8-2016

Infant Language Assessment Predicts Later Math Disabilities

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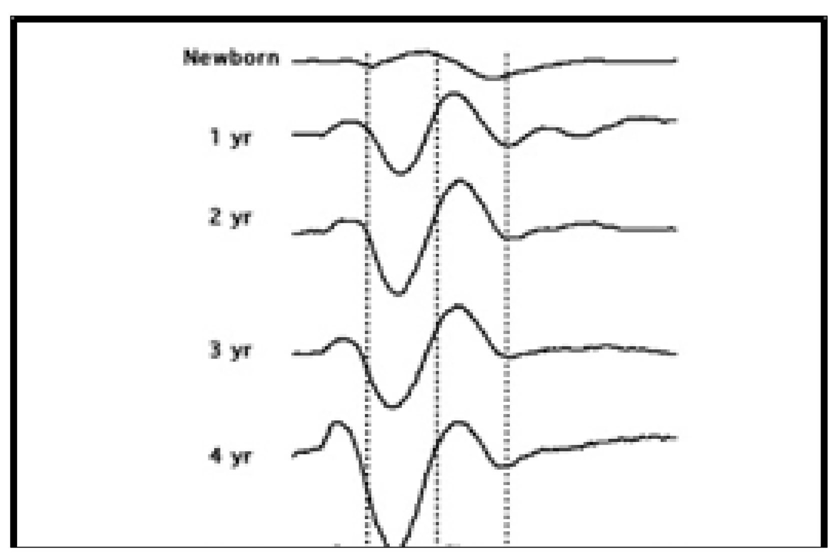
Background and Significance

Prevention of cognitive disabilities currently remains out of reach. Yet, interventions are crucial to maximizing developmental outcomes later in life. To be effective, interventions must occur at the earliest age possible to mitigate potential developmental problems. This study is an attempt to identify newborn infants at-risk for developing math disabilities later in life.

Several studies used assessment tests at relatively late ages in order to predict future cognitive abilities (Aarnoudse-Moens et al., 2013; Kiechl-Kohlendorfer et al., 2013). More recent research used MRI scans of neonate brains to investigate the relationships between academic abilities and preterm births (Ullman et al., 2015). While these studies laid groundwork for prediction models, they primarily focused on physiological and social factors associated with preterm births.

The present research examined possible precursors of math disabilities utilizing event-related potential (ERP) brain wave responses recorded from infants within 36 hours after birth. We hypothesized that infant brain responses to speech and nonspeech stimuli could predict individuals predisposed to developing math difficulties later in life.

Auditory evoked responses to speech and nonspeech stimuli recorded from newborn, 1, 2, 3, and 4 years of age.



Methods

Auditory stimulus was presented to 84 infants within 36 hours after birth. Auditory event-related potential (ERP) brain responses to stimuli were recorded from six electrode sites. Two electrodes were placed on left and right frontal (F_3, F_4), left and right temporal (T_3, T_4), and left and right parietal (P_3, P_4), and referred to linked ears (A_1, A_2). Two electrodes were placed supraorbital and canthal of the left eye to monitor eye movements and muscle artifacts. Mean electrode impedances were 1.5 kOhms before and after the test sessions. All electrode impedances were within 1 kOhm of each other.

Stimuli consisted of two computer-synthesized, consonant-vowel speech syllables (/ba/, /ga/), each composed of three formants with bandwidths of 60, 90, and 120 Hz (formant 1, 2, and 3 respectively). An additional two nonspeech analogs were used as control, each composed of three sine waves matched to the center frequency for each of the three formants of the speech syllables with 1 Hz bandwidth.

Methods (Continued)

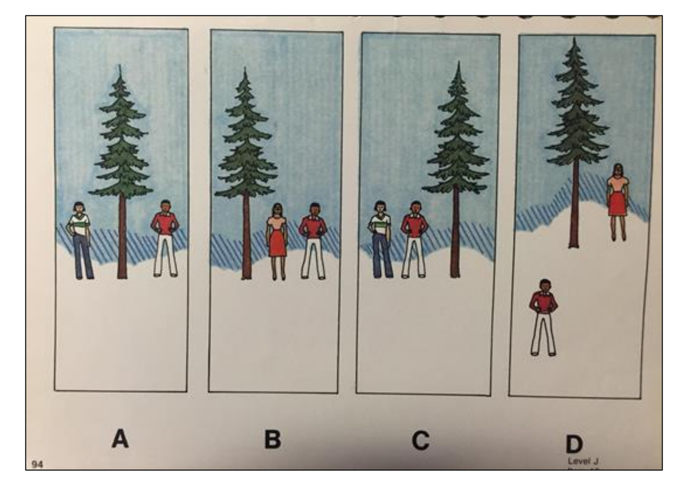
Each stimulus contained an initial 50-ms rapid-frequency transition followed by three steady state formants lasting 250 ms in duration. Rise and decay times were matched at 4 ms across stimuli. All stimuli were identical in peak intensity and duration.

Stimuli were presented using an 8-Ohm speaker positioned 1 m above the infant's head and equidistant from each ear. Intensity of stimuli was 80 dB SPL(A) as measured at the infant's ear. EEG activity and behavioral state were monitored throughout the testing session and were used to determine when stimuli were presented to the infant. Infants were presented information only during quiet, awake states as determined by both behavioral and EEG indices.

Results were used to identify predictors of the infants' math abilities through a quantitative reasoning test of the Stanford-Binet math subset administered at four years of age.

Example Stanford-Binet Quantitative Test Items

"Two children are playing ball. Another child comes to play with them. How many children will there be then?"



"Point to the picture that shows the girl standing between the tree and the boy."

Results

The averaged ERP amplitude and latency for N1, N2, and P2 peaks for each stimulus and each infant were analyzed using regression procedure in which the speech stimuli were used to predict quantitative performance as measured on the Stanford-Binet at four years of age. ERPs to five stimuli produced an r^2 of 0.332 in predicting performance. These predictors are displayed in the model summary of Table 1. The results of the ANOVA for each predictor are presented in Table 2.

Table 1

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics: R Square Change	F Change	df1	df2	Sig. F Change	Selection Criteria: Akaike Information Criterion	Amemiya Prediction Criterion	Mallows' Prediction Criterion	Schwarz Bayesian Criterion
1	.302[a]	.091	.080	12.334	.091	8.230	1	82	.005	424.050	.953	.	428.912
2	.377[b]	.142	.121	12.055	.051	4.840	1	81	.031	421.176	.921	.	428.468
3	.434[c]	.189	.158	11.798	.046	4.568	1	80	.036	418.511	.892	.	428.234
4	.485[d]	.235	.196	11.531	.046	4.748	1	79	.032	415.608	.862	.	427.763
5	.529[e]	.280	.233	11.259	.045	4.859	1	78	.030	412.532	.831	.	427.117
6	.576[f]	.332	.280	10.911	.053	6.063	1	77	.016	408.165	.789	.	425.181

a. Predictors: (Constant), N2 Latency Bsp 0 yr
b. Predictors: (Constant), N2 Latency Bsp 0 yr, N2 Latency Bnsp 0 yr
c. Predictors: (Constant), N2 Latency Bsp 0 yr, N2 Latency Bnsp 0 yr, N1 Latency Gnsp PL 0 yr
d. Predictors: (Constant), N2 Latency Bsp 0 yr, N2 Latency Bnsp 0 yr, N1 Latency Gnsp PL 0 yr, N2 Amp Gsp T3 0 yr
e. Predictors: (Constant), N2 Latency Bsp 0 yr, N2 Latency Bnsp 0 yr, N1 Latency Gnsp PL 0 yr, N2 Amp Gsp T3 0 yr, P2 Latency Gnsp T3 0 yr
f. Predictors: (Constant), N2 Latency Bsp 0 yr, N2 Latency Bnsp 0 yr, N1 Latency Gnsp PL 0 yr, N2 Amp Gsp T3 0 yr, P2 Latency Gnsp T3 0 yr, P2 Amp Gsp LF 0 yr

Table 2

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	1252.044	1	1252.044	8.230	.005[b]
	Residual	12474.195	82	152.124		
	Total	13726.238	83			
2	Regression	1955.360	2	977.680	6.728	.002[c]
	Residual	11770.878	81	145.319		
	Total	13726.238	83			
3	Regression	2591.235	3	863.745	6.206	.001[d]
	Residual	11135.003	80	139.188		
	Total	13726.238	83			
4	Regression	3222.472	4	805.618	6.059	.000[e]
	Residual	10503.766	79	132.959		
	Total	13726.238	83			
5	Regression	3838.465	5	767.693	6.056	.000[f]
	Residual	9887.773	78	126.766		
	Total	13726.238	83			
6	Regression	4560.181	6	760.030	6.385	.000[g]
	Residual	9166.057	77	119.040		
	Total	13726.238	83			

Discussion

The present findings suggest that early auditory discrimination abilities may relate to later emerging quantitative skills by four years of age. This pattern of responding suggests that those with better quantitative skills later in life show more advanced nervous system development at birth, which could allow for finer auditory distinctions. The present study, while showing a definite relationship between brain responses shortly after birth and differences in quantitative skills at four years of age, does not necessarily mean acoustic discrimination, per se, is critical for subsequent skill development. However, it does suggest some relationship exists between early auditory discrimination skills and the emergence of some aspects of later emerging cognitive development.

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Acknowledgments

A special thanks to these grants - NIH R01 HD073202 and NIH R01 HT17860 to D. L. Molfese and V. J. Molfese.