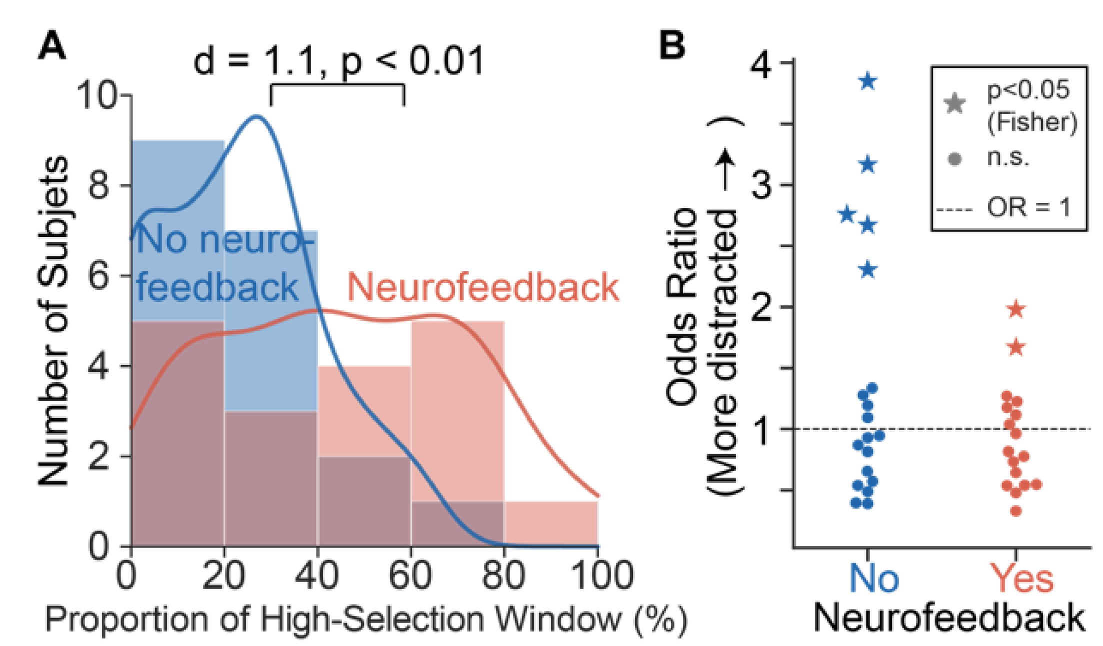
Two concurrent speech streams – a voice repeating "Up" five times and a voice repeating "Down" four times – were played together, in a female or male voice. Pre-stimulus visual cue (i.e., "Target coins are underneath, which means the target is down") directed attention. Attention was decoded from single-trial EEG signals. Subjects received neurofeedback (i.e., a gamified visual object on the computer screen moves downward if the EEG decoder determines that the "down" stream was attended; or vice versa). Subjects repeated this "neurofeedback training" for three sessions across 3 weeks.

Neurofeedback training elongates sustained attention





Saliency-overlap bridge analysis. **A.** Acoustic saliency time course of the non-target speech stream (top) and neural attentional-state time course (bottom) during two-talker listening. Salient peaks that occur during Low-Selection windows contribute to a participant-level odds ratio quantifying whether salient non-target-speech moments overlap low-selection windows more often than expected. **B.** Relationship between saliency-overlap odds ratio and a broader attentional strength. The negative association suggests that participants with stronger target-dominant tracking are more robust to salient events in the non-target speech stream.



Our neurofeedback training data show:
A. stronger sustained target-focused tracking and **B.** lower saliency-overlap vulnerability in the neurofeedback group than in the behavioral-feedback group.

Summary of the Study

Research Question

- Can Neurofeedback Training (NFT)[5] of auditory selective attention enhance distraction-resilient selective listening?

Approach

- EEG-based neurofeedback (NFT) training aims to directly reinforce attentional modulation of cortical responses to target and distractor speech streams.
- We recruited normal hearing participants: 38 native English speakers from Iowa, U.S., aged 18 – 55 years old.
- 50% of the participants were randomly selected to undergo a gamified neurofeedback training of auditory selective attention for three sessions across three weeks. The other group completed a similar selective attention task without receiving neurofeedback.
- Before and after training, participants completed a 20-minute selective listening task (listening to a podcast and answering comprehension questions).

Main Findings

- Participants who received neurofeedback training exhibited higher duration of high selection to target speech during the post-training selective listening task compared to those who did not receive neurofeedback training (Cohen's d = 1.1, $p < 0.01$).

Limitations and Future Directions

- Training a middle-aged group with prevalent "hidden" hearing loss and varying speech-in-noise abilities could clarify the characteristics of training responders.
- Further studies investigating the causal contribution of cortical networks to the maintenance of high- vs. low-selection states could be conducted using targeted neuromodulation (e.g., TMS, VNS).

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