

Using a Memory Game to Enhance Frontal Activation in 3.5-Year-Olds During an Executive Function Task

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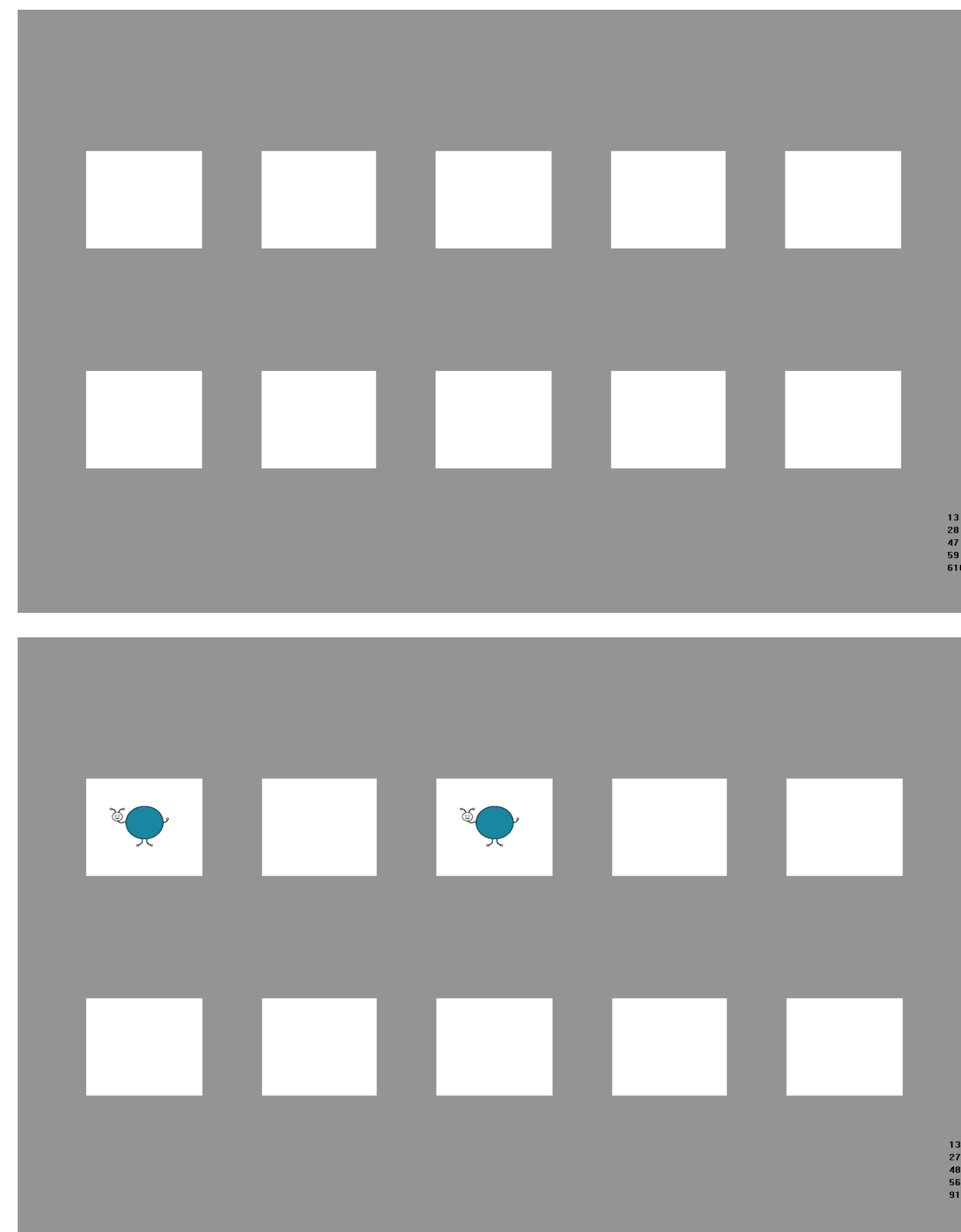
Introduction

The dimensional change card sort (DCCS) task requires children to sort cards by one dimension (e.g. shape) and then switch to sort by another dimension (e.g. color). Typically, 3-year-olds, but not 4-year-olds, perseverate and continue using the pre-switch dimension when instructed to switch. Prior exposure to the post-switch dimension in the form of a memory game facilitates performance of 3-year-olds in the post-switch phase of this task (Perone et al., 2015; 2019). The goal of this project was to explore the neural basis of this effect. Functional near-infrared spectroscopy (fNIRS) was used to measure hemodynamic activity while performing the DCCS from left frontal, left temporal, and right parietal regions previously implicated in dimensional attention (Morton et al., 2009; Buss & Spencer, 2018).

Tasks and Stimuli

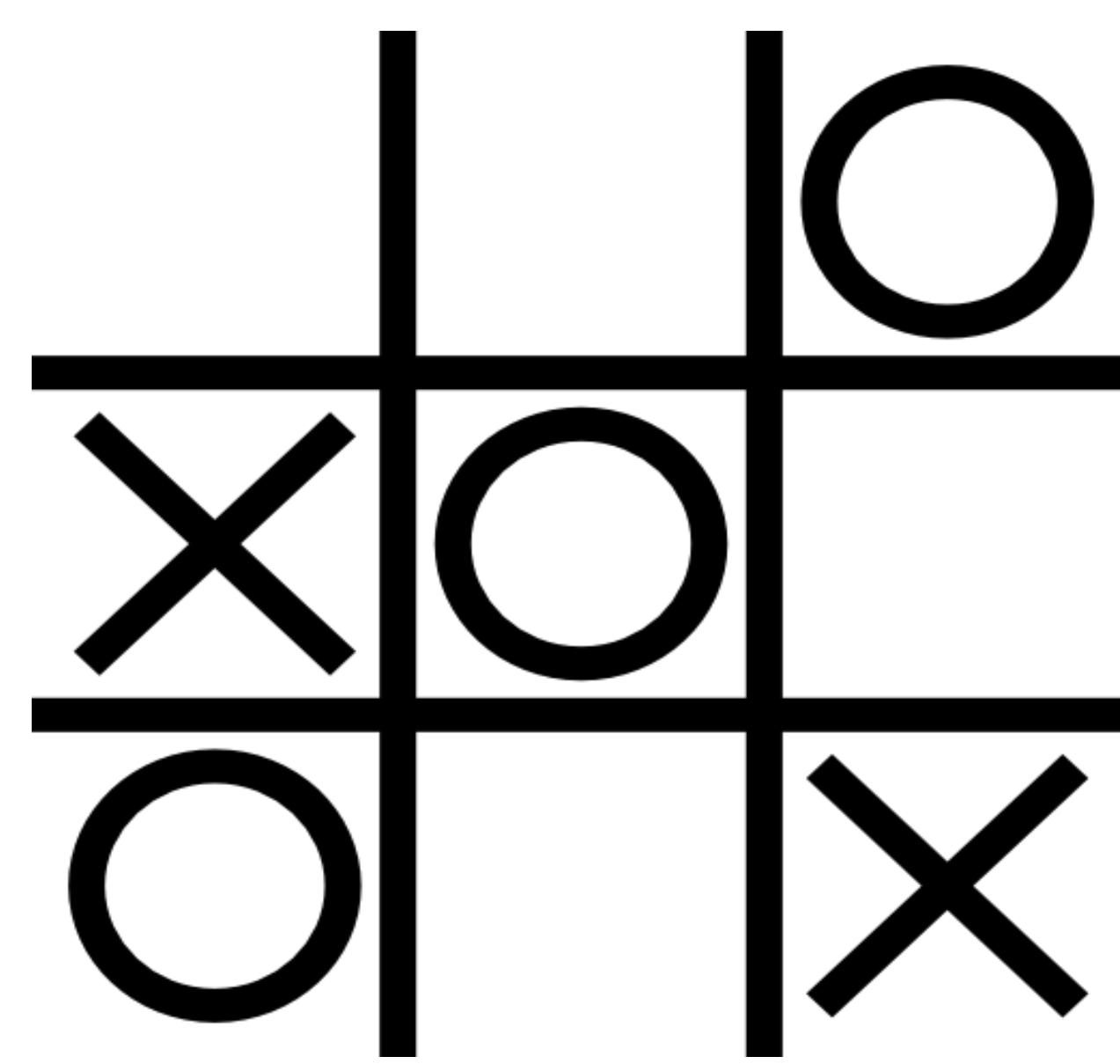
Examples of Stimuli and Tasks

Memory Game



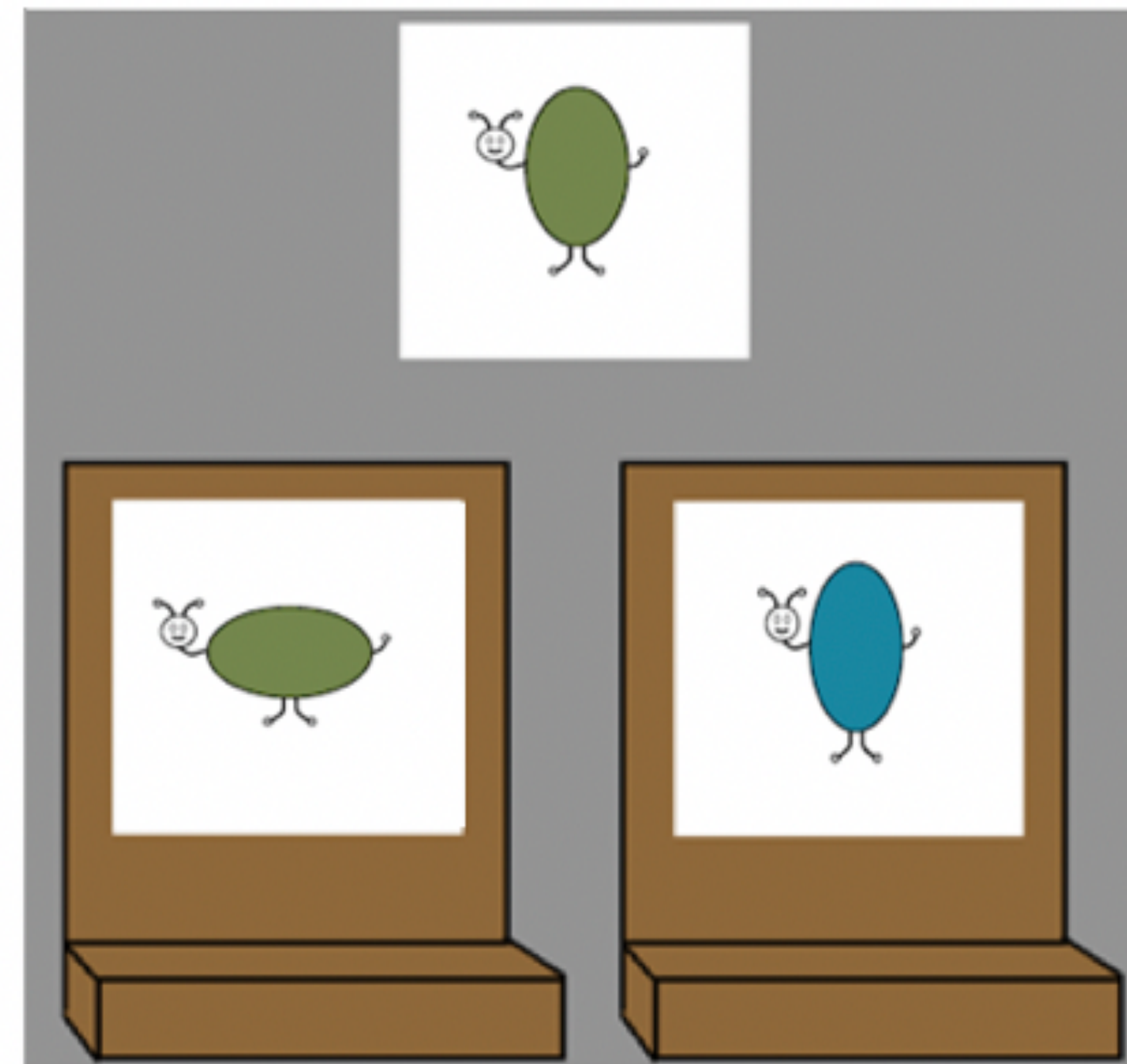
"Find two buggles that are the same color!"
(n=16)

Tic-Tac-Toe



"We're going to take turns making X's and O's!"
(n=17)

DCCS

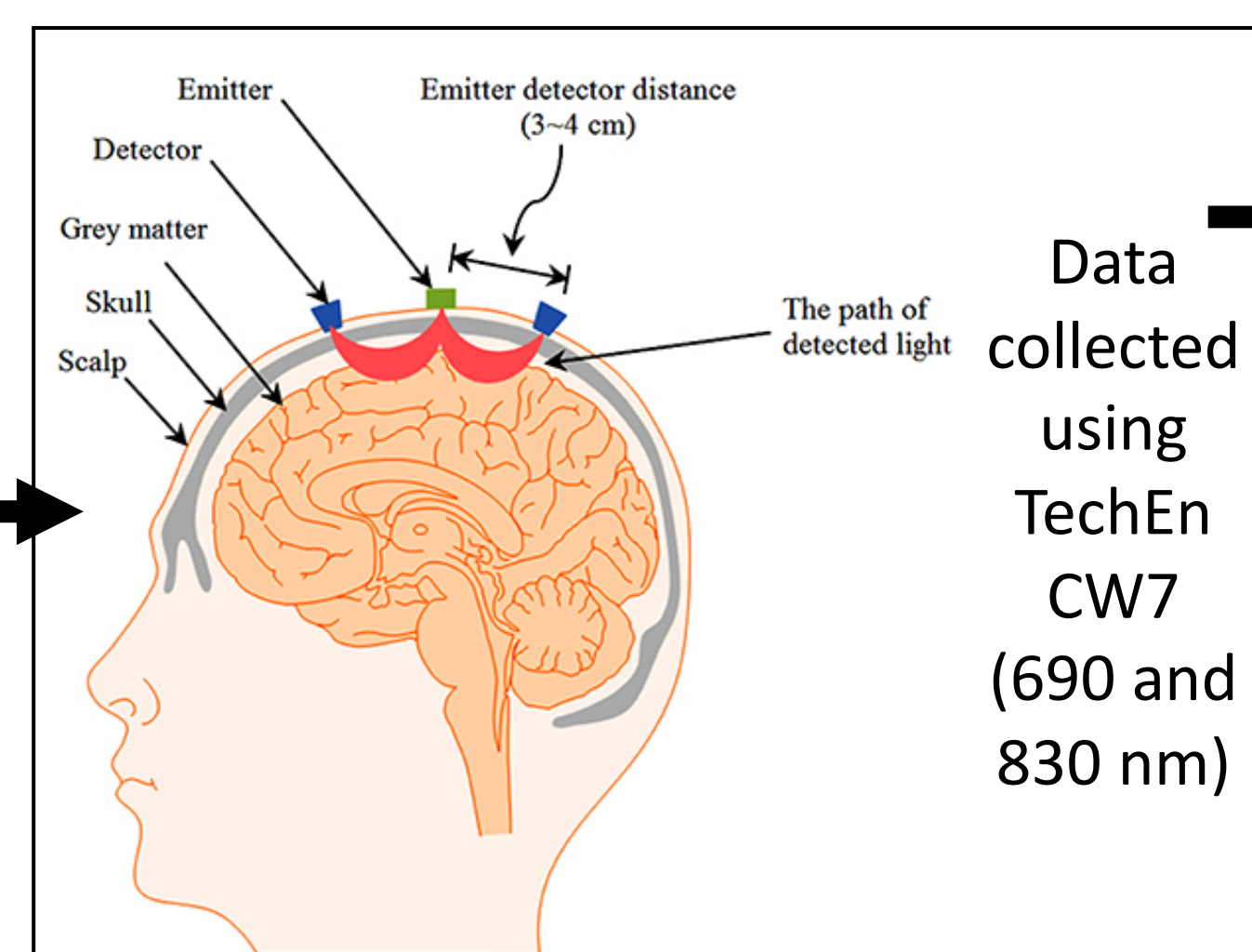
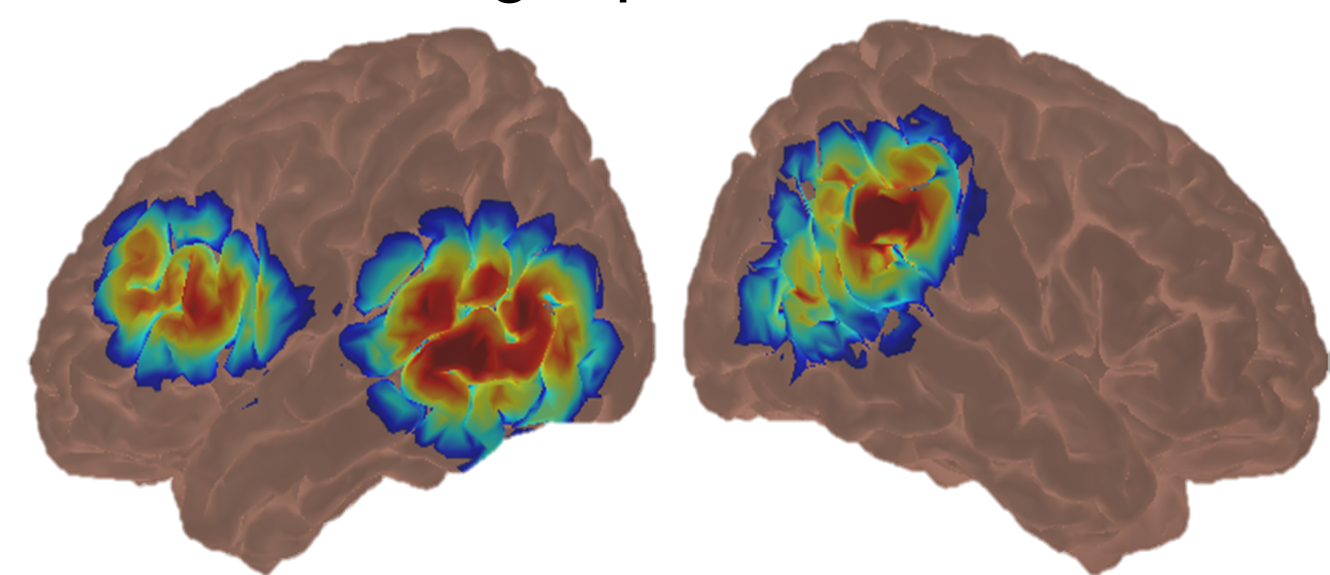


"Where does this green one go?"

- Thirty-three 3.5-year-old children
- One group played a memory game with the post-switch dimension (color matching) prior to DCCS
- Second group played standard tic-tac-toe prior to DCCS

fNIRS Data and Behavioral Analysis

Probe designed to record from network involved in dimensional attention: left lateral frontal cortex, left temporal cortex, and right parietal cortex



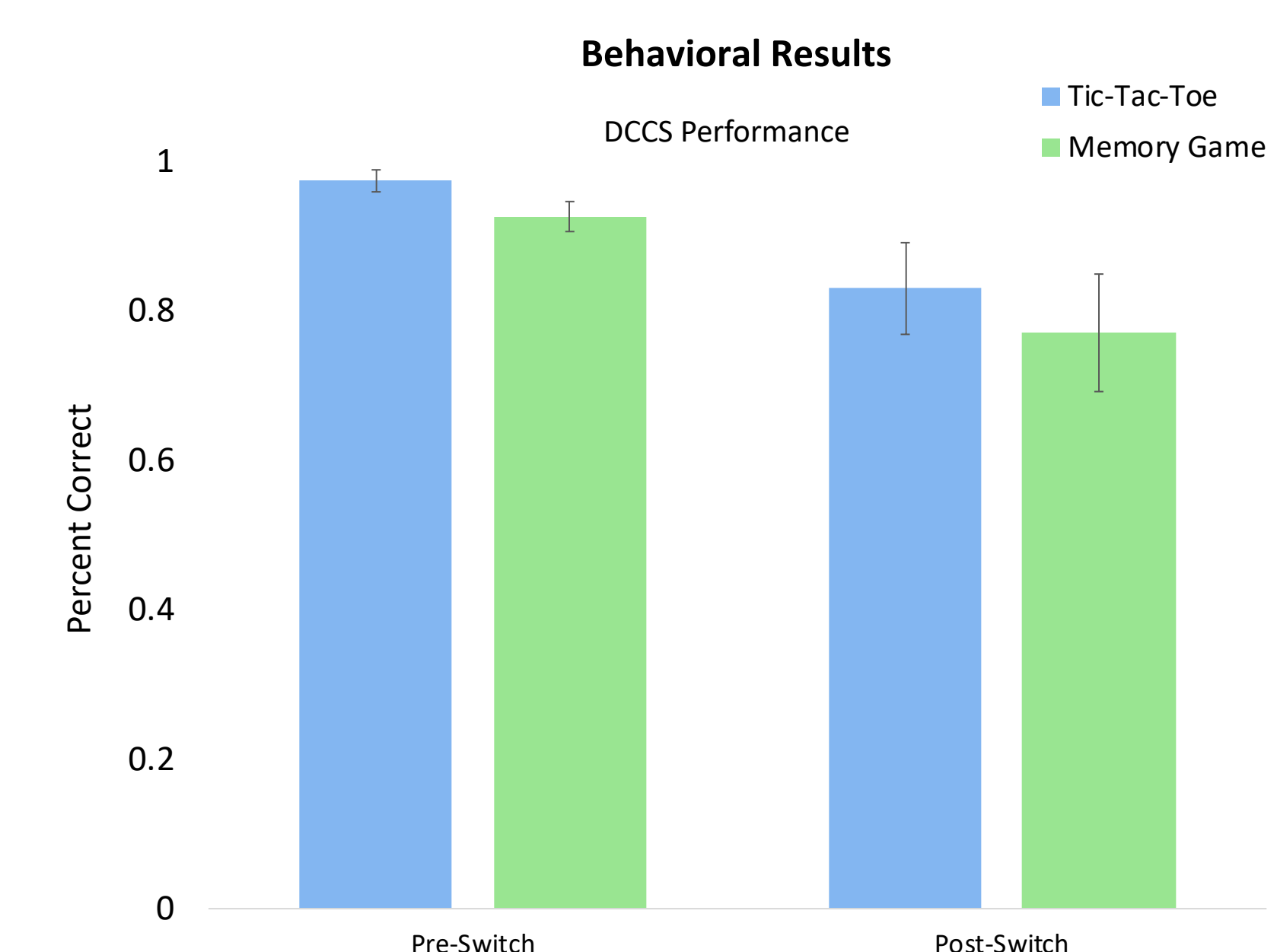
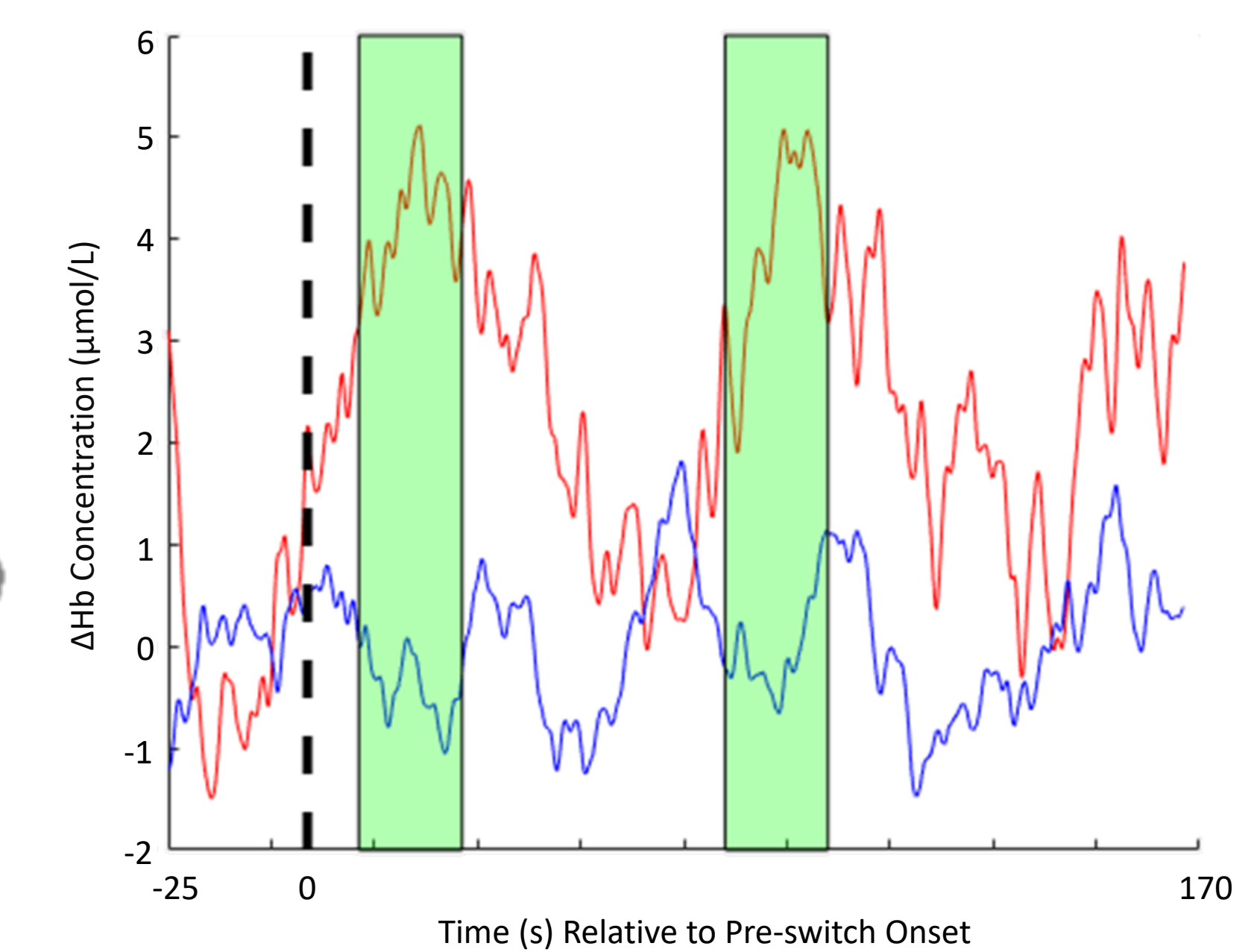
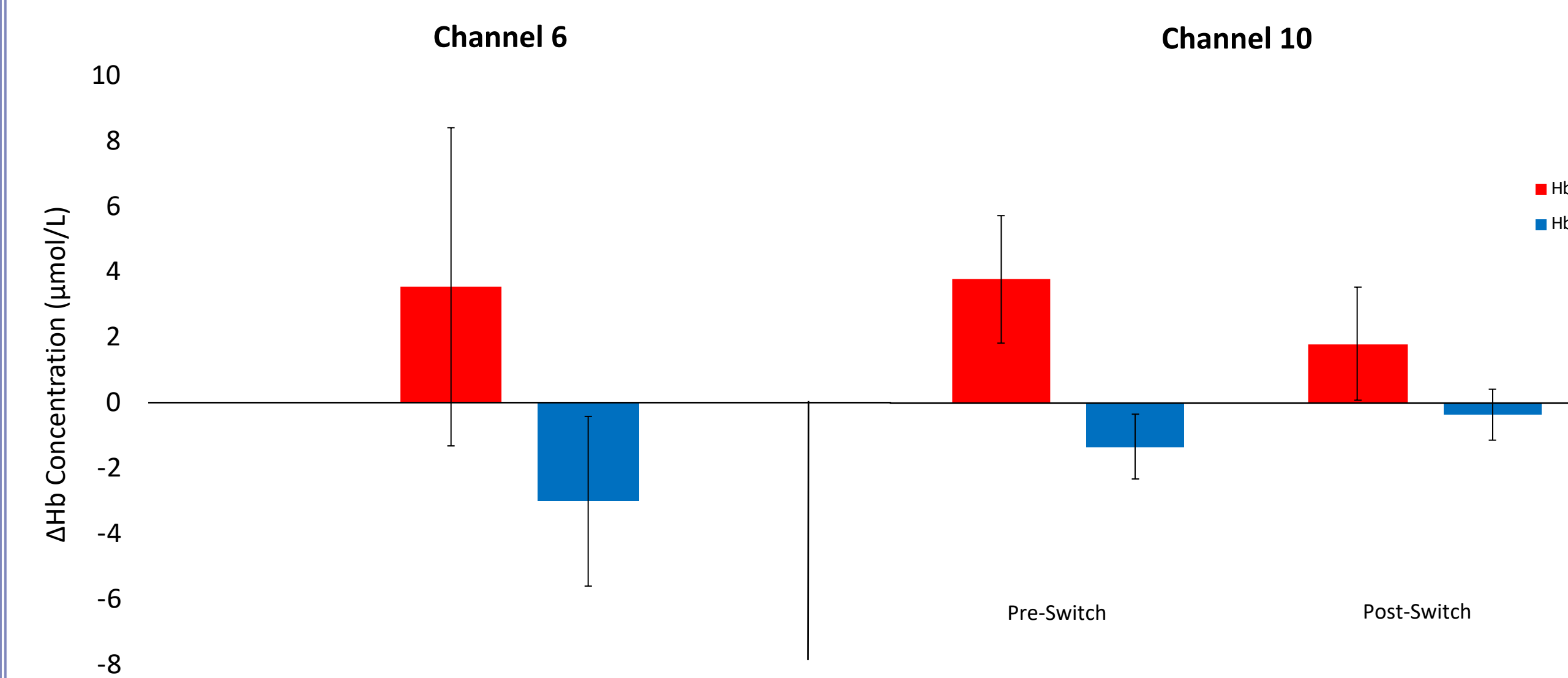
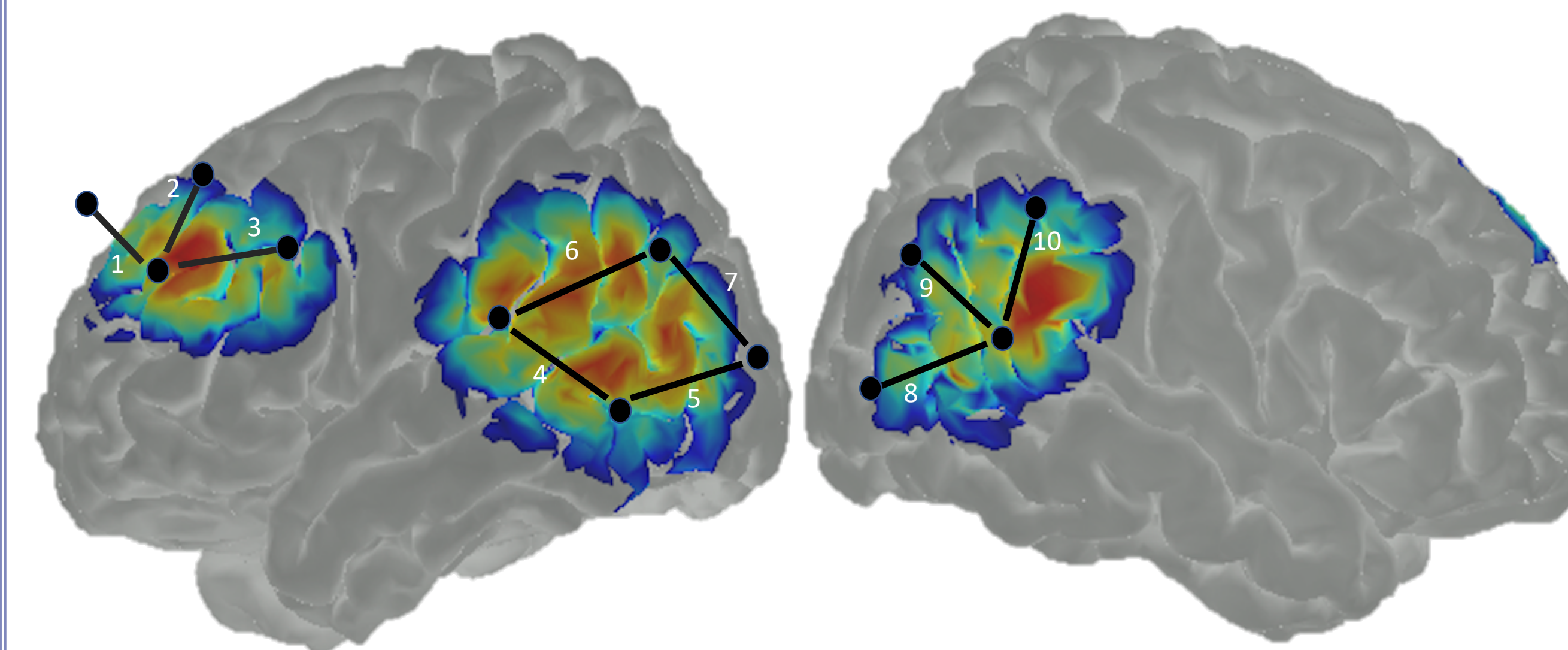
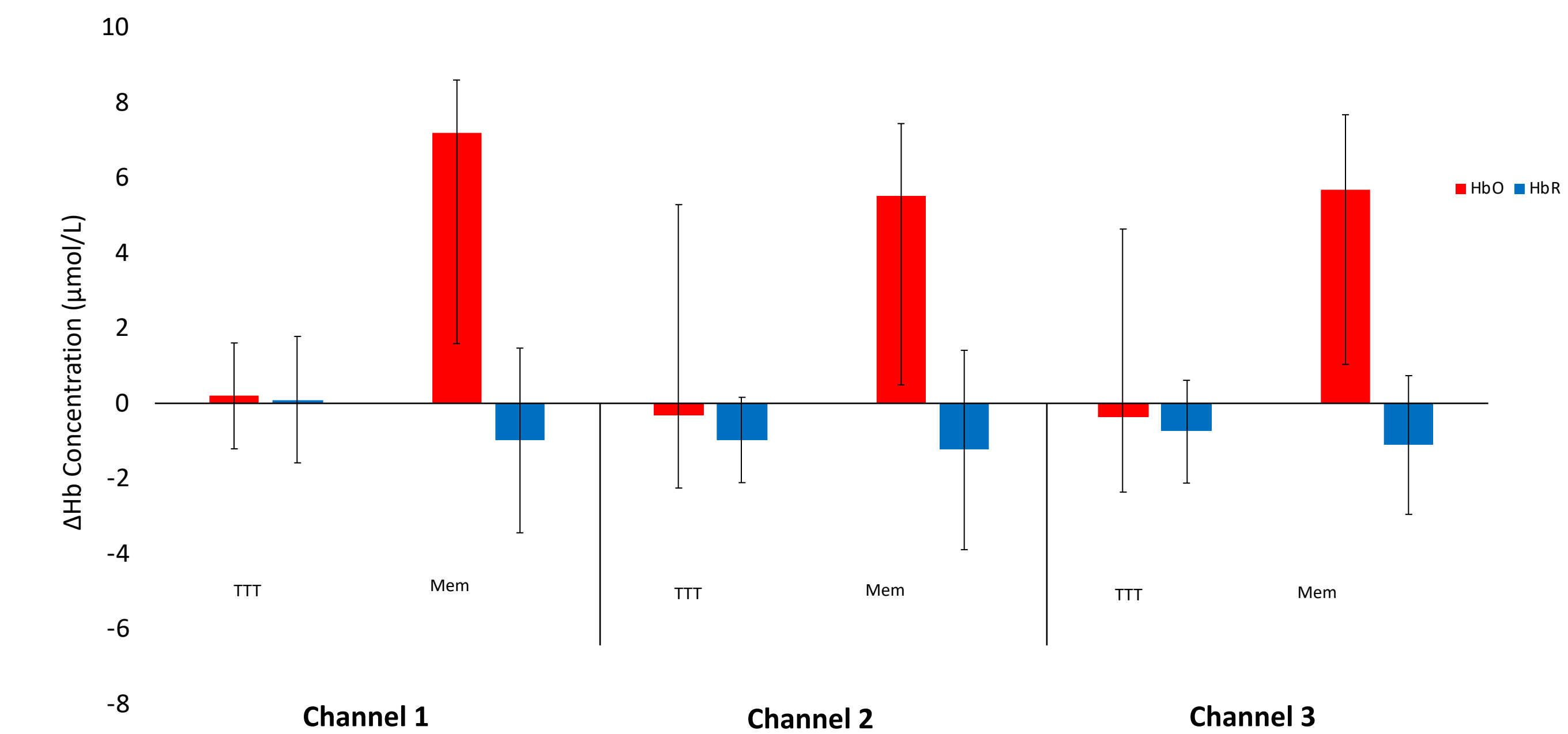
Data collected using TechEn CW7 (690 and 830 nm)

Standard pre-processing in EasyNIRS:

- Convert to optical density
- Wavelet motion filtering (iqr=0.5)
- Conversion to concentration values using modified Beer-Lambert equations (dpf=ppf=6.0)
- Average HbO and HbR calculated within the time window for task

Results

Channel	Effect (df)	F, p, η^2
1	Oxy (1,31)	9.951, .004, .243
	Oxy x Condition (1,31)	9.480, .004, .234
2	Oxy (1, 31)	6.977, .013, .184
	Oxy x Condition (1,31)	4.719, .038, .132
3	Oxy (1,31)	5.898, .021, .160
	Oxy x Condition (1,31)	4.726, .037, .132
6	Oxy (1, 31)	9.632, .004, .237
	Oxy x Phase (1, 31)	13.303, .001, .300



Conclusions

- Post-switch phase of DCCS showed activation in left frontal, left temporal, and right parietal cortices.
- Children that played the memory game prior to DCCS had greater activation of the left frontal cortex during the post-switch phase.
- Previous studies found an increase in post-switch performance in the memory game group (Perone et al., 2015; 2019), which may be associated with an increase in frontal cortex recruitment; however, performance differences were not found in the current study.
- Our results support predictions of a dynamic neural field model (Buss & Spencer, 2014; Perone et al. 2015), which demonstrates how experience with perceptual dimensions can enhance activation of frontal cortex.

References

- Buss, A. T. & Spencer, J. P. (2018). Changes in frontal and posterior cortical activity underlie the early emergence of executive function. *Developmental Science*, 21(4), e12602.
- Morton, J.B., Bosma, R., & Ansari, D. (2009). Age-related changes in brain activation associated with dimensional shifts of attention: an fMRI study. *Neuroimage*, 46(1), 249-256.
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- Perone, S., Plebanek, D.J., Lorenz, M.G., Spencer, J.P., & Samuelson, L.K. (2019). Empirical tests of a brain-based model of executive function development. *Child Development* 90(1), 210-226.