INFLUENCE OF AGE AND PERCEPTUAL TRAINING ON CORTICAL AUDITORY PROCESSING

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BACKGROUND

As we age, our brains change across several biological levels, affecting motor, sensory, and cognitive processing [1]. Aging is associated with declines in memory, such as relayed free recall, selective attention and working memory [2], that are required to successfully learn new skills; therefore, our learning capacity declines with age.

Perceptual learning is the improvement in sensory detection and/or discrimination through training. It has been studied as a manifestation of plasticity in the adult sensory cortices [3], as it induces functional changes in the brain that are accompanied by improvements in cognitive abilities in both, younger and older adults [4]. Animal models show that the plasticity required to learn a new task is increased in brains of older rats, making **perceptual training a promising target to ameliorate age-related perceptual declines** [5].

Adaptative auditory perceptual training decreases age-related distractibility by reducing the auditory processing of distractor signals [6], but **how training-related changes in neural activity evolve dynamically over the learning process**, and **how these changes differ between young and older adults remains unclear**. Understanding how the learning process is supported by changes in brain function, and how these changes differ between young and older adults is fundamental to advance potential interventions against age-related sensory declines. **In this study, we examine the neurophysiological changes induced by adaptive auditory training in auditory neural responses in young and older healthy adults.**

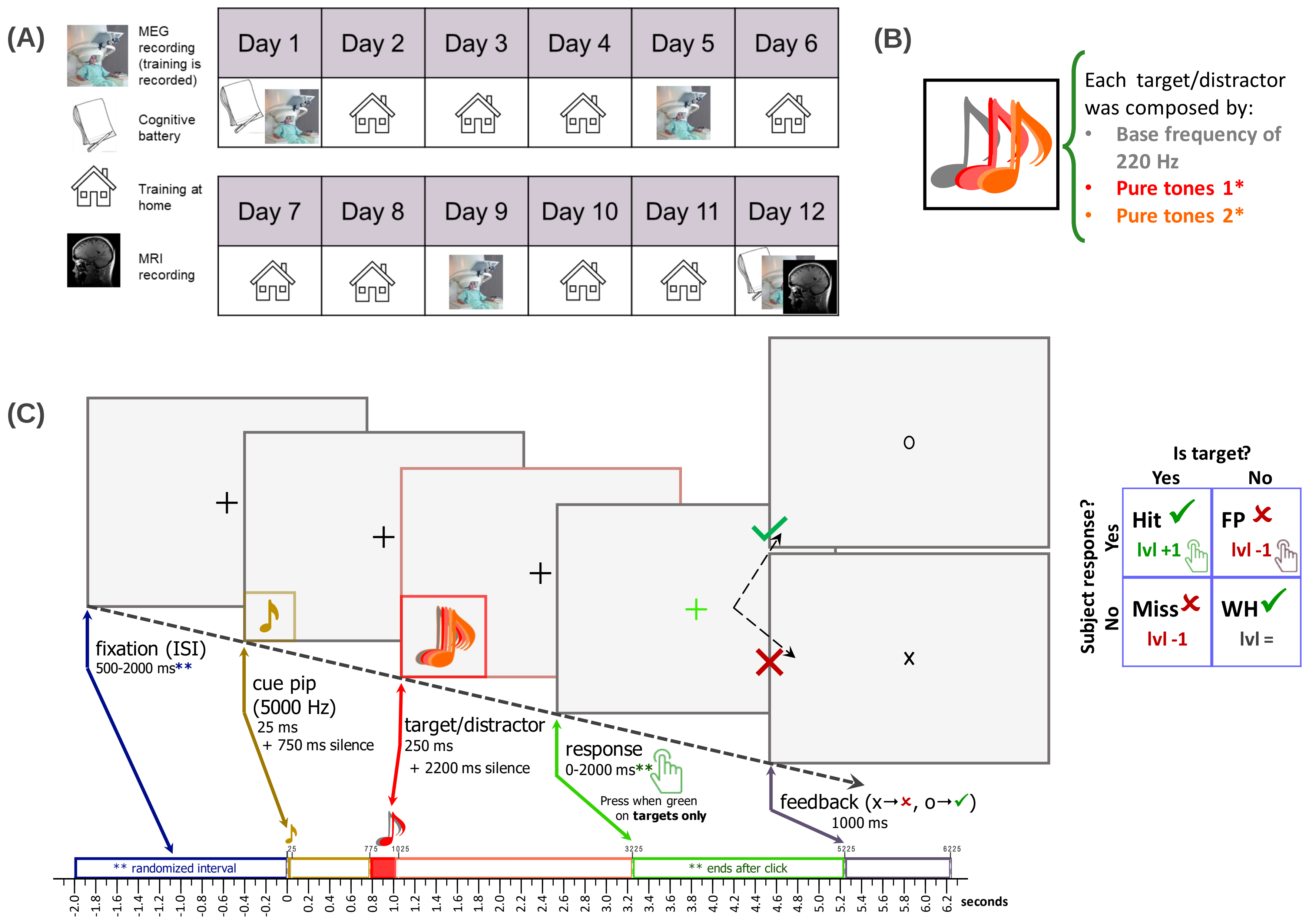
METHODS

Subjects: Eight young adults (mean age: 23.4 years old; 4 females) and eight older adults (mean age: 61 years old; 5 females) without cognitive impairment or hearing loss underwent twelve consecutive days of auditory perceptual training with four MEG sessions on days 1, 5, 9 and 12. The participants performed the adaptive training task while inside the MEG or at home on each of the twelve days (**fig.1.A**).

Training: Training consisted of an adaptive spectral discrimination task, where participants needed to respond to a target tone (**fig.1.B**) that changed at every session, and that was presented among distractor tones that became closer in frequency to the target as the task difficulty increased, following an *adaptive staircase procedure* (**fig.1.C**). Each training session consisted of 125 trials, of which one-third were targets and two-thirds were non-targets (i.e., no response required).

Data acquisition and processing: MEG recordings were preprocessed using the *Brainstorm software suite* and were\ source-imaged to the cortex using individual anatomical T1 MRIs. Event-related neural responses to the tones were examined in cortical regions known to be essential for auditory (primary auditory cortex) and sensory processing (insula).

Statistics: Linear mixed models (LMM) were used to examine age- and training-effects on these responses.



Each target/distractor was composed by:
- Base frequency of 220 Hz
- Pure tones 1*
- Pure tones 2*

	Is target? Yes	Is target? No
Subject response? Yes	Hit ✓ lvl +1	FP ✗ lvl -1
Subject response? No	Miss ✗ lvl -1	WH ✓ lvl =

Figure 1. Experimental design. **(A)** Eight younger and eight older adults underwent auditory training for 12 days. During the “training at home” days, participants use a tablet to do the training task from their homes. On Days 1, 5, 9 and 12, participants do the training task while being recorded through MEG. Anatomical MRI is acquired on Day 12. **(B)** Composition of the tones presented during the task. Difficulty was increased by decreasing the amplitude or changing the frequency of tones*. **(C)** Example of one trial of the staircase spectral discrimination task. Target is presented twice at the start of training, and then participant must identify and respond through a button press if the tone presented in each of 125 trials is the target or withhold if the tone presented is a distractor. Difficulty increases in hits (target identified) and decreases during false positive and misses (incorrect responses). ISI: Inter-Stimulus Interval

RESULTS

Both young and older adults demonstrated significant improvements in task performance as indicated by the maximum level reached (**fig.2**). As expected, there was a significant difference in performance between the two age groups, with young adults performing better. However, the rate of improvement across training days did not differ significantly between young and older adults. Performance was also evaluated using the daily counts of correct (hit, withhold [WH]) and incorrect responses (miss, false positive [FP]). However, no significant differences were found in any of these measures (**fig.3**). This result was expected due to the adaptive nature of the task.

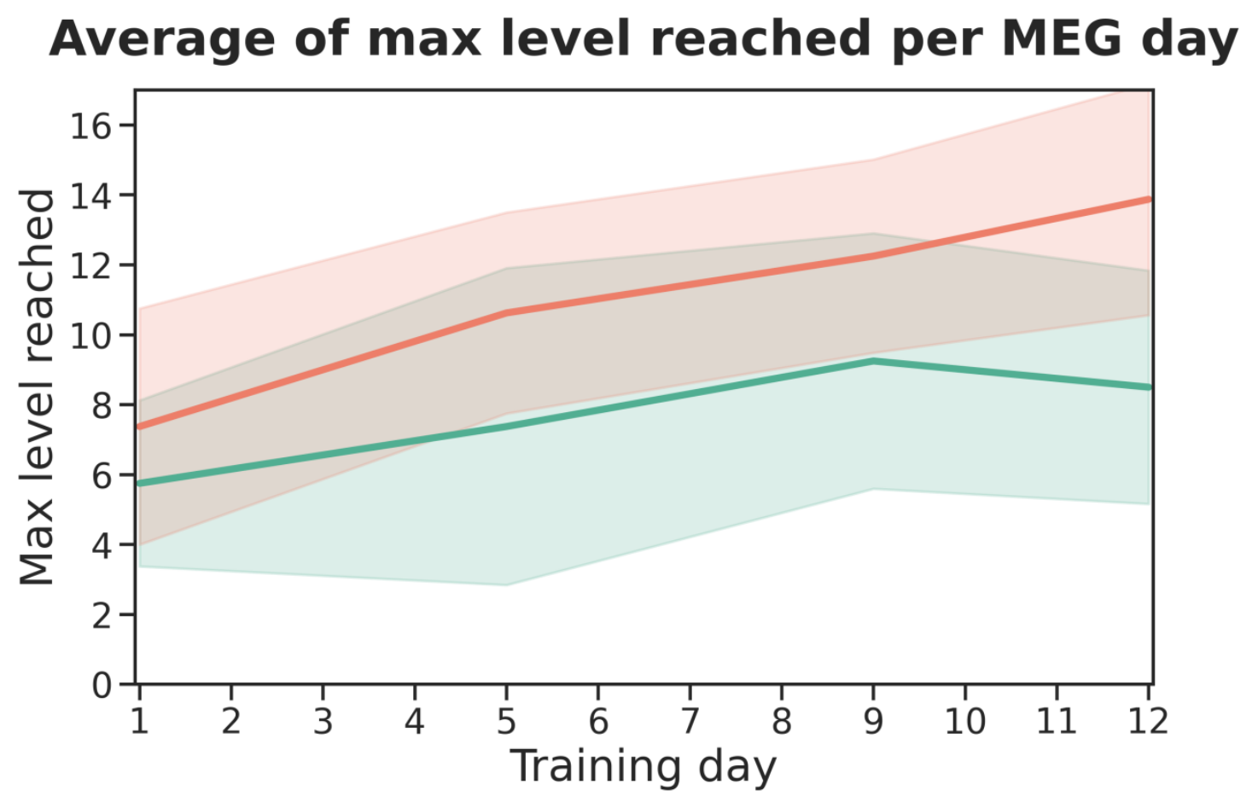


Figure 2. Average of maximum level reached on training days recorded inside MEG by group (young = orange, older = green). Shadowed area represents standard deviation (± SD). In both groups, LMM showed significant main effects of *training day* (young: 0.406, p=0.003, and older: 0.303, p=0.007), and overall *performance* (3.154, p=0.012). No significant effect was observed in the *rate of improvement* across training days (0.047, p=0.786).

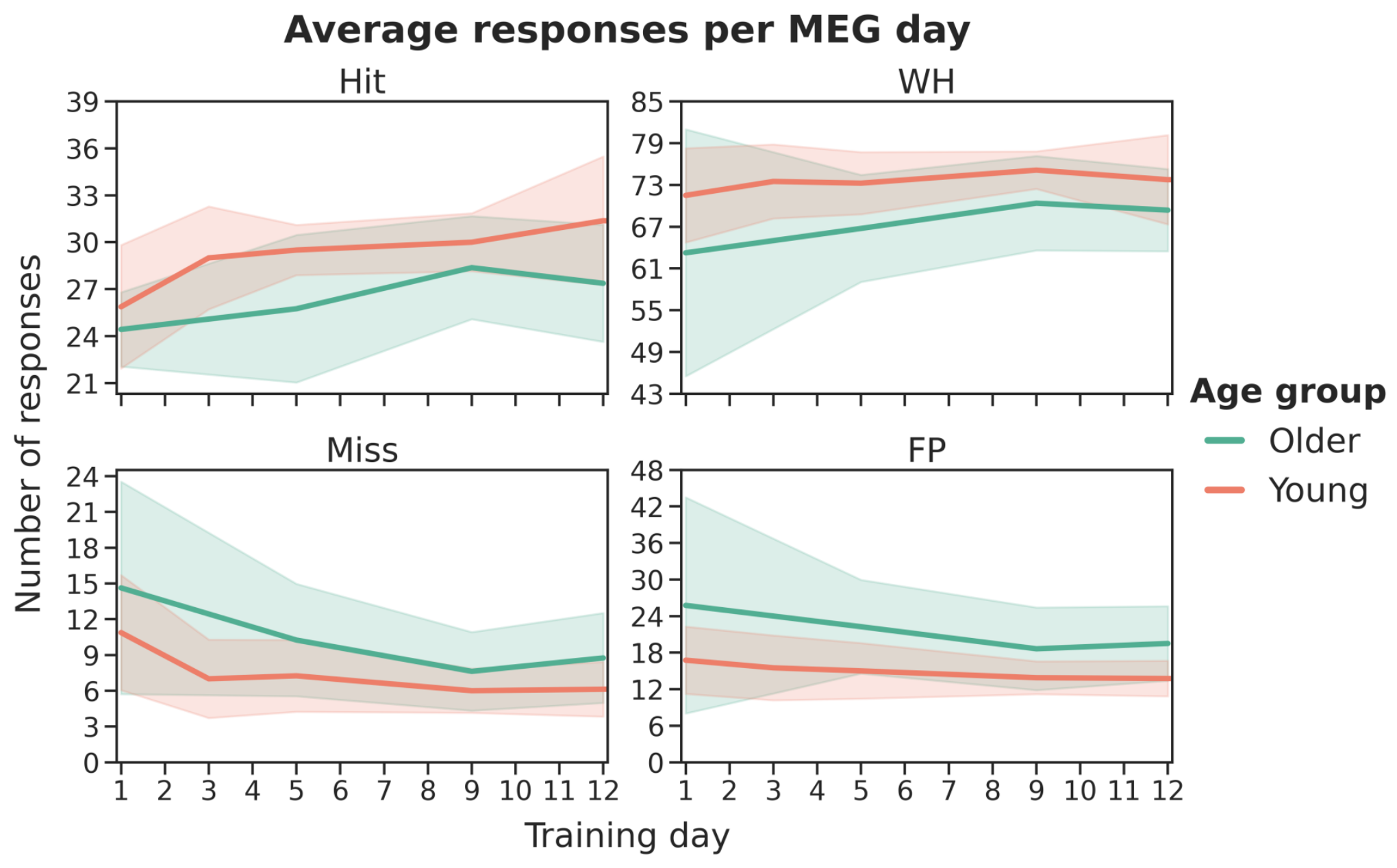


Figure 3. Average of the number of each response type on training days recorded inside MEG by group (young = orange, older = green). Shadowed area represents standard deviation (± SD). No significant differences found.

The maximum amplitude of the M100 response after the distractors was examined in the auditory and insular cortex in both hemispheres.

In the **auditory cortex** (**fig.4.A**), the M100 peak amplitude exhibited a notable increase corresponding to the training day, particularly in the right hemisphere. Interestingly, the training effect varied between age groups, with older adults showing amplitudes that further increased as the training progressed.

Similarly, the **insular cortex** (**fig.4.B**) demonstrated a general rise in M100 amplitude associated with the training day, as well as age-related differences in response to training.

These results suggest that as we age, our brains adopt distinct strategies to show improvements in the same tasks, as evidenced by the significant training-by-age effects observed in this study.

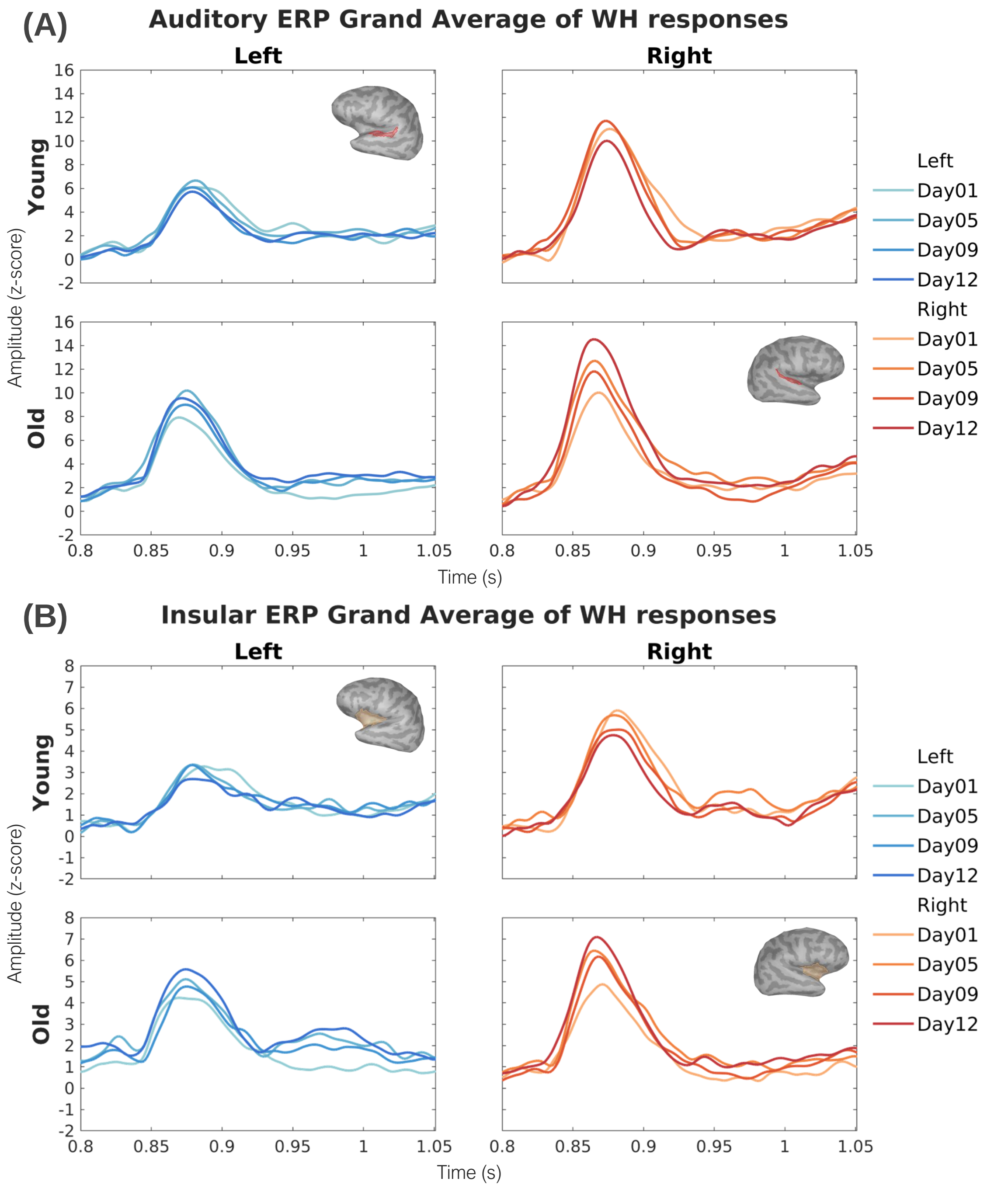


Figure 4. Event-related responses in trials where distractors were correctly identified (withholds) on the right (orange hues) or left (blue hues) auditory **(A)** and insular **(B)** cortex. **(A)** The **auditory** cortex showed bilateral significant main effects of *training* (left: 0.188, p=0.034; right: 0.349, p=0.002) and *training-by-age* (left: -0.192, p=0.035; right: -0.352, p=0.002), but no significant effects were found by *age only* (left: -1.833, p=0.255; right: 0.962, p=0.532). **(B)** The **insular** cortex also showed significant bilateral main effects of *training* (left: 0.117, p=0.020; right: 0.169, p=0.006) and *training-by-age* (left: -0.128, p=0.014; right: -0.184, p=0.004), but no effects related to *age group only* (left: -1.060, p=0.158; right: 0.458, p=0.600).

CONCLUSIONS

The perceptual training task was effective, as demonstrated by improvements in target recognition in both groups. This training effect was stronger in young adults. Neurophysiological responses (auditory and insular M100) to the distractor tones selectively tracked these training and training-by-age effects, providing valuable insights into the neural dynamics of learning and aging, and emphasizing the need for age-specific approaches in perceptual training interventions.

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