ERP Mismatch Negativity Predicts Reading Fluency in Young Children

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Background

- The mismatch negativity (MMN) is a pre-attentive electrophysiological response to a deviant item within a series of identical auditory stimuli, such as tones or syllables[1]
- Attenuated MMN response has been associated with dyslexia[2], an unexpected difficulty with reading that affects about 10% of children[3]
  - MMN differs in pre-reading children with vs. without a family history of dyslexia[4,5]
  - MMN responses predict later reading fluency better than behavioral measures of reading and language[6]
  - Attenuated MMN in children with dyslexia associated with rare genetic variants[7] in the region of dyslexia candidate genes on chromosome 6
- The Double Deficit Hypothesis suggests that either of two core deficits can cause developmental dyslexia: phonological awareness and processes underlying rapid automatized naming.[8] A lack of automaticity at the lower levels of reading impedes accuracy and fluency at higher levels.

Research Question

- Is the MMN response to speech syllables related to accuracy or fluency of reading-related skills at the sub-word, word, and connected text level in young children?

Methods

- Participants: 16 children (ages 4 - 11; *M*= 8:1, *SD* = 2:3), 9 females; 2 pre-readers
  - Native English speakers, typical language, hearing, and at least average IQ (KBIT Matrices Standard Score *M* = 110.5, *SD* = 12.7, range 92-132)

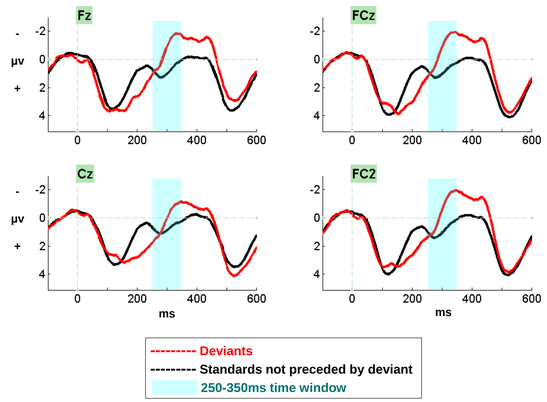
Level	Accuracy Measures	Raw Score Mean (SD)	Stand. Score Mean (SD)	SS Range
Sub-Word	**Comprehensive Test of Phonological Processing (CTOPP)** Phono. Awareness Composite (Elision, Blending, Nonword Rep)	37.0 (8.8)	105.2 (12.4)	85-121
Word	**Woodcock Reading Mastery Test (WRMT-R NU)** Word ID	56.9 (27.0)	113.7 (22.4)	83-175
Text	**Woodcock Reading Mastery Test (WRMT-R NU)** Passage Comprehension (n=14)	37.4 (10.7)	118.3 (19.0)	98-175
	Fluency Measures			
Sub-Word	**RAN/RAS Tests (Wolf & Denckla)** Rapid Letter Naming	36.7 (17.2)	100.2 (14.7)	76-126
Word	**Test of Word Reading Efficiency (TOWRE)** Total (Sight Word & Phonemic Decoding) (n=14)	85.5 (40.2)	110.2 (20.9)	70-150
Text	**Woodcock-Johnson Tests of Achievement (WJ-III)** Reading Fluency (n=14)	38.6 (21.2)	117.1 (21.3)	90-162

- Procedure: 64-channel EEG recording with Biosemi ActiveTwo system. Children watched a soundless movie while hearing stimuli through earphones (20 min).
- Stimuli: Natural speech "ba" and "da", 3000 Trials, 90% standards, 10% deviants
  - Group A: all "ba" standards, "da" deviants (*n*=8)
  - Group B: within-subject counterbalanced standard/deviant (*n*=8)
  - No group differences in standard scores or amplitudes (2-tailed t-tests, *p*>0.05)

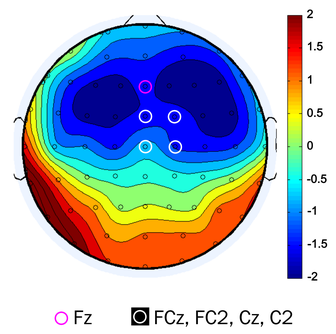
EEG/ERP Analysis

- EEGlab/ERPlab software in Matlab
- Filtering (band pass 0.1 Hz - 30.0 Hz)
- Average reference (excluding eye channels)
- Artifact rejection to exclude blinks and movement artifacts (moving window peak-to-peak threshold 100-150μV)
- Calculated difference wave = (deviants) – (standard not preceded by deviant)
- Measured mean amplitude of MMN response over 250-350 ms window

Group Waveforms



Group Voltage Map



MMN localized over right/frontal areas

Results - Correlations with Behavioral Measures

- Correlations for mean of group of electrodes in center of Frontal Midline/Right region of strongest MMN voltage (FCz, FC2, Cz, C2) and electrode site Fz, used in previous studies[4,6]

	Accuracy Measures – Raw Scores	FCz,FC2,Cz,C2	Fz
Sub-Word	**CTOPP Phonological Awareness** Composite	-.18	-.02
Word	**WRMT-R** Word ID	-.38	-.46
Text	**WRMT-R** Passage Comprehension⁺	-.26	-.04
	Fluency Measures – Raw Scores		
Sub-Word	**RAN/RAS** Rapid Letter Naming (latency)	.70**	.49
Word	**TOWRE** Total Sight Word & Phonemic Decoding Efficiency⁺	-.65**	-.52*
Text	**WJ-III** Reading Fluency⁺	-.60*	-.40

Correlations are Pearson's r, two-tailed; * *p*<.05; **p<.01; ⁺ For reading measures, *n*=14

- Greater (more negative) MMN amplitude associated with faster latencies for RAN letters, and higher reading scores on TOWRE and WJ-III. MMN not significantly related to accuracy measures.

Discussion

- Greater mean amplitude of MMN response is associated with fluency at the sub-word, word, and connected text levels, though not with accuracy measures at any of these levels in a heterogeneous sample of young children
- Attenuated MMN may reflect a lack of automaticity for linguisitic/auditory processing, rather deviant auditory processing per se
- The MMN response to deviant stimuli might reflect automaticity of processing that is required for fluent reading

Implications

- Implications for the identification of reading disability:
  - These findings support the notion that cognitive neuroscience techniques could be useful in efforts to identify children who will have reading difficulties, especially in the crucial domain of fluency, which is often overlooked in assessments of reading ability
  - MMN may provide an index of future reading ability well before beginning reading acquisition
  - Biological basis of fluency has been less-studied and is often excluded from reading studies
- Future directions
  - Prospective longitudinal study; Do EEG MMN and fMRI/MRI predict 2nd grade reading outcomes of 5-year-old pre-readers better than behavioral measures?

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