Atypical right hemisphere response to slow temporal modulations in children with developmental dyslexia

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Phase entrainment of neuronal oscillations is thought to play a central role in encoding speech. Children with developmental dyslexia show impaired phonological processing of speech, proposed theoretically to be related to atypical phase entrainment to slower temporal modulations in speech (< 10Hz). While studies of children with dyslexia have found atypical phase entrainment in the delta band (~2 Hz), some studies of adults with developmental dyslexia have shown impaired entrainment in the low gamma band (~35 - 40 Hz). Meanwhile, neuroimaging studies of neurotypical adults suggest asymmetric temporal sensitivity in auditory cortex, with preferential processing of slower modulations by right auditory cortex, and faster modulations processed bilaterally. Here we compared neural entrainment to slow (2 Hz) versus faster (40 Hz) amplitude-modulated noise using fNIRS to study possible hemispheric asymmetry effects in children with developmental dyslexia. The recording optical unit was a multi-channel continuous wave fNIRS instrument (ETG-4000 Hitachi Medical Corporation, Tokyo, Japan). The present investigation made use of 32 laser diodes light sources (16 emitting light at 695 nm, and 16 at 830 nm) and 14 detectors. Probe arrangement enabled us to record hemodynamic activity bilaterally from parietal and temporal brain regions. The cortical regions underlying each optode and channel were estimated using the LONI Probabilistic Brain Atlas. The experimental procedure included two 2 blocks of 5 minutes stimulation at each amplitude modulation rate used (2 Hz and 40 Hz), presented sequentially in a semi-random order. During each 5 minute block, 15 s periods of stimulation were interspersed with 15 s periods of silence. The children were watching a silent video during data acquisition. We also collected three measures of phonological processing were administered as part of ongoing testing in the year that fNIRS was recorded, as were three psychoacoustic measures of sensitivity to non-speech amplitude envelope rise time.

We predicted atypical right hemisphere responding to 2 Hz modulations for the children with dyslexia in comparison to control children, but equivalent responding to 40 Hz modulations in both hemispheres. We performed an analysis for the HbO concentration on a single channel basis, aimed at identifying the core region that differed between the children with dyslexia and the control group. For each channel, we performed a mixed ANOVA with modulation rate as the within-participant factor (2 levels: 2 Hz and 40 Hz) and group as the between-participant factor (2 levels: control and dyslexic). We then collated those channels exhibiting a frequency x group interaction, which signified a differential effect of modulation rate between the two groups.

Following these procedures, only the HbO response of channels 43 and 44, two adjacent channels in the right supramarginal gyrus, revealed a significant interaction after multiple comparison correction (ch. 43: $F(1,28)= 16.64$, $p< .005$; ch. 44: $F(1,28)=11.11$, $p< .005$). Such region was significantly more active in children with dyslexia than in control children for 2 Hz stimulation (but not for 40 Hz stimulation). Furthermore, the hemodynamic response at 2 Hz was significantly associated with basic sensory processing of amplitude rise time and with vocabulary and reading development. We interpret the results with respect to a neural ’temporal sampling’ framework for conceptualizing the phonological deficits that characterise children with developmental dyslexia across languages.