Neural Mechanisms of Surface Feature Labeling in Early Childhood

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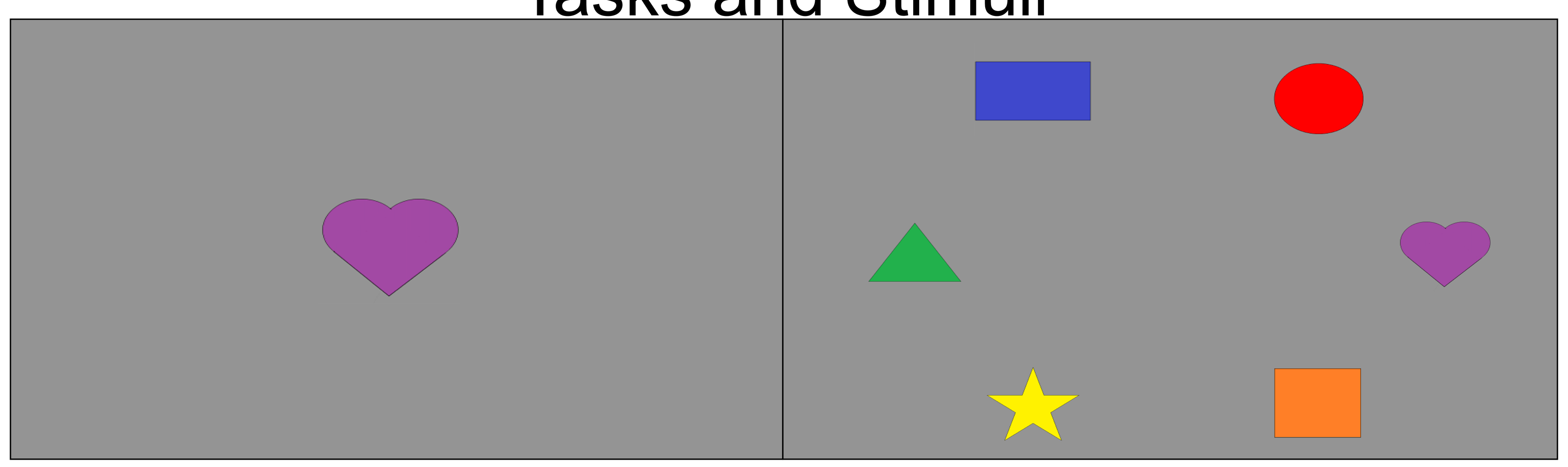
Introduction

- Data comes from a longitudinal grant comparing verbal label knowledge and cognitive switching abilities at age 2 to later executive function ability at age 4 and school readiness at age 5.
- Executive function ability in early childhood is a predictor of later academic and quality of life outcomes. Thus, dimensional labeling as a prediction for later executive function skills is important.
- Previous studies have found that label knowledge is predictive of executive function ability.
- Our lab has found that parietal-and not frontal-activation at age 2 is associated with executive function at age 3, suggesting that frontal activation on simple labeling tasks is less advantageous than parietal activation.
- Hypothesis: 2-year-olds with better color and shape labeling abilities will show greater parietal and lower frontal activation.

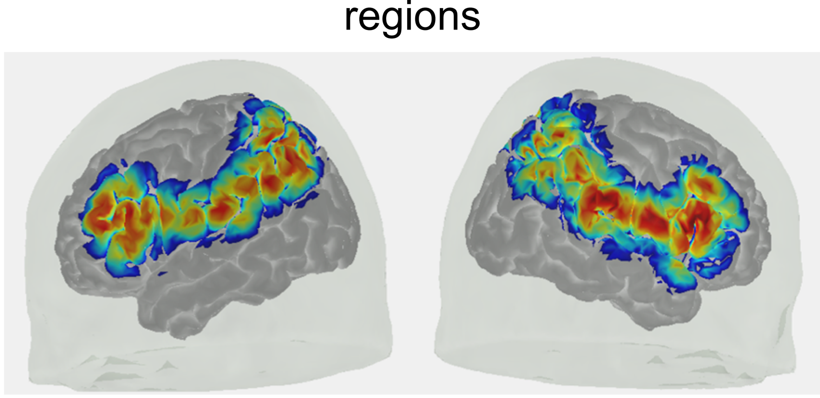
Tasks and Stimuli

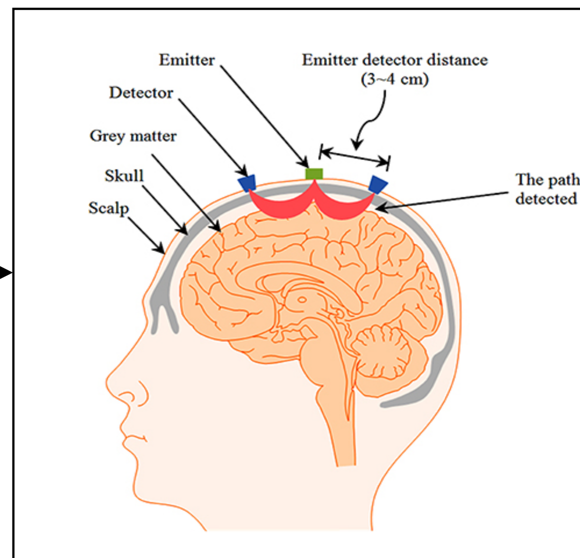


Production Comprehension

fNIRS Data Collection and Analyses

Probe designed to record measuring from bilateral frontal, temporal, and parietal regions



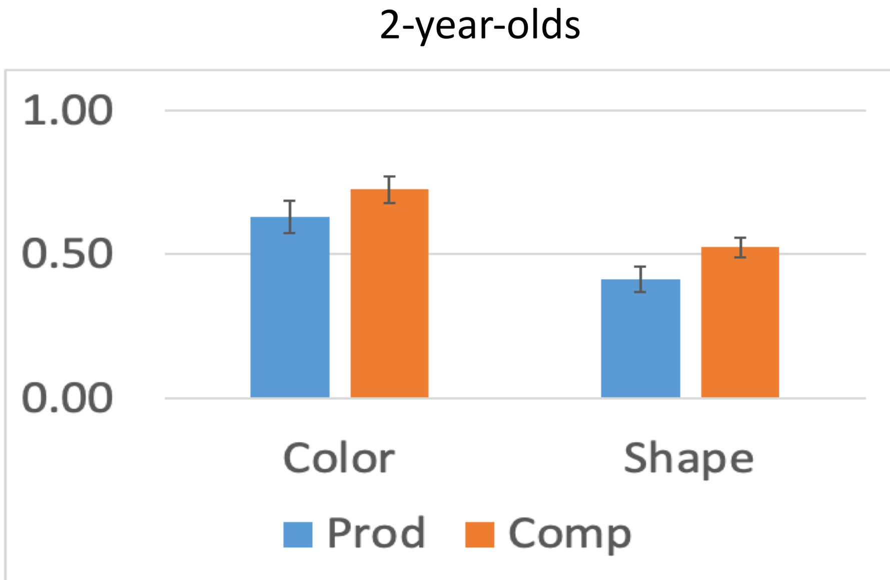


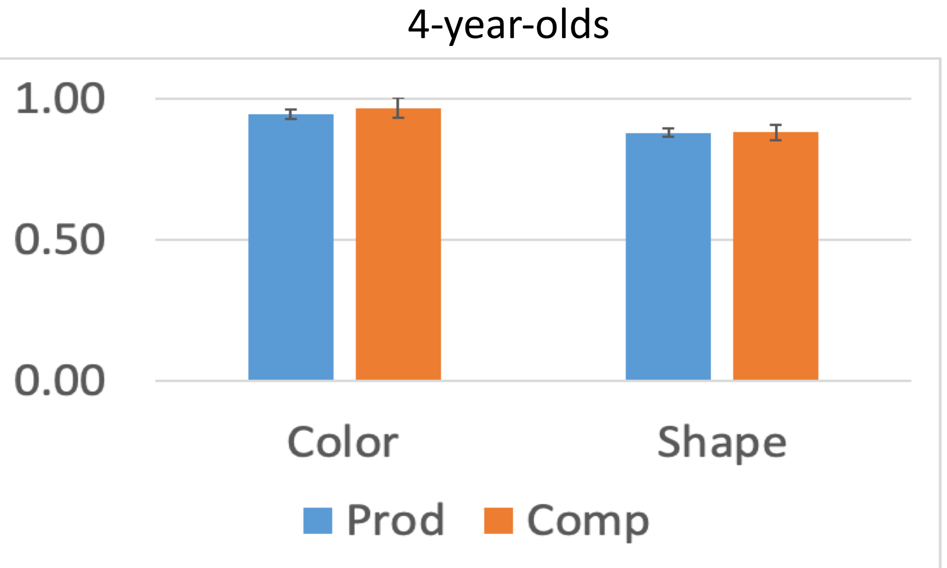
Data collected using TechEn CW6 (690 and 830 nm)

Pre-processing and connectivity analyses using AnalyzIR Toolbox

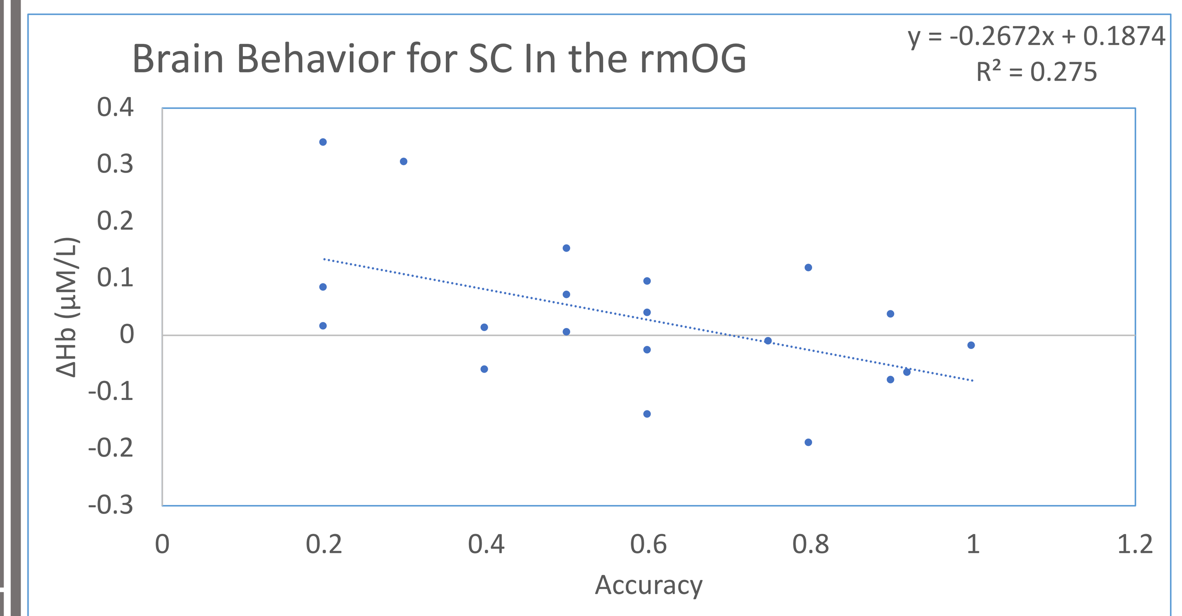
- Data were converted to optical density
- TDDR used to remove baseline shifts and spike motion artifacts
- Conversion to concentration values using modified Beer-Lambert equations (dpf=ppf=6.0)
- Average HbO and HbR calculated within 4-6s time window for each task
- Group masks were created using voxels in which at least 60% of subjects contributed data
- Voxel-wise estimations of ΔHbO/R for each condition are created with global signal regressed GLM betas, group sensitivity profiles, and absorption coefficients of two wavelengths (NeuroDOT functions *reconstruct_img* and *spectroscopy_img*).

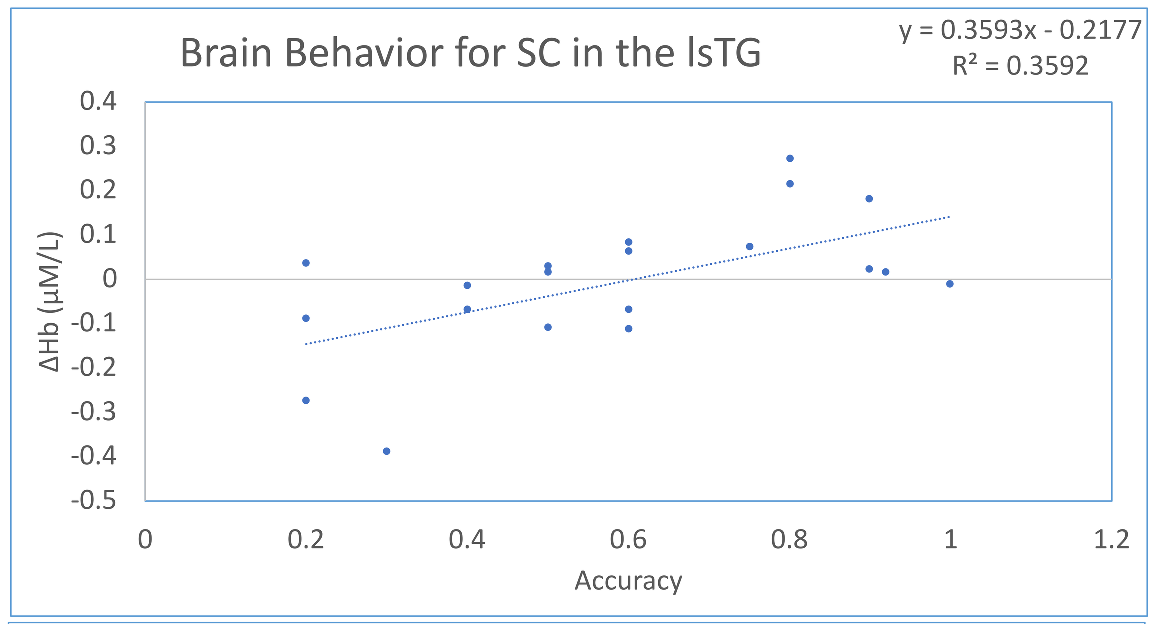
Behavioral Results

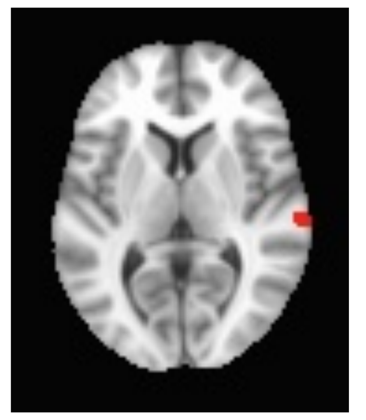


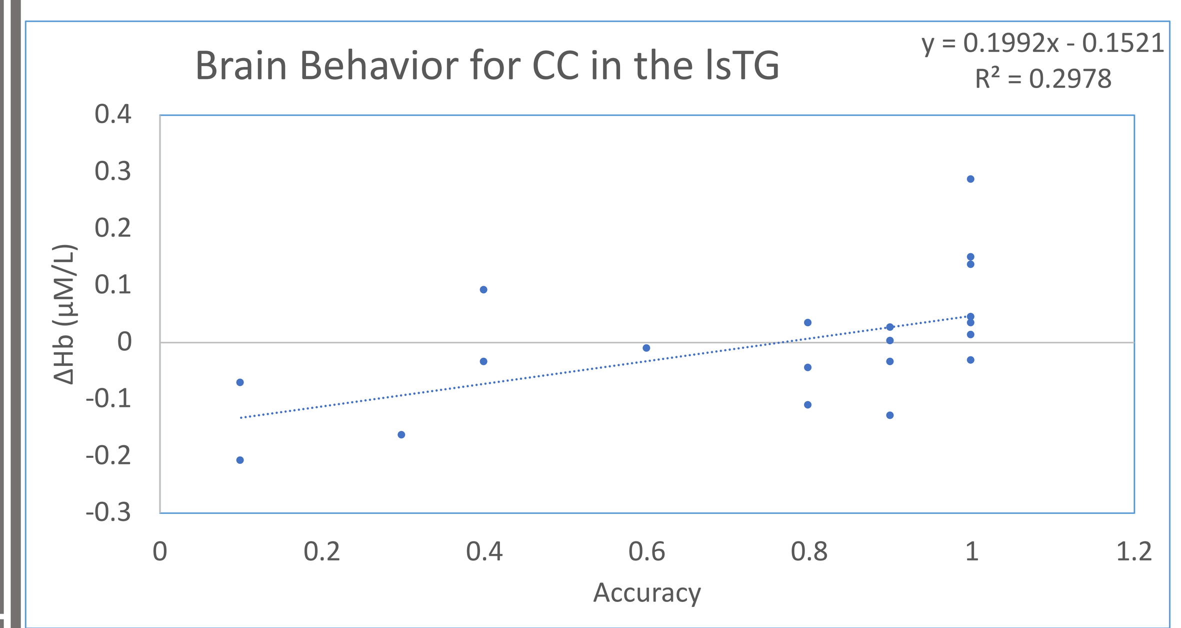


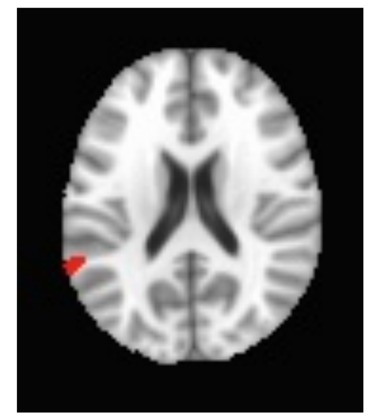
Neural Results

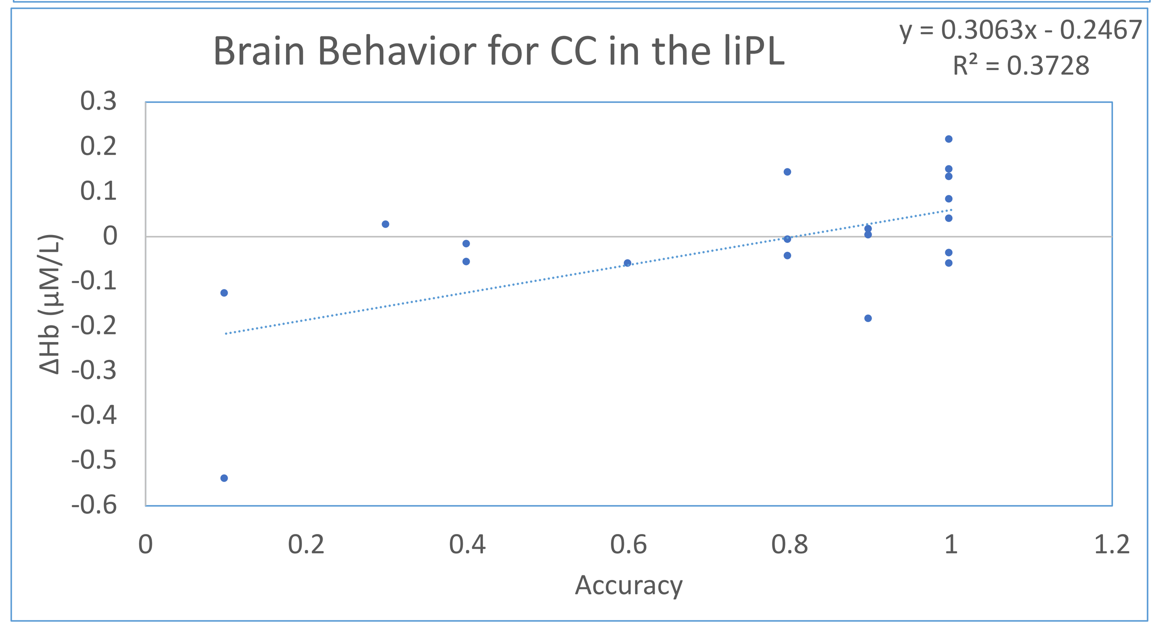




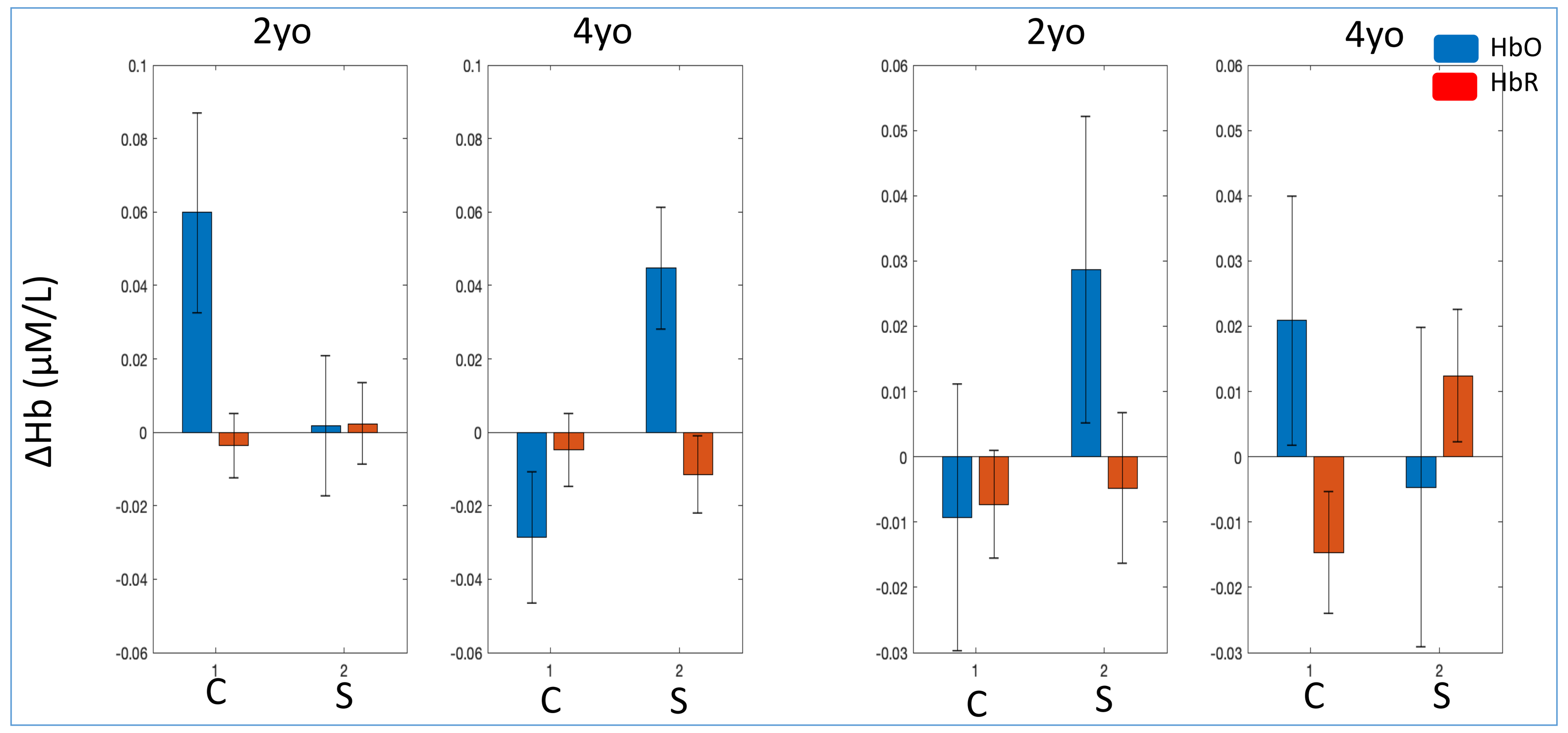


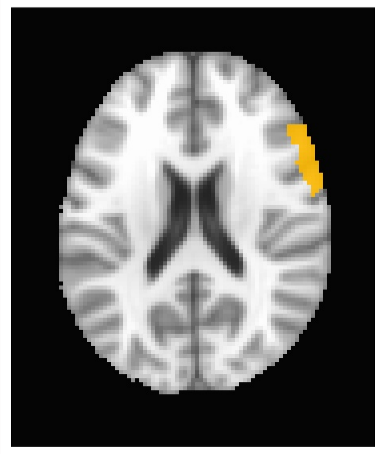




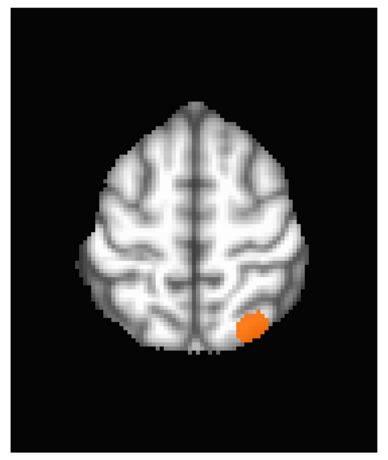


Dimension by Age Effects

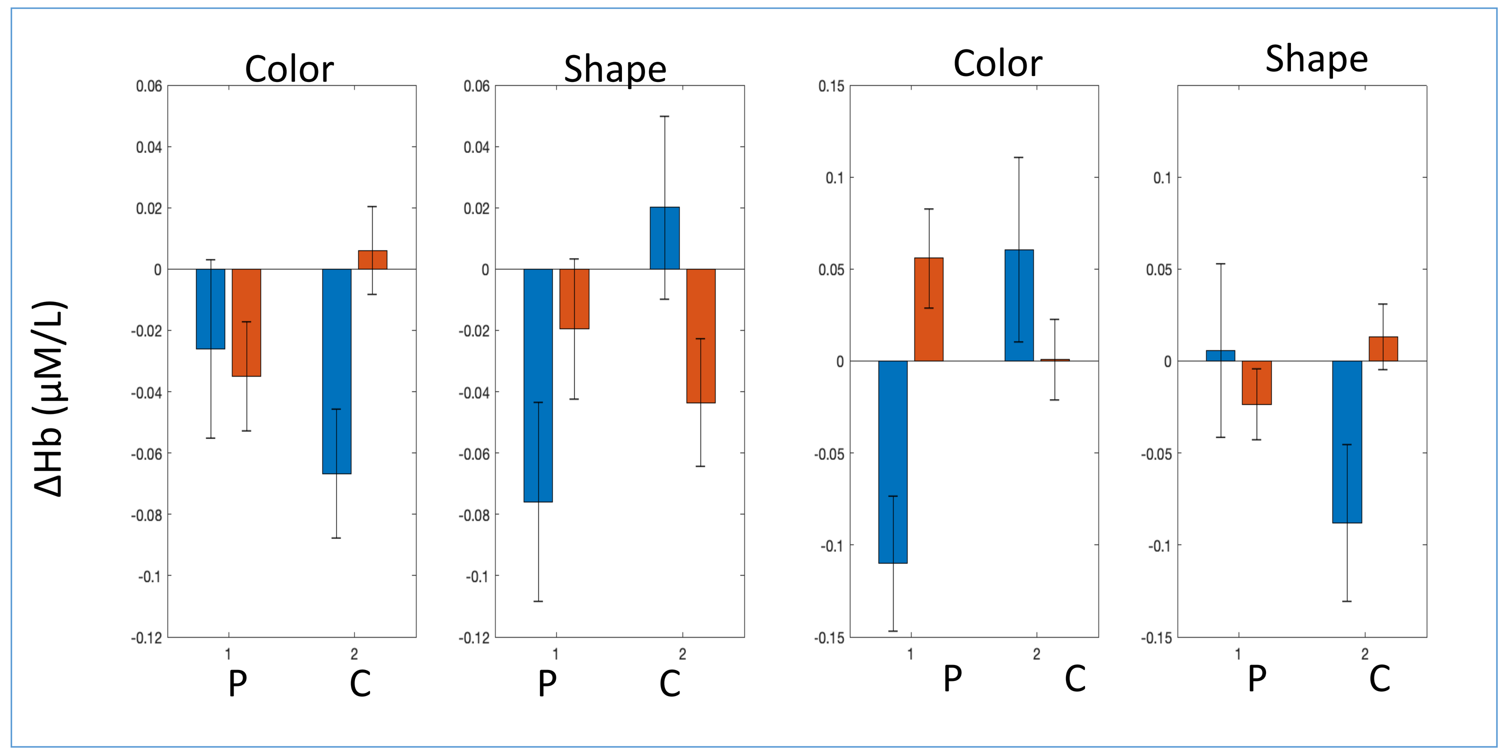


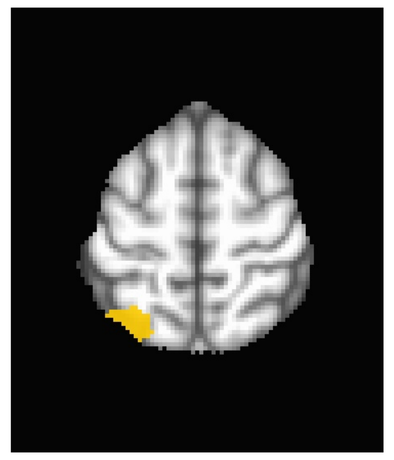


- Right inferior Frontal Gyrus: greater activation for 2-year-olds during color tasks, vice versa for 4-year-olds
- Right superior Parietal Lobule: greater activation for 2-year-olds during shape, vice versa for 4-year-olds



Task by Dimension Effects





- Collapsing across age
- Left superior Parietal Lobule: shape comprehension activation
- Left inferior Parietal Lobule: color comprehension activation

Conclusions

- Frontal activation is associated with executive function and critical thinking skills. Because of this, it is plausible that activation in this area would mean that the participant finds the task difficult. This may be why 2-year-olds, who are not yet proficient in colors, would show activation in this region for the color task, and vice versa for 4-year-olds. Activation in the parietal lobule may be occurring in the two ages for different reasons. 2-year-olds may be exhibiting activation in this region because shape is too complicated for them to activate frontal regions in order to complete the task, which is why they also have poorer performance in comparison to 4-year-olds. In contrast, 4-year-olds may have activated parietal and not frontal regions during color tasks because the color tasks were so easy that they did not require much effort.
- This may be due to a goldilocks effect where shape is just the right amount of complex at age 4 to activate the frontal region.
- It's possible that frontal activation during comprehension and production tasks may be less advantageous as it shows lack of expertise. Training on shape and color labels at a young age may improve executive function ability at older ages.

References

Buss, A. T., Fox, N., Boas, D. A., and Spencer, J. P. (2014). Probing the early development of visual working memory capacity with functional near-infrared spectroscopy. *NeuroImage, 85,* 314–25., Simmering, V. R. (2012). The development of visual working memory capacity during early childhood. *Journal of Experimental Child Psychology, 111*(4), 695–707. , Simmering, V. R., and Perone, S. (2013). Working memory capacity as a dynamic process. *Frontiers in Psychology, 3,* 1–26., Cragg, L., and Nation, K. (2010). Language and the development of cognitive control. *Topics in Cognitive Science, 2*(4), 631–42., Lowery, K., Nikam, B., & Buss, A.T. (2022). Dimensional label learning contributes to the development of executive function. *Scientific Reports, 12*(1), 1-12.