

Targeting VWFA-pSTG Coactivation with Real-Time fMRI Neurofeedback to Enhance Consolidation of Newly Learned Letter-Speech Sound Associations

Nada Frei ^{1*}, Amelie Haugg ^{1*}, Alexander Zeller ¹, Chayenne Garcia ¹, Vinzenz Kasper Schmid ¹, Anna-Marie Conrad ¹, Sara Steinegger ¹, Silvia Brem ^{1,2}

¹ [Department of Child and Adolescent Psychiatry and Psychotherapy], [University Hospital of Psychiatry Zurich, University of Zurich], [Zurich], [Switzerland]

² [Neuroscience Center Zurich], [Zurich], [Switzerland]

**equal contribution*

Introduction

Reading acquisition relies on the successful integration of visual letter forms and speech sounds, a process that is often impaired in individuals with dyslexia (Blomert 2011, Aravena et al. 2013). Real-time functional magnetic resonance imaging (rt-fMRI) neurofeedback has emerged as a promising approach to modulate brain regions of the reading network (Haugg et al., 2023). Whether modulation of key nodes within the reading network can enhance letter–speech sound (LSS) association learning remains largely unexplored. The present study investigated whether rt-fMRI neurofeedback targeting the coactivation of the visual word form area (VWFA) and posterior superior temporal gyrus (pSTG) facilitates the consolidation and application of newly acquired false font–speech sound (FF-SS) associations. We hypothesised that participants receiving targeted neurofeedback would exhibit greater increases in VWFA–pSTG coactivation and superior performance on artificial script reading tasks compared with the sham group.

Methods

Forty healthy, right-handed native German-speaking adults with typical reading skills were randomly assigned in a double-blind design to either rt-fMRI neurofeedback targeting VWFA–pSTG coactivation or sham neurofeedback based on bilateral amygdala activity. Across three MRI sessions, participants first learned an artificial script comprising novel FF-SS associations (Fraga-Gonzalez et al., 2023; Frei et al., 2025) and completed behavioural and fMRI assessments before and after neurofeedback training. The neurofeedback session consisted of eight training runs interspersed with four no-feedback runs (pre, middle, post, transfer). During regulation blocks (20 sec), participants were instructed to increase VWFA–pSTG coactivation by mentally recalling the learned FF-SS associations, while during rest blocks they imagined performing jumping jacks. Neural target ROIs (VWFA, pSTG) were individually defined using functional localizer tasks, and real-time visual feedback was provided from both areas throughout training. Behavioural outcomes included explicit and implicit artificial script reading tasks, FF-SS reading fluency, and FF-SS association performance, complemented by functional MRI measures of reading-related brain activation.

Results

Participants successfully learned the artificial letter–speech sound associations, reaching high accuracy after training. Functional localizer tasks successfully identified the VWFA and pSTG in individual participants. During neurofeedback training, whole-brain analyses revealed significant VWFA activation only in the experimental group; however, direct comparisons between groups showed no significant differences, and neither group successfully upregulated pSTG activity. ROI analyses revealed a significant effect of time on VWFA activation across neurofeedback runs, whereas no significant effects of group or group × time interaction were observed. A trend towards a time effect was found for pSTG activation. During no-feedback runs, no significant group or interaction effects emerged in either ROI, although VWFA activation showed a trend towards changes over time. Whole-brain analyses likewise revealed no significant between-group differences across pre-, mid-, post-, or transfer assessments.

Time-course analyses demonstrated similar BOLD response profiles in both groups during neurofeedback and no-feedback runs, with no evidence of sustained transfer effects. While the VWFA showed the expected task-related positive activation, pSTG responses were substantially

weaker. They did not indicate successful upregulation, suggesting differential engagement of the two target regions during neurofeedback training.

Both groups showed significant pre- to post-training improvements in reading fluency for Latin and artificial scripts, indicating general learning or repetition effects rather than neurofeedback-specific benefits. Correspondingly, pre- to post-training ROI analyses revealed no significant group differences in VWFA or pSTG activation during the explicit FF-SS reading task. Although pSTG activation changed over time during the implicit task, these effects were independent of the neurofeedback condition.

Conclusions

The present findings demonstrate the feasibility of combining rt-fMRI neurofeedback with artificial script learning to investigate the modulation of reading-related networks. However, we found no evidence that targeted VWFA–pSTG neurofeedback resulted in neurofeedback-specific enhancements of neural activation or behavioural performance beyond general learning effects. The limited ability to modulate pSTG activity highlights the challenges associated with regulating distributed reading network nodes and suggests that successful network-level neurofeedback may require optimized strategies to reliably engage all relevant nodes of the targeted network. Future studies should refine neurofeedback protocols, explore approaches to improve target signal controllability, and investigate whether this approach can be adapted to populations with reading difficulties, where targeted modulation of reading-related networks may have clinical relevance.

References

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