Neural changes in children with residual speech sound disorder (RSSD) after ultrasound biofeedback therapy

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Rationale:

In typical speakers, speech generation involves a network of inferior frontal and superior temporal brain regions, ventral motor and premotor cortices, insula, and cerebellum.[1,2] Children with residual speech sound disorders (RSSD) have shown differences in speech processing, including speech production[4]. However, changes in speech processing after speech therapy have not been investigated. Therefore, the goal of the present study was to identify phonological and speech motor network activations during speech in children with RSSD before and after an ultrasound biofeedback therapy program[5].

Syllable Repetition Task:

We adapted the Syllable Repetition Task (SRT)[7] for fMRI in order to investigate neural activation during speech. The SRT consists of 2-, 3- and 4-syllable nonsense words with a limited set of phonemes. In our experiment, we adapted this task to create a "SRT-Late Sounds" with the phonemes /ɹ, s, l, tʃ, ɑ/.

Hypothesis:

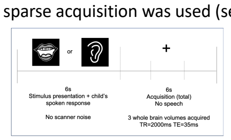
We hypothesized that children with RSSD would show patterns of hypoactivation at baseline, with normalized activation patterns after speech therapy.

Methods:

Participants: 13 children with RSSD (6F; ages 8:0-12:6) and 16 children with typical speech development (TD; 8F; ages 8:5-14:0) completed the difficult SRT fMRI experiment at baseline. Children with RSSD then participated in an 8-week ultrasound therapy program for /ɹ/ articulation errors. After the conclusion of the program, children with RSSD (n=10) completed the fMRI experiment again. Children with TD (n=16) completed the experiment a second time after a period of 8 weeks (no intervention). All participants demonstrated expressive and receptive language skills within normal limits and passed a hearing and vision screening. All participants were scanned on a 3T Phillips MRI scanner.

SRT: The subject heard a target word and was asked either to repeat the word immediately or to only listen. The task consisted of 18 target words, which were presented in both "speak" and "listen" conditions and counter-balanced across blocks of 6 targets each. A sparse acquisition was used (see Figure 1).

Figure 1.



Analysis: We used a region of interest (ROI) analysis approach. Regions were identified a priori using the activation map of "speech production" generated by Neurosynth. Thirty-five of these regions contained 20 or more contiguous voxels and were used in the current analysis. Each participant's average activation (z-score) was calculated for each ROI. ANOVA s were performed at each ROI to compare differences in neural activation at Time 1(pre-therapy) and Time 2 (post-therapy) between RSSD and TD groups.

Results

Figure 2.

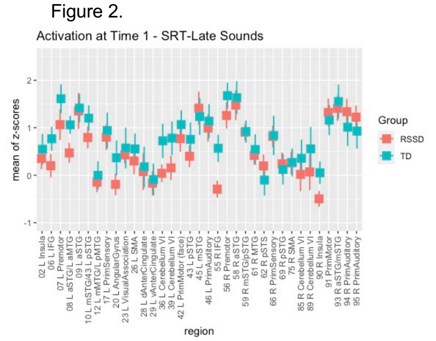


Figure 3.

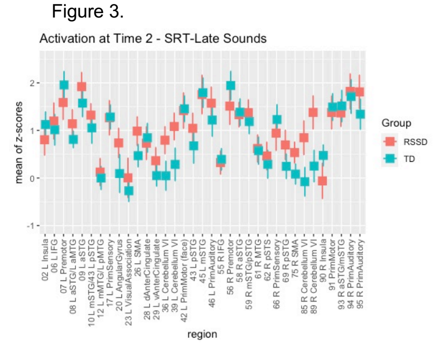


Figure 4.

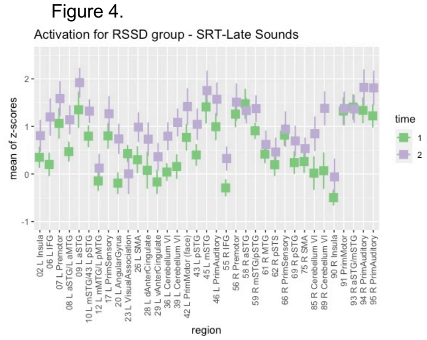
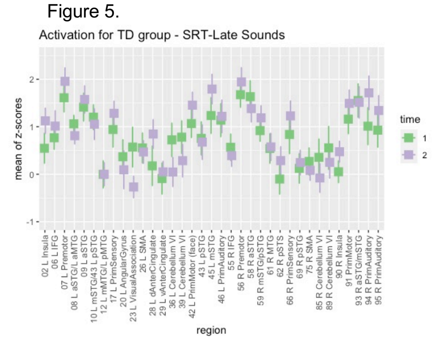


Figure 5.



Means and standard errors for z-scores at each ROI are shown in Figures 2-5. One-way ANOVAs were conducted for each ROI to compare groups and repeated measures ANOVAs were conducted to compare ROIs at timepoints. False-discovery rate (FDR) corrections were conducted to correct for multiple comparisons. No significant differences were detected at any ROI under any condition. No significant group*timepoint interactions were detected for any ROI.

Figure 6.

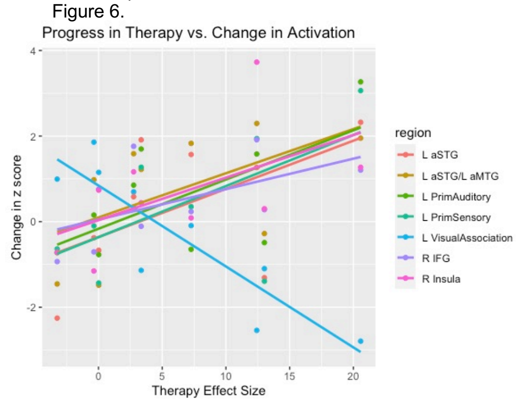


Table 1. Regions with strong Spearman correlations between activation and therapy effect size.

Region	*rs*
L aSTG	0.567
L aSTG/L aMTG	0.633
L PrimAuditory	0.567
L PrimSensory	0.55
L VisualAssociation	-0.867
R IFG	0.583
R Insula	0.583

For 9 participants, change in z-score from Time 1 to Time 2 was correlated with progress in therapy using a Spearman correlation. Positive relationships were seen in left superior and middle temporal regions, left primary auditory, left primary somatosensory, right inferior frontal, and right insula regions. A negative relationship was observed with activation in the left visual association cortex. Correlations in select regions with R^2 >0.5 are shown in Figure 6 and Table 1.

Discussion

Children with RSSD demonstrated no significant differences in neural activation on the difficult SRT. This finding is similar to previous findings on neuroimaging.[3,8] The RSSD group showed trends of increased activation at Time 2 (after therapy), aligning more with the TD group than at Time 1 (before therapy). Results suggest that children with RSSD use similar neural resources on the SRT, even after speech therapy. Subtle differences in neural function may be associated with variations in response to therapy. In our study, greater progress in therapy was associated with increased activation in left phonological, primary auditory, primary sensory, and right motor control region. This may indicate that improvement in speech production is related to an upregulation of phonological, sensory, and homologous speech motor regions. On the other hand, greater progress in therapy was associated with a decrease in activation in the visual association cortex. Differences in occipital regions have been observed in previous research in children[6] with RSSD and may reflect the importance of visual processes for visualizing speech as well as reading.

References

1. Bohland, J. W., & Guenther, F. H. (2006). An fMRI investigation of syllable sequence production. *Neuroimage*, *32*(2), 821-841.
2. Guenther, F. H. (2006). Cortical interactions underlying the production of speech sounds. *Journal of communication disorders*, *39*(5), 350-365.
3. Pigdon, L., Willmott, C., Reilly, S., Conti-Ramsden, G., Liegeois, F., Connelly, A., & Morgan, A. T. (2020). The neural basis of nonword repetition in children with developmental speech or language disorder: An fMRI study. *Neuropsychologia*, 107312.
4. Preston, J. L., Felsenfeld, S., Frost, S. J., & Mencl, W. E. (2012). Functional Brain Activation Differences in School-Age Children With Speech Sound. *Journal of Speech Language and Hearing Research*, *55*(August), 1068–1083.
5. Preston, J. L., McAllister, T., Phillips, E., Boyce, S., Tiede, M., Kim, J. S., & Whalen, D. H. (2018). Treatment for residual rhotic errors with high-and low-frequency ultrasound visual feedback: A single-case experimental design. *Journal of Speech, Language, and Hearing Research*, *61*(8), 1875-1892.
6. Preston, J. L., Molfese, P. J., Mencl, W. E., Frost, S. J., Hoeft, F., Fulbright, R. K., ... & Pugh, K. R. (2014). Structural brain differences in school-age children with residual speech sound errors. *Brain and language*, *128*(1), 25-33.
7. Shriberg, L. D., Lohmeier, H. L., Campbell, T. F., Dollaghan, C. A., Green, J. R., & Moore, C. A. (2009). A Nonword Repetition Task for Speakers With Misarticulations: The Syllable Repetition Task (SRT). *Journal of Speech Language and Hearing Research*, *52*(5), 1189.
8. Spencer, C., Vannest, J., Maas, E., Preston, J. L., Redle E., Boyce, S. E. (accepted) Neuroimaging the Syllable Repetition Task in children with residual speech sound disorder. *Journal of Speech, Language, and Hearing Research.*

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