# Covert and Overt Sound-Blending in the Brain

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## Introduction

Pre-reading children's proficiency at phonemic awareness (PA), the ability to mentally manipulate phonemes in spoken words, is one of the strongest predictors for subsequent reading developmental and developmental dyslexia [1]. Auditory tasks commonly used clinically to assess PA include sound blending (SB) (e.g., hear /b/, /a/ /t/ and say the word these sounds make), but such tasks are challenging to implement in the context of fMRI given the intense background noise associated with EPI. Previous techniques such as temporally sparse sampling [e.g., 2] separate stimulus presentation from MR volume acquisition in time, but they often require prolonged acquisition time. We present data here comparing SB with a similar auditory lexical decision task (LDT), with an event-related technique referred to as Hemodynamics Unrelated to Sounds from Hardware (HUSH). HUSH is similar to temporally sparse sampling, but provides improved time efficiency [3-4].

## Methods

The subject was a 33 year-old male native English speaker. Data was acquired on a Siemens 3T Trio system. FMRI-EPI scan parameters were: TR/TE = 2000/38 ms, matrix = 64 X 64, bandwidth = 125 kHz, FOV = 25.6 cm X 25.6 cm, slice thickness = 5mm (for a total of 25 slices). Each trial consisted of a stimulus phase (6s; no MR acquisition) and an MR acquisition phase (6s; 3 volumes acquired in 3 TRs). Data from 1 functional run with 39 trials (12 sec/trial; total imaging time ~8 min; 13 trials per condition) were acquired in the HUSH paradigm. The 3 conditions were: (a) SB, in which the subject heard a phoneme sequence (e.g., /b/ /a/ /t/), mentally blended them, and said the word immediately upon seeing a visual cue ("SAY") on the computer screen; (b) LDT, in which the subject heard a phoneme sequence, mentally blended them, and pressed a button with his right thumb if the blended phonemes formed a word immediately after the visual cue was shown ("WORD?"); and (c) Rest, in which he saw a visual cue ("None") and rested while no sounds were presented. All visual cues were presented 4.5 sec after each trial started. The phoneme sequences were 2 to 4 sec long in duration each and sampled from a set of 72 without replacement. All stimuli were presented with an MR-compatible audiovisual system.

The data was processed using the CCHIPS / IDL [5] software developed in our laboratory. The data was retrospectively corrected for motion, transformed into Talairach space, and sorted according to experimental conditions. A repeated-measures type analysis was used to account for variation in the baseline MR signal due to the spins not being in steady state. Results were displayed with a voxelwise threshold of t = +4.0 with a cluster size of 10.

## Results and Discussion

Relative to rest, strong activation was detected in a network of areas related to hearing (e.g., BA 41), auditory analysis and short-term memory (e.g., BA 42, 21, 22, encompassing broad areas of the superior and middle temporal gyri), single word processing and lexical access (e.g., fusiform gyrus BA 19), subvocal rehearsal and working memory (e.g., insula, anterior cingulate, BA 44, 45, 46, 9) and motor response (bilateral cerebellum, BA 4 & 6) when subjects performed SB. Activation was largely bilateral and relatively symmetric. Significant activation in very similar areas, although at lower magnitude, was detected in LDT. Because the perceptual demands of the two tasks are largely comparable in the LDT and the SB tasks, this difference may reflect the fact that the visual cue was shown a few seconds after the phoneme sequence was heard. That is, the subject might have had to keep the word to be spoken in working memory in the SB condition but not in the LDT condition.

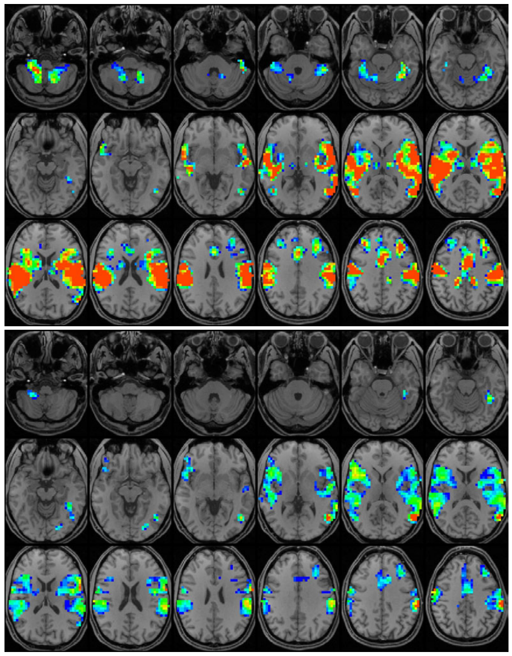

**Figure 1.** Regions with significant activation in the SB (top) and the LDT (bottom) task relative to rest. Images are in radiological convention. All regions displayed exceeded a threshold of t= +4.0 (uncorrected) with warmer colors indicating higher magnitude. Image slices in each figure are in Talairach space, from axial location Z = -45 to Z = +40.

## Conclusion

This study demonstrates the feasibility of using HUSH to perform fMRI studies using PA tasks with overt responding, closely mimicking aspects of these tasks when applied in clinical settings. As expected, the SB task engaged a extensive network of cortical areas, including classical language (Broca's and Wernicke's) areas but also extending to other areas involving working memory and attention. The widespread network of brain areas engaged for this task may indicate sensitivity of this task in predicting future reading development. Future studies will explore its use in children and clinical populations.

## References

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