Development of the Neurocognitive Processes used to Retrieve the Meaning of a Word from its Written Form

Jonah Kember, Department of Child and Youth Studies, Brock University, Dr. Erin Panda

Child and Youth Studies Developmental Neuroscience Lab

Introduction

From 'Learning to Read' to 'Reading to Learn'

- A shift in reading development occurs around the fourth grade when an emphasis is put on higher-order reading skills like comprehension (Coch, 2014)
- For children to successfully navigate this shift, they must be able to automatically and efficiently recognize words and their meanings.
- To ultimately help the many children who struggle with this shift, this study uses electroencelephagrom (EEG) to understand how the neurocognitive processes associated with automatic word recognition (semantic retrieval and integration) develop.

Semantic Priming

- These neurocognitive processes can be measured with semantic priming, where a word that is related in meaning is shown in advance, to facilitate the retrieval of a new word.
- Typical measurement of these processes involves examining EEG in the time-domain (The N400 and P600 Event-Related potentials).
- This study additionally analyzes EEG in the time-frequency domain (Oscillatory Power), which is thought to better represent the brain-waves underlying cognition.

Event-Related Potentials

N400: Retrieval of a word's meaning from memory (Kutas, 2011).

P600: Integration of meaning into context (Delogu, Crocker & Brouwer, 2019).

Oscillatory Power

Theta-Band (4-7 Hz): Lexical-semantic retrieval during language processing (Bastiaansen et al., 2005).

Alpha-Band (8-13 Hz): Retrieval of lexical-semantic content from memory and cognitive inhibition (Klimesch, 2012)

Despite their strength, no studies have used oscillatory power to measure these abilities as they develop.

Hypotheses

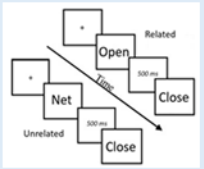
- Unrelated words will show larger N400s and P600s, that will differ as children's reading and language abilities developed. Oscillatory power will provide a more sensitive measure of the neural activity underlying semantic priming.

Participants

16 children aged 7 to 14 participated (9 male). All were right handed and typically developing.

Stimuli

EEG was recorded while children were presented with an explicit semantic priming paradigm, displayed on a monitor. A model of the paradigm can be seen to the right. Children responded with a button click whether they thought the words were related, unrelated, or if they weren't sure.



Measures of Reading and Language Ability

Peabody Picture Vocabulary Test: Receptive vocabulary

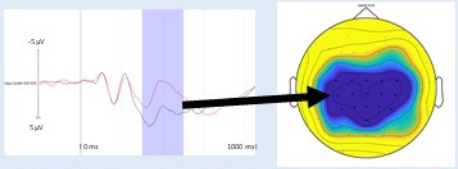
WASI Matrix Reasoning Subtest: Non-verbal abilities, controlled for in correlations.

WASI Vocabulary Subtest: Expressive vocabulary

WJ Word-Letter Identification: Word reading ability

TOWRE: Test of word reading efficiency

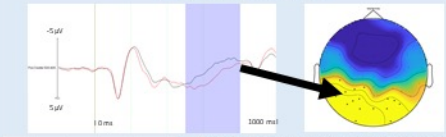
N400 Effect

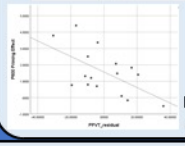


Left: N400 for related (**black**) and unrelated (red) words.

Right: Topographical map of the difference between conditions (Unrelated – Related); p <.001

P600 Effect



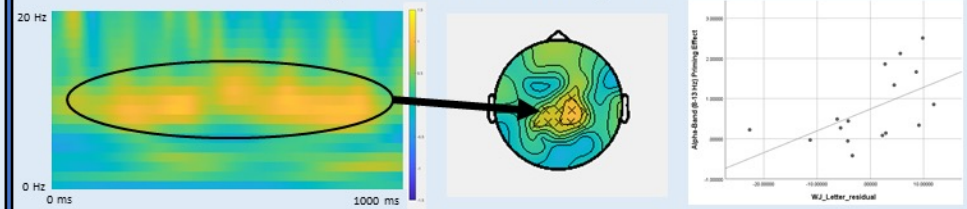


Top Left: P600; Blue: 500-800 ms

Top Right: Map of the difference between conditions (Unrelated – Related)

Bottom Left: P600 priming effect and receptive vocabulary (r=.597, p=.019)

Alpha-Band Priming Effect

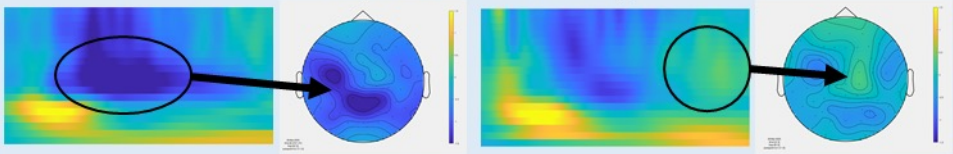


The semantic priming effect, measured as the difference between conditions (Unrelated – Related), was positively correlated with children's word reading ability (r = .557, p = .031)

Alpha-Band Activity

Related

Unrelated



Left: Event-related decrease in power to related words, that became stronger as children's vocabularies developed (r = -.726, p = .002) **Right:** Event related increase in power to unrelated words.

These provide an extended look at the priming effect. Unexpectedly, theta activity (4-7 Hz; seen here as early positive activity) showed no significant difference between conditions)

Methods

- Continuous EEG was acquired with a 64-channel Neuroscan Amplifier at 1000 Hz.
- Low-pass filter at 40 Hz for ERPs, 90 Hz for power
- Channels referenced to an average
- ERPs averaged relative to a 100ms baseline
- ICA to remove eye blinks; Artifacts rejected at a threshold of +/- 100 mV
- Power calculated using complex Morlet wavelets (5 cycle width, 3 SD Gaussian time window function) relative to a -300-500ms baseline
- Cluster based permutation tests used for effects

Discussion

ERPs

- N400 and P600 effect both indexed processes that became more efficient as children's language developed.
- Neither ERP effects revealed relationships with reading.
- Oscillatory power may be a more sensitive measure of the neurocognitive activity involved with reading.

Oscillatory Power

- Alpha-Band activity showed an extended semantic priming effect that became stronger with reading development
- Early alpha-activity likely reflects lexical-semantic retrieval, and may be sensitive to the maturation that occurs during this period, like synaptic pruning.
- Later alpha activity could be indexing the inhibition of task irrelevant cortical areas when integrating meaning into context.
- Activity in the Alpha-Band (8-13 Hz) plays an important role in semantic priming and the development of children's ability to read words.

Future Research

- These results help us understand the role of oscillatory activity at the local level. Future research should examine how these oscillations synchronize to create neural networks.
- An understanding of the neural networks involved with reading could be crucial to understanding the altered neural networks of children with reading disabilities.