Prefrontal Lobe Activity During Cognitive and Motor Tasks in Infancy Using fNIRS

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Abstract

fNIRS is a brain-imaging technology used to measure oxygenation and blood flow that reflect levels of brain activity. We examined links between locomotion and executive function in 8-14-month-old infants using fNIRS. In session one, infants engaged in active crawling and passive movement in a stroller. In session two, infants attended to two cognitive tasks that evaluate executive function. Results revealed differences in peak Oxy and HbT levels for crawling vs. strolling and between the two cognitive tasks. Additionally, we found correlations between the total score of the Switch Task and the peak Oxy levels for crawling, pre-switch, and post-switch.

Introduction

Functional near-infrared spectroscopy (fNIRS) technology uses LED light and optical sensors to measure the concentration changes from baseline in oxy-Hb and deoxy-HB in the capillaries to the prefrontal cortex. The prefrontal cortex is an area linked to executive functioning — neurocognitive and regulatory processes associated with inhibitory control, cognitive flexibility, and the planning and initiation of voluntary actions (Diamond, 2013). Some researchers (e.g., Koziol & Lutz, 2013) have suggested that self-guided locomotion contributes to the development of executive function, as they both make use of the same prefrontal cortical area of the brain.

This study analyzed changes in Oxy and HbT levels in the prefrontal cortex during passive versus active movement and examines the differences in oxygenation between two tasks designed to measure attention, cognitive flexibility, and inhibition.

Participants engaged in two sessions while wearing the fNIRS device for the entire duration of both sessions. In the first session of the study, participants engaged in passive movement by being pushed toward their parent in a stroller, and active movement by crawling toward their parent. In the second session, participants watched a Cat Puppet Task and a Switch Task (Kovacs & Mehler, 2009) on a plasma screen. The Switch Task involves attentional control and switching away from an established response — hallmarks of executive function, while the Cat Puppet Task requires only simple looking.

The hypothesis stated that there will be a greater increase in Oxy levels when the infant actively moves by crawling compared to passively moving in a stroller. In addition, we predicted that there will be a greater increase in Oxy levels during the Switch Task as compared with the Cat Puppet Task, both before and after the switch occurred.

Methods

Design & Participants

- This study used a within-subjects design with two separate sessions: locomotion and cognition.
- Participants were 12 typically developing 8-14 month-old infants who were crawling at the time of their participation (see Figure 1).

Figure 1

Materials

- fNIRS device from BIOPAC Systems, Inc.
  - 2-ch wireless pediatric sensor
- ASL Eye tracking system

Measures

- Oxy: Oxygenation concentration changes determined by the difference between oxy-Hb and deoxy-Hb relative to baseline (see output in Figure 2)
- HbT: Sum of oxy-Hb and deoxy-Hb relative to the local baseline; higher HbT levels indicate an increase in blood volume
- Baseline: Measurement of oxygenation and blood flow that occurs when participant is at rest

Figure 2

Procedures

- Session 1
  - Passive movement: The participant was pushed in a stroller for a distance of 12 feet towards their parent.
  - Active movement portion: The participant crawled 12 feet towards their parent.
  - The order of crawling and strolling was counterbalanced across participants.
- Session 2
  - The participant was seated in a car seat facing a plasma screen. Participants' eye movements were tracked.
  - Cat Puppet Task (see Figure 3)
    - Displayed a cat puppet that danced on the screen to music for 15 seconds
    - Reflects passive attention to a stimulus
  - Switch Task (see Figure 4)
    - A cartoon animal puppet appeared for nine trials on the right side and then switched to the left side.
    - Used to measure the participant's ability to learn a rule to anticipate the position where the puppet would appear, and then inhibit the original response to learn a new rule.

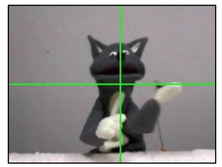

Figure 3

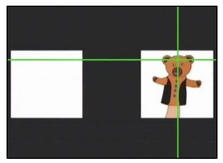

Figure 4

Results

A series of t-tests and correlations were carried out to test for differences and relationships across tasks (see Table 1 and Figures 5 and 6).

Figure 5

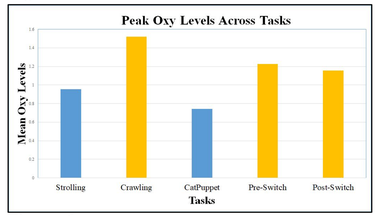

Figure 6

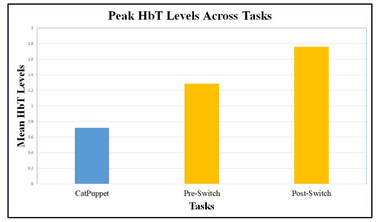

Table 1 Paired Differences

	M	*SD*	*t*	*p*	*η2*
Crawling vs Strolling Peak Oxy	.565	.624	3.14	.009	.47
Cat Puppet vs Pre-switch Peak Oxy	-.485	.694	-2.419	.034	.35
Cat Puppet vs Post-switch Peak Oxy	-.415	.612	-2.345	.039	.33
Cat Puppet vs Post-switch Peak HbT	-1.04	1.44	-2.496	.030	.36
Pre-switch vs Post-switch Peak HbT	-.472	.730	-2.239	.047	.31

Significant correlations were found between total Total Switch Task Score and Crawling (p = .028), Total Switch Task Score and Pre-Switch (p = .017), Total Switch Task Score and Post-Switch Score (p = .053) (see Table 2).

Table 2 Correlations

		Crawling Peak Oxy	Pre-Switch Peak Oxy	Post-Switch Peak Oxy
Total Switch Score	**Pearson Correlation**	.630	-.669	-.570
	Sig. (2-tailed)	.028	.017	.053
	N	12	12	12

Discussion

Both of our hypotheses were supported by the data. Crawling was shown to have higher peak Oxy levels compared to strolling, and the Switch Task was shown to have higher peak Oxy levels compared to the Cat Puppet Task. The higher levels of peak Oxy during crawling and the Switch Task indicate that these tasks require more prefrontal lobe activation compared to the passive tasks of strolling and the Cat Puppet Task. The HbT measure revealed increased blood volume during the Switch Task post-switch compared with the Cat Puppet Task. These results support Koziol and Lutz's (2013) claim that active locomotion and executive function tasks make use of the same prefrontal cortical area of the brain.

These findings promote the understanding of the development of executive function and have implications for treating children with delayed or impaired motor function.

References

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