Neural Connectivity During Language Processing in 4 Year-Old Predicts Later Reading Ability

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INTRODUCTION

Understanding how pre-literate children's language abilities and underlying brain networks relate to future reading ability is important to identifying pre-literate children who may be at-risk for reading problems, and contributes to our understanding of cognitive development.

Developing brain networks for language become highly overlapping with brain networks that emerge during literacy acquisition

Specific Aim: To examine whether language ability, neural activation, and neural connectivity in pre-readers predict reading ability one year later (ages 4.5-5.5) once children begin learning to read.

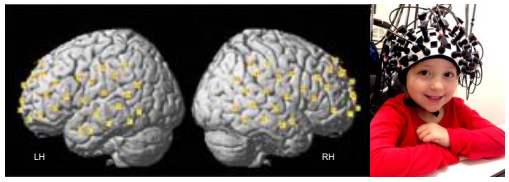
New: Psycho-physiological interaction (PPI) for fNIRS

METHODS

Participants. 37 children ages 3.5 to 4.5

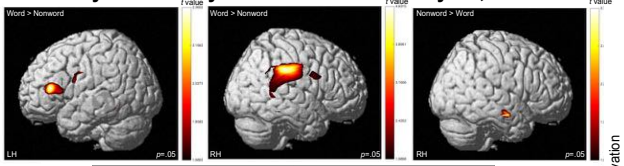
Measure	Time 1	Time 2 (1year later)
n	37	28
Age	4.2 (0.5)	5.2 (0.6)
Gender (Male:Female)	22:13	16:13
IQ	114 (10)	--
Letter Knowledge (TOEPL)	115 (16)	--
Phono. Awareness (CTOPP)	31 (7)	36 (7)
Phono. Memory (CTOPP)	9 (3)	12 (3)
Rapid Naming (CTOPP)	15 (8)	20 (6)
Picture Vocabulary (PPVT)	122 (14)	120 (11)
Letter-Word Decoding (WJ)	--	117 (16)
"Word Attack" Pseudoword Reading (WJ)	--	121 (15)
Passage Comprehension (WJ)	--	108 (13)

fNIRS Neuroimaging.
Block design: 24 trials.
Each trial: 6 stimuli presented auditorily with 100ms ISI
12 words, 12 pseudowords
NIRS-SPM for GLM analyses

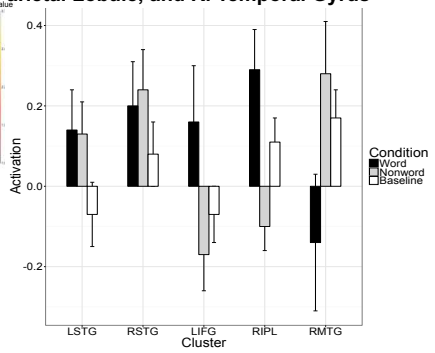


RESULTS

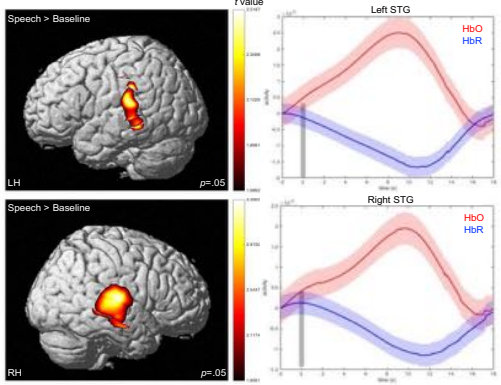
Sensitivity to lexicality in L. Inferior Frontal Gyrus, R. Inferior Parietal Lobule, and R. Temporal Gyrus



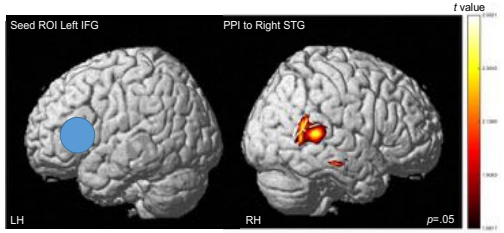
Contrast	Region	BA	X	Y	Z	*t* value	*p* value
Speech > Baseline	L. STG	22/42	-69.3	-34.6	10.4	2.01	0.05
Speech > Baseline	R. STG	22/42	71.7	-27.2	7.4	2.46	0.05
Words > Nonwords	L. IFG	46	-54.1	33.4	13.0	1.90	0.05
Words > Nonwords	R. IPL	40	69.0	-35.3	35.7	2.57	0.05
Nonwords > Words	R. MTG, R. ITG	21	69.7	-8.0	-19.0	2.04	0.05



Speech-related activation in bilateral STG



Task-modulated connectivity in L. IFG to R. STG



fNIRS PPI Methods

Standard GLM analysis was conducted to model the contribution of predictors (i.e. onset and offset of experimental stimuli) to the time-course of each channel. To estimate the neural signal from the hemodynamic response, the first eigenvariate time-course data of the voxels within the seed ROI were deconvolved. We used a seed ROI of left IFG and left STG, respectively. The GLM for the PPI consisted of 1) a vector corresponding to the experimental factor, 2) the deconvolved neural signal in the ROI, and 3) the interaction term generated from the element-by-element product of the mean-centered time-course neural signal data in each region. A contrast vector where the interaction term is weighted 1 and all other regressors are weighted 0 assigns the main effects of the experimental task and physiological correlations as covariates of no interest. This contrast accounts for voxels which may exhibit non-task-specific correlations with the seed ROI due to shared anatomical connectivity or subcortical inputs. Group maps were generated comparing the activation to the task relative to baseline as modulated by activation in the seed ROI.

Neural activation and connectivity for speech predict future reading ability

Predictor		Letter Word Decoding			"Word Attack"			Passage Comp.		
		β	*t*	*p*	*β*	*t*	*p*	*β*	*t*	*p*
Demographic	Age at Time 2	0.212	1.847	0.083	--	--	--	0.161	1.254	0.225
	IQ	--	--	--	**-0.284**	**-2.795**	**0.012**	-0.198	-1.527	0.143
	SES	--	--	--	--	--	--	--	--	--
Language Ability	Letter Knowledge	0.258	1.633	0.122	--	--	--	--	--	--
	Phono. Awareness	**0.659**	**4.295**	**0.001**	**0.722**	**6.349**	**< .001**	**0.642**	**5.072**	**< .001**
	Phono. Memory	-0.236	-2.050	0.057	--	--	--	**-0.280**	**-2.129**	**0.047**
	Rapid Naming	--	--	--	--	--	--	--	--	--
	Picture Vocabulary	-0.231	-1.607	0.128	--	--	--	--	--	--
Brain Activation	LSTG activation	--	--	--	--	--	--	--	--	--
	RSTG activation	-0.184	-1.321	0.205	-0.235	-1.796	0.088	--	--	--
	LIFG activation	-0.191	-1.492	0.155	**-0.333**	**-3.236**	**0.004**	-0.155	-1.301	0.209
Connectivity	LIFG-LSTG PPI	0.217	1.576	0.135	0.252	2.026	0.057	--	--	--
	LSTG-RSTG PPI	0.232	1.816	0.088	**0.322**	**2.604**	**0.017**	**0.384**	**3.265**	**0.004**
	LIFG-RSTG PPI	**0.239**	**2.125**	**0.050**	**0.253**	**2.481**	**0.023**	**0.478**	**4.004**	**0.001**

FINDINGS

Reading ability at Time 2 was predicted by language ability, neural activation in LIFG and STG, and connectivity at Time 1.

New: Time 1 neural connectivity between left IFG and right STG accounted for reading abilities at Time 2—beyond what behavior and neural activation explained)
Increased connectivity associated with increased reading ability

Activation
Greater activation for words and pseudowords in bilateral STG. Greater activation for words vs. pseudowords in LIFG

Connectivity
Connectivity between LIFG (seed) an right STG – modulated by task (words vs. baseline)

Predicting Reading
Letter-word decoding ability predicted by phonological awareness, phonological memory, and neural connectivity (LIFG-RSTG PPI).

Pseudoword reading ability predicted by phonological awareness and neural connectivity.

Passage comprehension predicted by phonological awareness, Left IFG activation, and neural connectivity.

Summary: Such insights into the brain-basis of emergent healthy/typical reading can be used to understand children who are struggling to learn to read –early identification of at-risk children.

Provide understanding whether reading deficits result from delayed or deviant neural reading circuits.

PPI analysis adapted for fNIRS data are new source of insight into brain function in development.

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