Neural entrainment of natural language in a large-scale sample of school-aged children

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Introduction

- Neural entrainment is the alignment between EEG and stimuli (Buiatti et al., 2009; Goswami, 2011)
- Neural entrainment affects how we perceive speech (Kösem et al., 2018)
- When developmental deficits occur, it is likely neural entrainment is weaker at specific frequencies (Lehongre et al., 2011; 2013; Power et al., 2016; Soltész et al., 2013)
- Neural entrainment at **Delta (< 4 Hz)** is associated with processing **prosodic** information, **Theta (4-7 Hz)** and **Alpha (8-12 Hz)** are associated with processing **syllabic** information, and **Beta (13-30 Hz)** is associated with processing **phonemic** information (De Vos et al. 2017; Giraud & Poeppel, 2012; Mayer, 2018)
- **The goal of this study is to uncover the role of neural entrainment to natural speech to better understand its role in language and reading**

Cerebro-acoustic phase coherence to natural speech predicted performance on several language assessments, phonemic decoding efficiency, and nonword repetition

Methods

Participants

- Selected from Child Mind Institute Healthy Brain Network
- 713 children 5- to 18-years-old
- *M* = 10.17, *SD* = 3.33 years

Child Mind Institute
HEALTHY BRAIN NETWORK

Tasks

Language Tasks

- Weschler Individual Achievement Test (WIAT III): *Comprehension + oral discourse composite and the listening comprehension + receptive vocabulary composite*
- Clinical Evaluation of Language Fundamentals (CELF-5) Screener

The following tasks were administered to children suspected of Language Disorders (LDs) based on the CELF-5 screener:

- Peabody Picture Vocabulary Test (PPVT; *n* = 65)
- Expressive Vocabulary Test (EVT-2; *n* = 65)
- All CELF-5 subtests (*n* = 40)

Reading Tasks

- Comprehensive Test of Phonological Processing (CTOPP-2; *n* = 630): all subtests
- Test of Word Reading Efficiency (TOWRE-2; *n* = 571): SWE and PDE

EEG Task

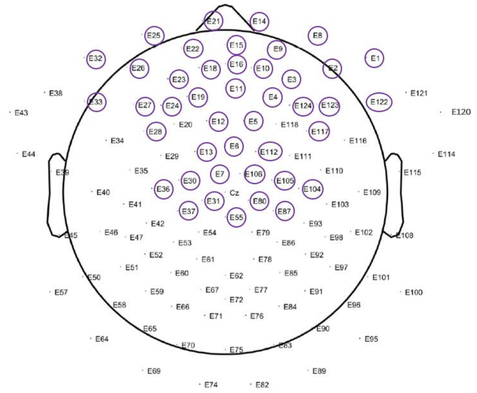
- Stimulus: a 2.72-minute-long educational video clip "Fun with Fractals"
- Recording: 128-channel EEG Geodesic Hydrocel
- Sampling rate: 500 Hz
- Reference electrode: vertex

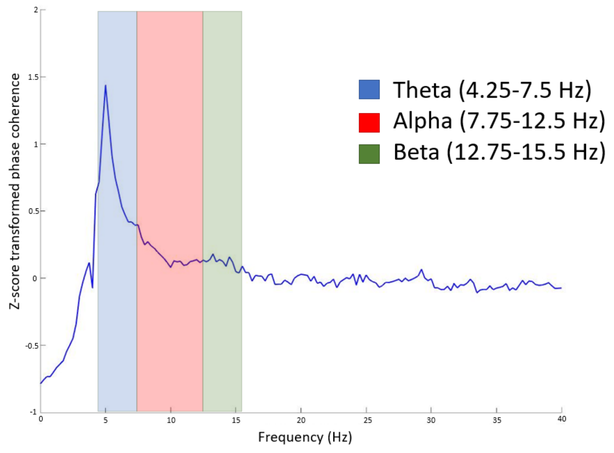
Cerebro-Acoustic Phase Coherence

- The audio signal and EEG were epoched (4000 ms/epoch) and converted to the frequency domain
- The phase of the EEG and audio were aligned
- Coherence was calculated for each fronto-central electrode and averaged
- Coherence values were z-score transformed and compared to chance

Cerebro-acoustic phase coherence:
0: no phase coherence
1: complete phase coherence

- Linear regressions were conducted with the language and reading measures as dependent variables and the coherence values as covariates





Results

Cerebro-acoustic phase coherence was significantly above chance from 4.25 Hz to 15.5 Hz

Frequency Band	Measures	R^2	*df*	*t*	*p*	Interpretation
	Language					
Theta	Understanding spoken paragraphs (CELF-5)	.127	1, 39	-2.35	.024	Lower coherence predicted greater scores
	EVT-2 Standard score	.066	1, 64	-2.11	.039	
	PPVT Standard score	.070	1, 64	-2.18	.033	
	Meta-pragmatics (CELF-5)	.116	1, 35	-2.11	.042	
	Reading					
Theta	Non-word repetition (CTOPP)	.009	1, 629	2.40	.017	Greater coherence predicted greater scores
Alpha	Phonemic decoding efficiency (TOWRE)	.009	1, 570	2.29	.023	

Discussion

- Theta coherence, related to processing syllables, primarily predicted performance on assessments given to children suspected of having LDs (CELF-5, EVT, PPVT).
- Lower coherence in the theta frequency band predicted greater performance on the language measures.

These results are based on children who were suspected of having LDs. It is possible entrainment was atypical. Less entrainment could mean less effort was required.

- Greater coherence in the theta band predicted greater nonword repetition.

This finding provides further evidence that theta coherence is critical for speech intelligibility (Ding & Simon, 2014).

- Greater coherence in the alpha band, also related to syllable processing, predicted greater performance on phonemic decoding efficiency.

This finding provides further evidence that alpha synchronization is related to phonological skills, at least in normal readers (De Vos et al., 2017).

- Delta entrainment was not above chance. This band is related to processing non-speech acoustic rhythm (Ding & Simon, 2014). A measure assessing rhythmic tracking may better uncover these abilities.
- Neural entrainment at the beta frequency band did not predict performance on any language and reading measures.
- **Overall, these findings highlight the important role neural entrainment plays in language and reading.**