Auditory Sensory Memory and Language Development in 2 to 5 Year Olds

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Introduction

- Language delays are a risk factor for language disorders such as Specific Language Impairment (SLI).[1]
- Auditory short term memory deficits have been shown to be a predictor of language development in children with SLI. [2,3]
- The mismatch negativity (MMN) of event-related potentials (ERPs) is thought to represent auditory sensory memory.[4]
- The conventional MMN oddball paradigm is lengthy, especially when testing for several durations of auditory sensory memory and thus, can be prohibitive in studies involving young children who do not tolerate long testing sessions. A time-saving MMN paradigm was developed by collapsing the standard tones into trains allowing for many stimuli to be delivered in a very short time while preserving a 7:1 ratio of standard to deviant tones.[5]
- This time-saving MMN oddball paradigm has been used to investigate auditory sensory memory in young children.[6,7]
  - One study included children ages 2 to 5 years, but did not use the same inter-train interval (ITI) across the ages (2 yr olds received 500 and 1000 ITI or 500 and 2000 ITI, 3 and 4 yr olds received 500 and 2000 ITI, and 5 yr olds received 3000 ITI or 5000 ITI.[6]
  - The other study only included 4 year olds and investigated a 500 ms ITI & 2000 ms ITI.[7]
- Consequently, the same ITIs have not been used in young children across 2 to 5 years of age incorporating a complete within-study design.

Purpose

- To examine the changes in auditory sensory memory measured by MMN elicited using the time-saving oddball paradigm in young children across the ages of 2 to 5 years with all children receiving the same ITIs.
- To determine if MMN in the auditory sensory memory paradigm relates to expressive and receptive language abilities in young children ages 2 to 5 years.

Methods

Participants

- 36 Children out of 40 (18 males) 2 to 5 years of age (M = 43 months, SD = 12.9) completed the study.

Procedures

- Participants were seated quietly in a relaxed position while watching an animated silent video (Shaun the Sheep) during the auditory stimuli presentation.
- Mismatched Negativity Paradigm
  - 4 conditions (different inter-train intervals; ITI) with 700 standard and 100 deviant tones each.
  - Standard tones were 1000 Hz and had a duration of 100 ms.
  - Deviant tones were 1200 Hz and had a duration of 100 ms.
  - Each train contained 4 tones and was led with either a standard or a deviant tone (See Figure 1).
  - 8 blocks of each ITI (500, 1000, 2000, 3000 ms) presented in pseudo random order. A block consisted of 50 trial of the same ITI.

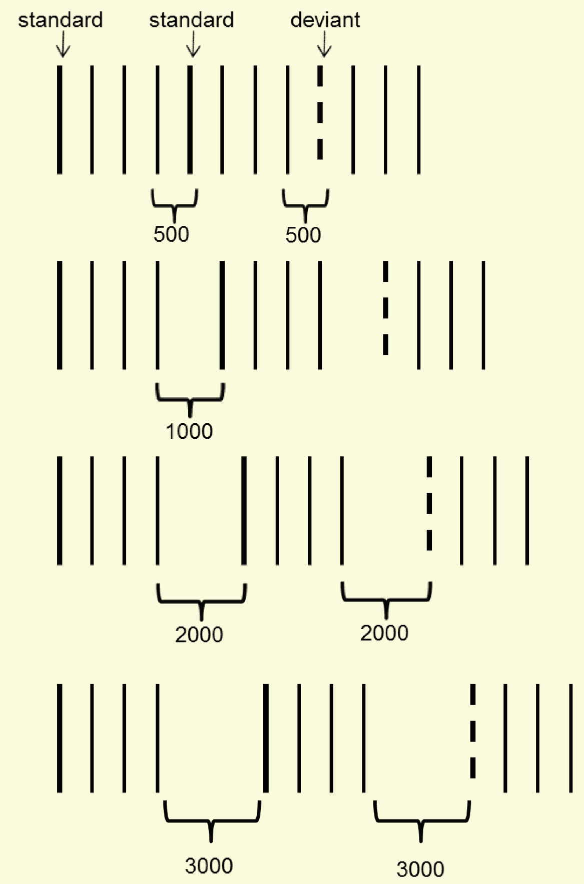

Figure 1. Graphic representation of the auditory trains separated by various ITIs.

Electrophysiological Recordings

- BioSemi EEG ActiveTwo system
- 32 scalp sites, 2 bipolar eye monitors
- Recorded at A-D Rate=1024 Hz,
- Bandwidth=268 Hz, Gain: 1000
- Offline filter .23-20 Hz band pass for scoring MMN
- EOG artifact rejection (+/- 100 µV)
- Only Fz site reported here for ERPs
- MMN scored as average voltage with 210-250 ms window post-stimulus onset

Results

Standard vs Deviant

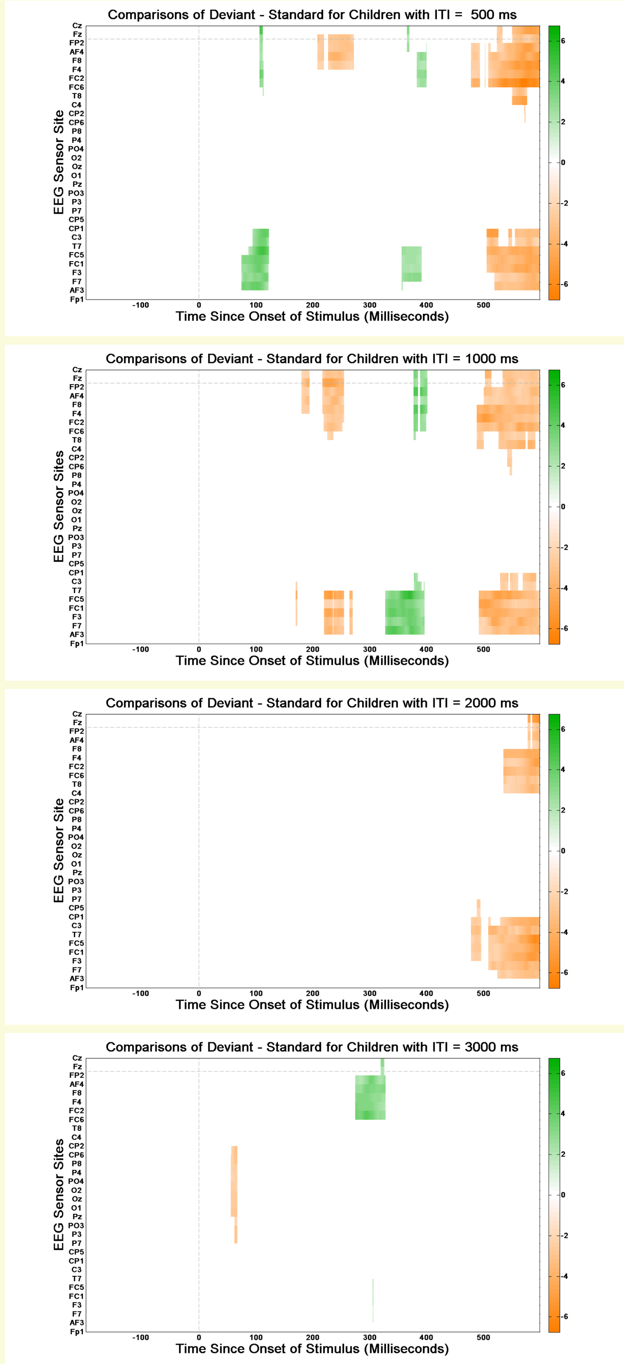

Figure 2. T-Maps for each ITI showing statistically significant differences between standard and deviant by time and scalp site.

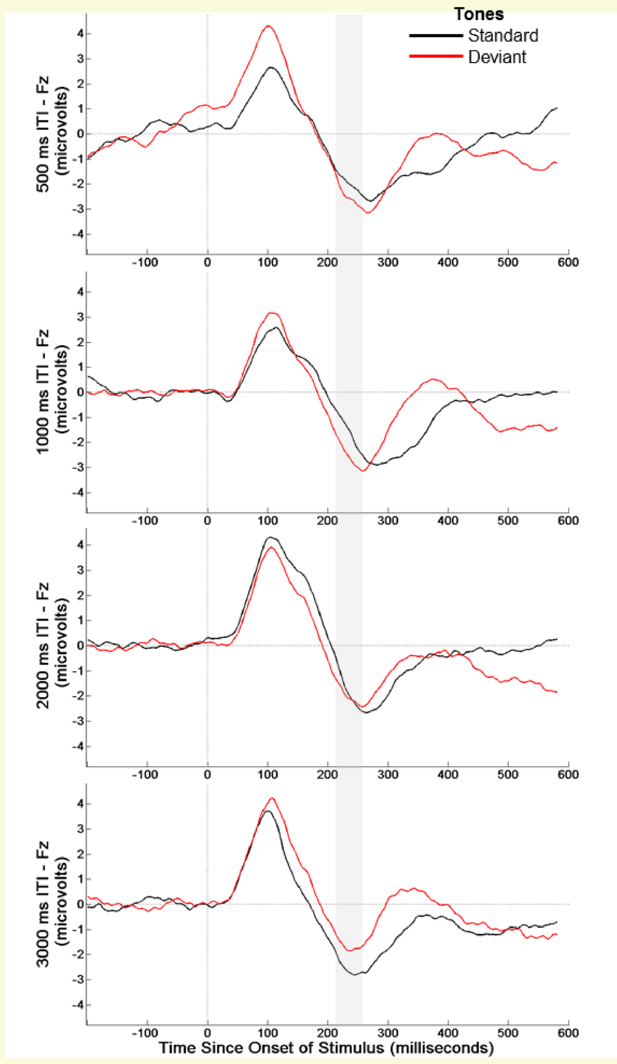

Figure 3. Grand averaged ERPs of Fz for each ITI. Grey area depicts significance shown in T-Maps for 500 & 1000 ITIs.

MMN

- Averaged amplitude of MMN was largest for the 1000 ITI and smallest for the 3000 ITI (see Table 1 and Figure 4)
- Significant Differences were found between ITIs, $F_{(3, 105)} = 3.83$, $p = .012$

Descriptive Statistics

	Mean	Std. Deviation	N
Age (months)	43.08	12.927	36
MMN of 500 ITI	-.2382	2.36891	36
MMN of 1000 ITI	-1.1744	2.44838	36
MMN of 2000 ITI	-.7988	2.56047	36
MMN of 3000 ITI	.6367	2.63713	36

Table 1. Mean amplitudes of ITIs.

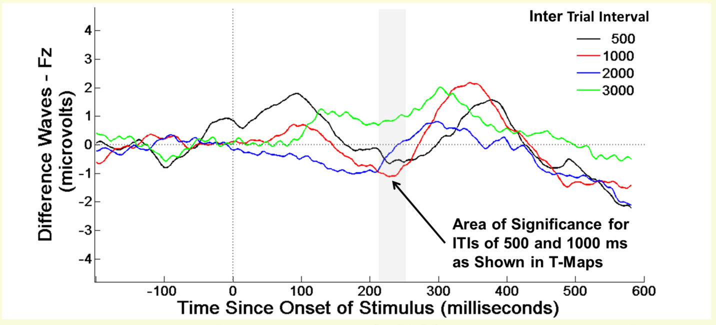

Figure 4. Grand average of difference waves by ITIs.

Relationship Between MMN and Language Measures

- Separate 2-Step Regression Models were used to evaluate the relationship of MMN to language across the developmental period of 2 to 5 years of age
- For Expressive Language:
  - Step 1 revealed that age by itself was a significant predictor of expressive language, $R^2 = .76$, $F_{(1, 33)} = 105.94$, $p < .0005$
  - Step 2 revealed the full model predicts expressive language, R^2 change = .044, $F_{(5, 29)} = 24.24$, $p < .0005$
  - Examination of Beta weights reveal only MMN of the 3000 ITI was a significant predictor, $t = 2.16$, $p = .04$ (see Table 2)

Coefficients[a]

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.	Correlations Zero-order	Correlations Partial	Correlations Part
1	(Constant)	-13.945	6.122		-2.278	.029			
	Age (months)	1.392	.135	.873	10.293	.000	.873	.873	.873
2	(Constant)	-12.169	6.352		-1.916	.065			
	Age (months)	1.311	.144	.822	9.129	.000	.873	.861	.745
	MMN of 500 ITI	-.178	.719	-.021	-.248	.806	-.126	-.046	-.020
	MMN of 1000 ITI	-.078	.747	-.009	-.105	.917	.064	-.019	-.009
	MMN of 2000 ITI	-.686	.667	-.086	-1.029	.312	.079	-.188	-.084
	MMN of 3000 ITI	1.593	.739	.205	2.156	.040	.458	.372	.176

a. Dependent Variable: EOWPVT Raw Score

Table 2. Results of Regression Analysis Evaluating Relationship of MMN to Expressive Language.

- For Receptive Language:
  - Step 1 revealed that age by itself was a significant predictor of expressive language, $R^2 = .74$, $F_{(1, 33)} = 90.92$, $p < .0005$
  - Step 2 revealed the full model predicts expressive language, R^2 change = .05, $F_{(5, 29)} = 21.34$, $p < .0005$
  - Examination of Beta weights reveal only MMN of the 1000 ITI was a significant predictor, $t = 2.04$, $p = .05$ (see Table 3)

Coefficients[a]

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.	Correlations Zero-order	Correlations Partial	Correlations Part
1	(Constant)	-3.593	6.128		-.586	.562			
	Age (months)	1.290	.135	.857	9.535	.000	.857	.857	.857
2	(Constant)	-3.744	6.373		-.587	.561			
	Age (months)	1.217	.143	.808	8.515	.000	.857	.845	.731
	MMN of 500 ITI	-1.024	.707	-.126	-1.449	.158	-.211	-.260	-.124
	MMN of 1000 ITI	-1.541	.755	-.192	-2.042	.050	-.094	-.355	-.175
	MMN of 2000 ITI	-.552	.660	-.073	-.836	.410	.100	-.153	-.072
	MMN of 3000 ITI	1.180	.732	.162	1.612	.118	.352	.287	.138

a. Dependent Variable: ROWPVT Raw Score

Table 3. Results of Regression Analysis Evaluating Relationship of MMN to Receptive Language.

Conclusions

- The T-Maps indicate that for children ages 2 to 5 years of age there is a significant difference between the standard and deviant for 500 ITI and 1000 ITI, but not for 2000 or 3000 ITI.
- The MMN amplitude was largest for 1000 ITI, in this study. Notably the MMN amplitude for the 500 ITI was smaller than the 1000 ITI and 2000 ITI. According to other studies,6,7 we predicted that the MMN amplitude would be largest for the 500 ITI for young children. This suggests that the MMN amplitude for the 500 ITI may reflect involvement of a different neuro-mechanism.
- As expected age was a significant predictor of both expressive and receptive language measures.
- The MMN of the 3000 ITI condition was a significant predictor for expressive language. However, the relationship is opposite of what we predicted. These data revealed that children with smaller MMN amplitudes during the 3000 ITI condition had better expressive language.
- The MMN of the 1000 ITI condition was a significant predictor for receptive language. In this case, the relationship was as expected. Children with larger MMN amplitudes during the 1000 ITI condition had better receptive language scores.
- Most interesting is the age relationship with MMN amplitude at the 3000 ITI. The two-year olds had larger MMN amplitudes than the five-year olds. This is converse of what is expected based on previous research. [6,7]

References

1. Rescorla, L., Roberts, J. & Dahlsgaard, K. (1997). Late talkers at 2: Outcome at age 3. Journal of Speech & Hearing, 40(3), 556-566.
2. Botting, N., Faragher, B., Simkin, Z., Knox, E. & Conti-Ramsden, G. (2001). Predicting pathways of specific language impairment: What differentiates good and poor out-come? Journal of Child Psychology and Psychiatry, 42, 1013-1020.
3. Conti-Ramsden, G. & Hesketh, A. (2003). Risk markers for SLI: A study of young language-learning children. International Journal of Language and Communication Disorders, 38, 251-263.
4. Näätänen R (2003) Mismatch negativity: clinical research and possible applications. International Journal of Psychophysiology, 48, 179-188.
5. Grau, C., Escera, C., Yago, E., & Polo, M. D. (1998). Mismatch negativity and auditory sensory m memory evaluation: a new faster paradigm. Cognitive Neuroscience, 9(11), 2451 – 2456.
6. Glass, E., Sachse, S., & von Suchodoletz, W. (2008). Development of auditory sensory memory from 2 to 6 years. An MMN study. Journal of Neural Transmisssion, 115, 1221–1229.
7. Grossheinrich, N., Kademann, S., Bruder,J., Bartling, J. & von Suchodoletz, W. (2010). Auditory sensory memory and language abilities in former late talkers: A mismatch negativity study. Psychophysiology, 47, 822-830.

Acknowledgements: Funded in part by Office of the Minister of Research, Science and Technology, New Zealand, International Mobility Fund to SS, TK, WG, PD and Occupational Therapy Department, Colorado State University to PD & WG.

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Presented at the 6th Conference on Mismatch Negativity (MMN) and it Clinical and Scientific Application, New York, NY, USA., May 1st – 4th, 2012.