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

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Background

- Previous brain-imaging studies¹,² 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

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

Triad Task:
Participants:
Triad Task: 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).

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

Results: Event-Related Potentials

Experiment 1: Auditory ERPs

Experiment 2: Auditory ERPs

Results: False Discovery Rate Analysis

Experiment 1: False Discovery Rate Analysis

Experiment 2: Cluster Permutation Analysis

Conclusions

- 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 broader in the control group.
  - A mid-latency anterior positivity (374-490ms) was present only in the Meijer group.

Experiments 1 & 2:
- Both groups were successful in the training paradigms.
  - 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).
  - The post-versus-pre training ER effect was larger in the Meijer group, but it’s 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.

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

References


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