



Hearing Shapes: ERPs Reveal Changes in Perceptual Processing as a Result of Sensory Substitution Training



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Background

- Previous brain-imaging studies^{1,2} have suggested that auditory-visual sensory substitution training can lead to increased functional connectivity between visual processing areas (LOC) and the auditory cortex.
- Due to the poor time resolution of fMRI, however, it is currently unknown whether sensory substitution is mediated by rapid (direct, automatic) interactions between auditory and visual areas or via slower indirect associative pathways.
- Here, we examine electrophysiological (ERP) changes due to sensory substitution training when cross-modal information is task-relevant (Exp1) and task-irrelevant (Exp2).

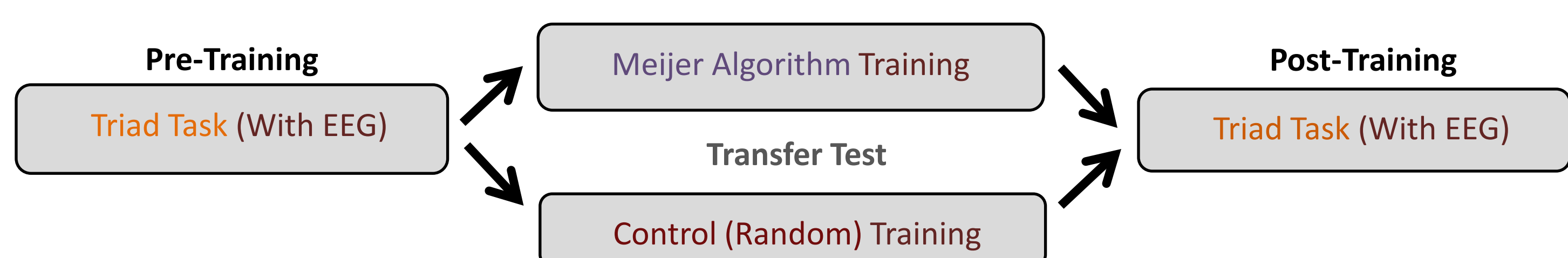
Stimuli



Meijer Image-to-Sound Conversion Algorithm³

1. The vertical dimension of the image is coded into frequencies between 500Hz-5000Hz, with higher spatial position corresponding to higher pitch.
2. The horizontal dimension is coded into a 500ms long left-to-right panning of the sound.

Methods



Experiment 1: Task-Relevant

Participants:

Thirty-one participants were randomly assigned to the Meijer group (N=16) or the Control group (N=15).

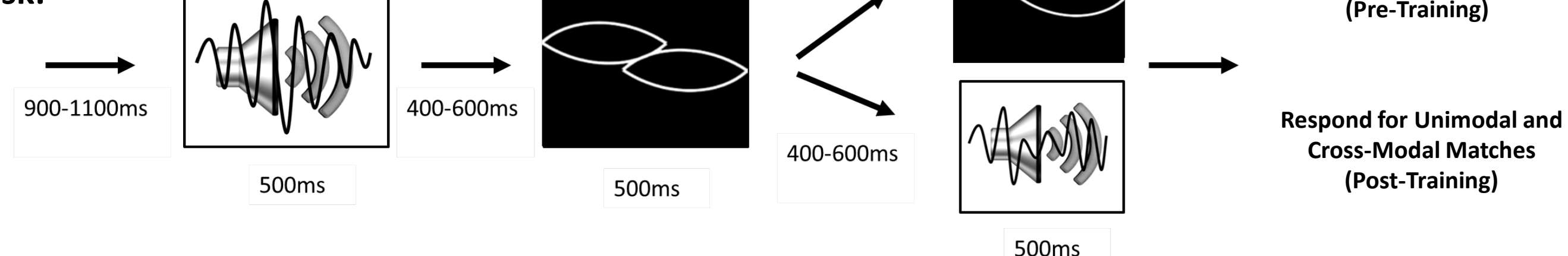
Control Group:

In contrast to the Meijer group who learned sound-image pairs according to the conversion algorithm, the control group learned random sound-image pairs (i.e. each image had a unique sound, but their relationship did not follow the Meijer algorithm).

EEG Recording:

- 96 equidistant electrodes
- Average mastoid reference
- 500Hz sampling rate
- 30Hz low-pass filter
- ERPs time-locked to the onset of the 1st stimulus

Triad Task:



Experiment 2: Task-Irrelevant

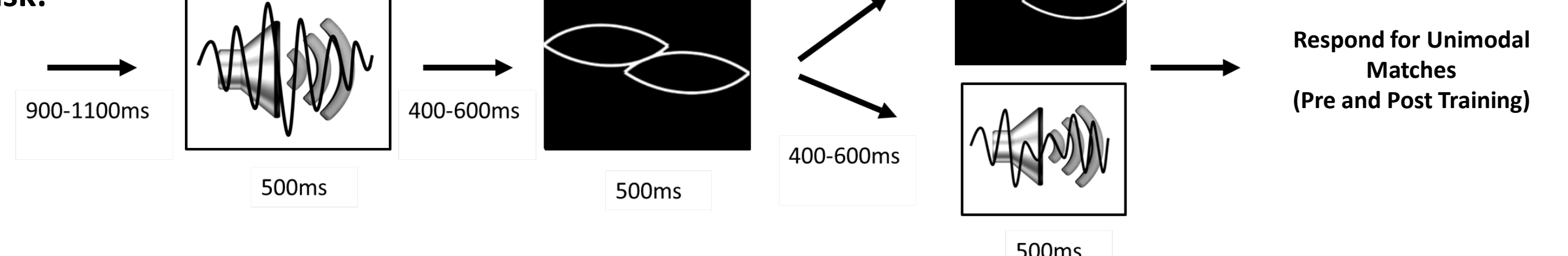
Participants:

Thirty-two new participants were randomly assigned to the Meijer group (N=16) or the Control group (N=16).

Task-Relevance:

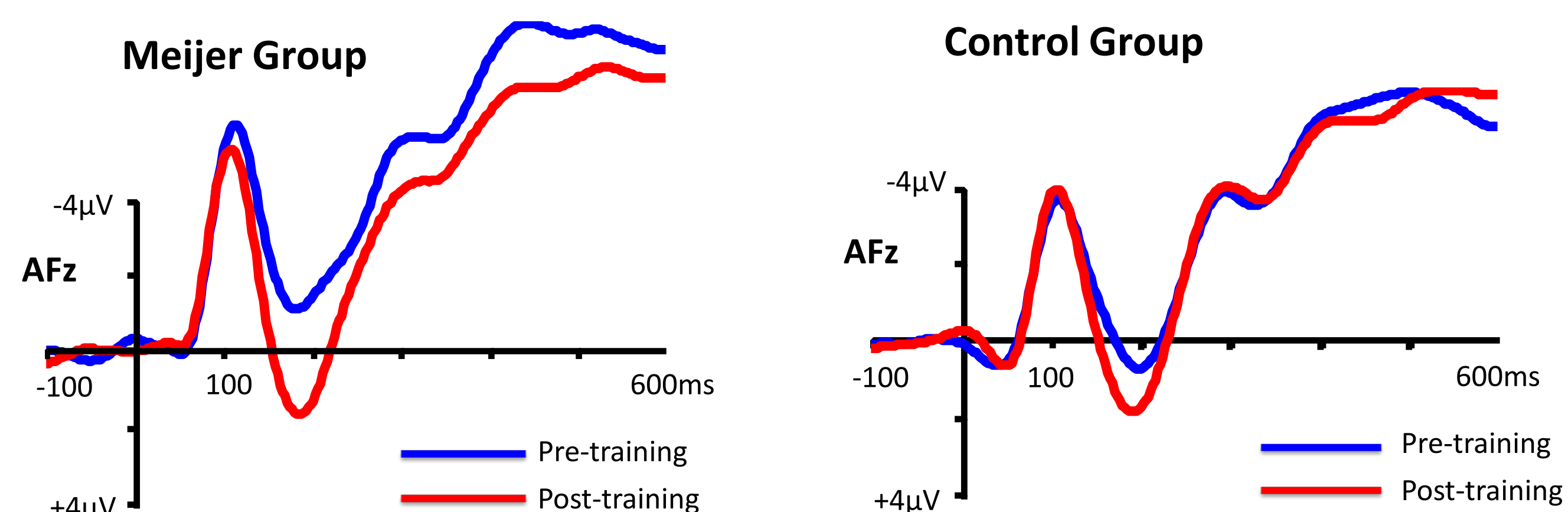
Before and after training, participants performed the exact same task, looking for unimodal matches.

Triad Task:

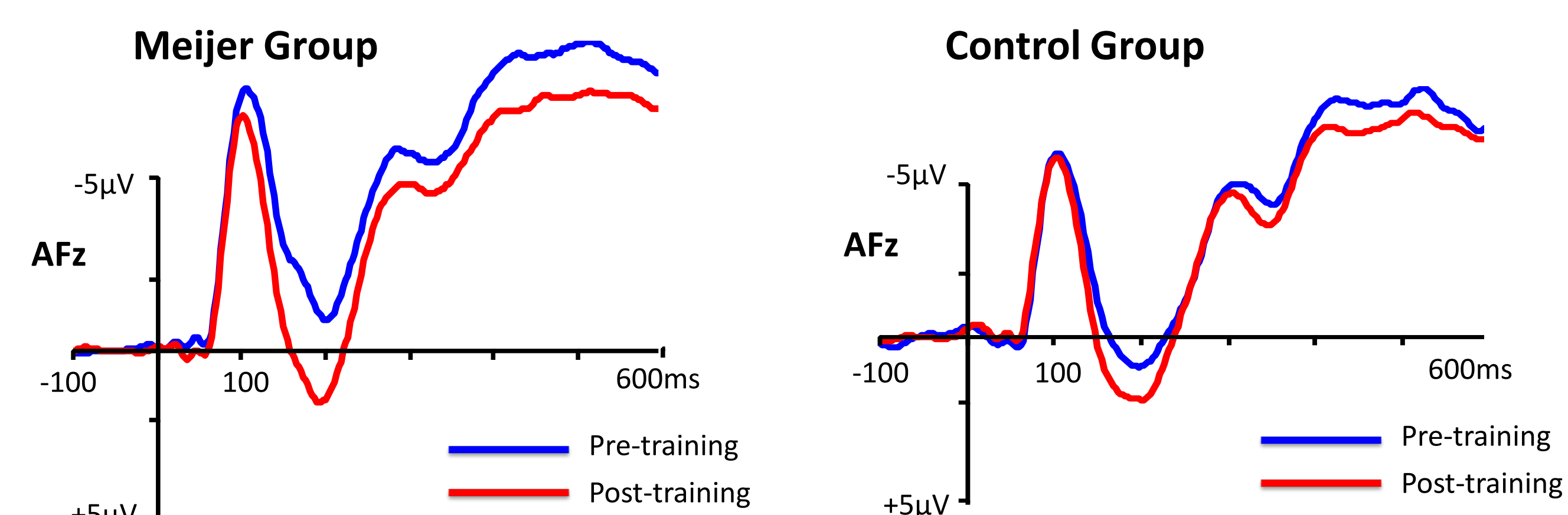


Results: Event-Related Potentials

Experiment 1: Auditory ERPs



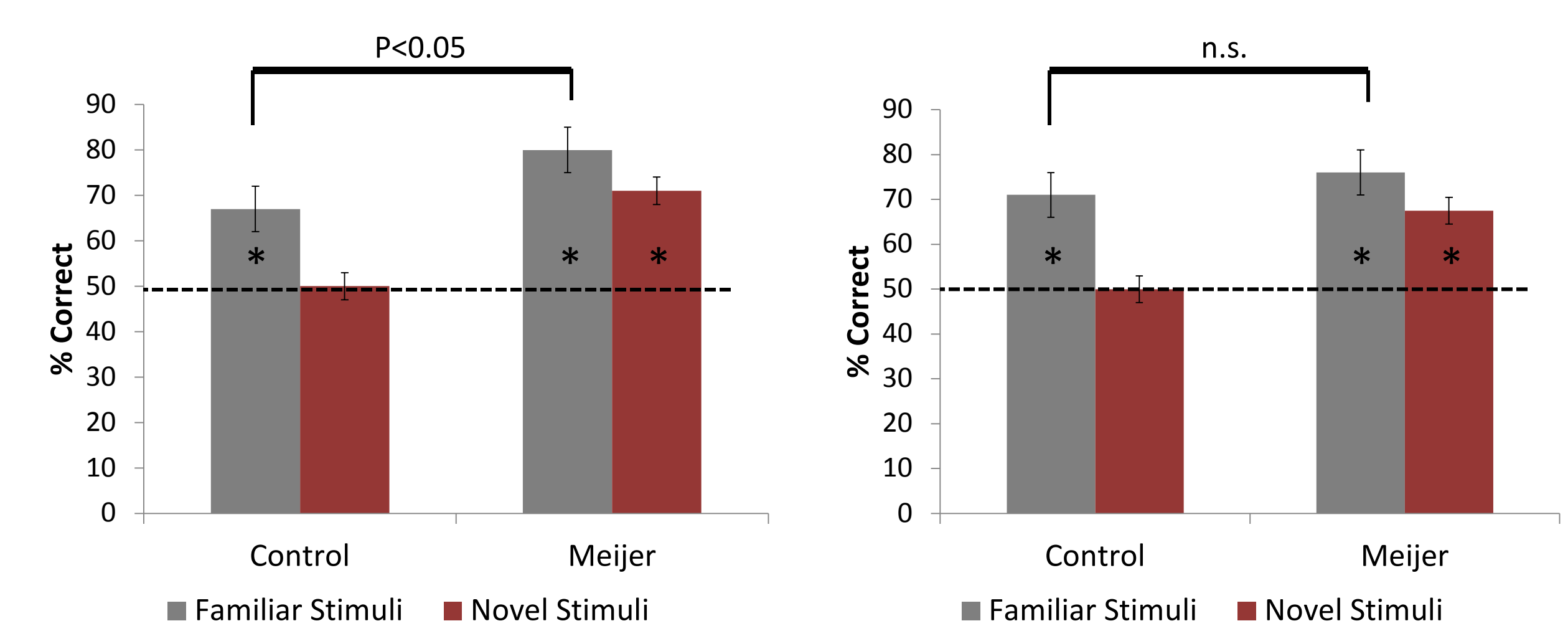
Experiment 2: Auditory ERPs



Behavioral Results

Experiment 1: Transfer Test Accuracy

Experiment 2: Transfer Test Accuracy



Conclusions

Experiment 1:

- Both Meijer and Control participants were successful in the training paradigm.
- The Meijer group was able to generalize what they learned to novel stimuli.
- An early anterior positivity (134-254ms) in the post-versus-pre training difference wave was significant only in the Meijer group, although it appeared to be trending in the control group.
- A mid-latency anterior positivity (374-490ms) was present only in the Meijer group.

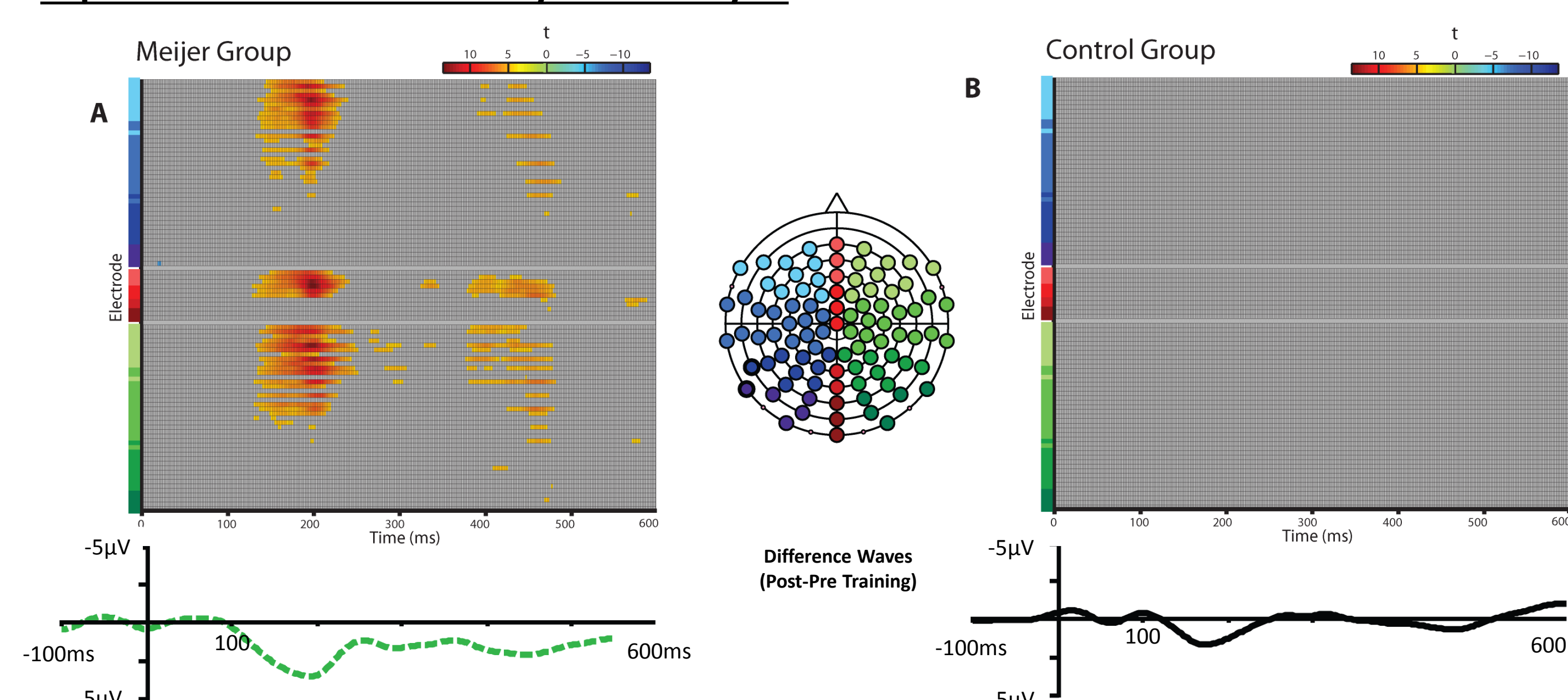
Experiment 2:

- Again, both groups were successful in the training paradigm.
- The Meijer group was able to generalize what they learned to novel stimuli.
- The early anterior positivity replicated in the Meijer group and was now significant in the control group as well (using CP analysis on the time-window identified by FDR analysis in Exp 1).
 - This post- versus pre-training ERP effect was larger in the Meijer group, but its presence in both groups suggests a non-specific role in perceptual learning or simple exposure to repeated stimuli.
- The mid-latency anterior positivity was only present in the Meijer group (replicating exp 1) and was found here even when cross-modal information was task-irrelevant.
 - This post- versus pre-training difference appears to uniquely index neural changes due to sensory substitution training, and occurred relatively early in time (374ms), i.e. prior to the completion of the soundscape stimulus (500ms).

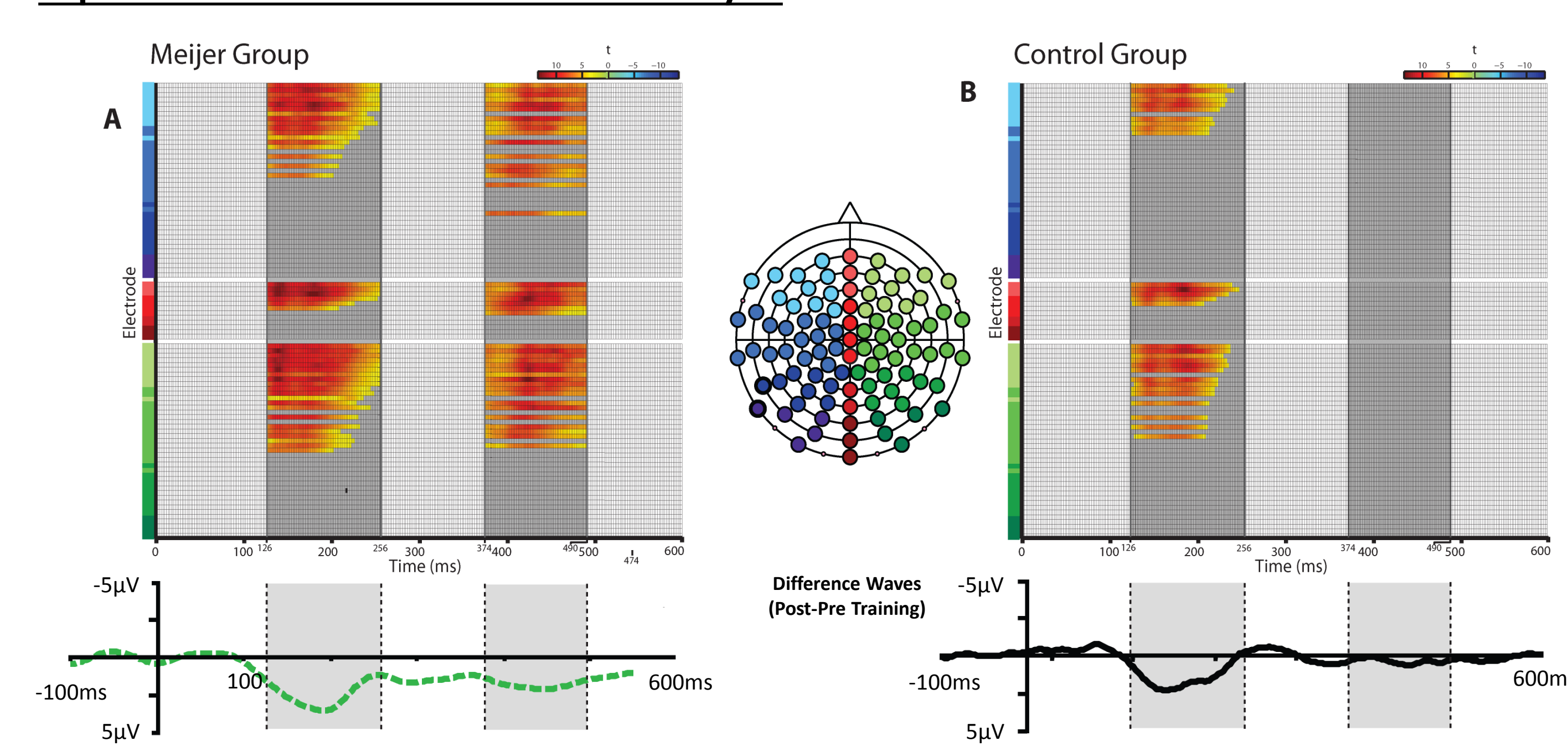
Auditory-visual sensory substitution training results in early (374ms) and automatic (task-irrelevant) changes to auditory processing, suggesting direct cross-sensory interactions.

Results: Mass Univariate Analysis

Experiment 1: False Discovery Rate Analysis



Experiment 2: Cluster Permutation Analysis



References

1. Kim, J.K. & Zatorre R.J. (2011). Tactile-auditory shape learning engages the lateral occipital complex, *Journal of Neuroscience*, 31(21), 7848-7856.
2. Poirier, C., et al. (2007). What neuroimaging tells us about sensory substitution, *Neuroscience & Biobehavioral Reviews*, 31(7), 1064-1070.
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4. Groppe, D. et al. (2011) Mass univariate analysis of event-related brain potentials/ fields I: A critical tutorial review. *Psychophysiology* 48, 1711-1725.

Acknowledgements

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