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Influence of Environment on Speech–Sound Discrimination: Findings From a Longitudinal Study

Dennis L. Molfese
Department of Psychological and Brain Sciences
University of Louisville

Victoria J. Molfese
Center for Research in Early Childhood
University of Louisville

Alexandra Fonaryova Key
Department of Psychological Brain Sciences
University of Louisville

Spencer D. Kelly
Department of Psychology/Neuroscience Program
Colgate University

Event-related potentials (ERPs) from 134 children were obtained at 3 and 8 years of age and recorded to a series of consonant-vowel speech syllables and their non-speech analogues. The HOME inventory was administered to these same children at 3 and 8 years of age and the sample was divided into 2 groups (low vs. high) based on their HOME scores. Discriminant functions analyses using ERP responses to speech and non-speech analogues successfully classified HOME scores obtained at 3 and 8 years of age and discriminated between children who received low vs. high levels of stimulation for language and reading.

Requests for reprints should be sent to Dennis L. Molfese, Department of Psychological and Brain Sciences, 315 Life Sciences, Belknap Campus, University of Louisville, Louisville, KY 40292. E-mail: dmolfese@louisville.edu

There is compelling evidence that the child's environment plays a very important role in the development of cognitive skills. Studies of both normal and "at risk" children provide evidence of strong correlations between the types and amounts of activities in the child's environment (e.g., family activities involving the child, books and toys for learning, opportunities for parent–child interactions) and performance on cognitive assessments in infancy and childhood (e.g., Aylward, 1997; Bee et al., 1982; Bradley et al., 1993; Longstreth et al., 1981; V. Molfese, DiLalla, & Bunce, 1997; Sameroff, Seifer, Barocas, Zax, & Greenspan, 1987; Wallace, Escalona, McCarton-Daum, & Vaughan, 1982; Yeates, MacPhee, Campbell, & Ramey, 1983). Although the effects of social and environmental variables have been theorized to vary according to how directly the child is affected, with proximal variables directly affecting the child (e.g., number of books and magazines in the home) and distal variables less directly affecting the child (e.g., parental education, occupation, and intelligence, and family income), both proximal and distal variables clearly have some influence on cognitive development. It has also been theorized that the effects of the home environment decline across the childhood period as the number of environments children are exposed to increases, with socioeconomic status (SES) variables increasing in influence on older children. However, results have been mixed (Bradley, 1993; Bradley et al., 1989; Gottfried & Gottfried, 1984; Schaimberg & Lee, 1991; Wilson, 1985). Some studies have found that the influence of the home environment remains constant or increases from preschool through the early primary grades (Bee et al., 1982; V. Molfese et al., 1997; Yeates et al., 1983), and others have reported that SES has a strong influence on the development of cognitive abilities from early childhood onward (Espy, Molfese, & DiLalla, 2001). However, these studies all contribute to the accumulating evidence in support of the influence of both home environment and family SES on the development of skills in childhood.

The dynamics in the child's environment seem to have a broad-based influence on the development of cognitive abilities. Researchers have reported that children develop larger vocabularies, better reasoning skills, and more advanced reading abilities in environments where conversational skills are encouraged and children are engaged in regular reading times (Lonigan, Anthony, Bloomfield, Dyer, & Samwel, 1999; Share, Jorm, Maclean, Matthews, & Waterman, 1983). Hess, Halloway, Dickson, and Prince (1984) reported that specific maternal behaviors (e.g., expectancies, communication style, parenting practices, and affect) during the preschool period influence both school readiness at 5 and 6 years of age and subsequent achievement in the sixth grade. Dickinson and Tabors (1991) reported that home reading activities and language experiences of preschool children are related to verbal skills and literacy-related knowledge (e.g., print knowledge and narrative skills). Children's home experiences that expose them to print do relate to early word-reading skills (Baker, Fernandez-Fein, Scher, & Williams, 1998). Other researchers have reported that measures of the home environment relate to reading achievement scores in children up to 11 years of age (Bradley, Caldwell, Rock, Hamrick, & Harris, 1988; Dubow & Ippolito, 1994), with higher scores on home environment measures related to higher achievement test scores. The influence of early literacy experiences in the home has been reported to be especially important for children from low-SES homes (Catts & Kamhi, 1998). Thus, activities in home environment interact with parenting practices, and these variables are influenced by a mix of education, health, housing, finances, work, and other resources that characterize families.

Although researchers have studied environmental and social variables that influence general and specific cognitive behaviors for many years, there has been little work conducted to assess the influence of these variables on brain processing. This article reports a preliminary investigation into how the environmental and social variables work to influence not just behavioral development but also brain responses. Event-related potentials (ERPs) were recorded from infants and children at three chronological ages (birth, 3 years, and 8 years) and analyzed to determine whether components of these brain responses relate to differences in child-centered activities and parenting practices in the homes of the participants.

The ERP technique is derived from the electroencephalogram (EEG), in that electrodes are placed on the scalp to allow the brain's electrical activity to be measured. One limitation of the EEG is that because it is continuous, it is difficult to isolate variations in this ongoing brain electrical activity that reflects the effects of specific stimuli or events. ERPs, on the other hand, overcome this limitation, because the focus of analysis is on a small portion (usually about 1 sec) of the ongoing EEG electrical activity that is repeatedly time-locked to the beginning of a stimulus presentation (e.g., sound, picture). The term *time-locking* refers to the fact that the only part of the EEG wave that is analyzed is the portion following the onset of a word, sound, or picture stimulus. The term *repetition* refers to the fact that researchers repeatedly present the same stimulus. The brain's responses to these repeated stimulus presentations are averaged together to remove random and non-stimulus-related background electrical activity that is inherent in the ongoing EEG. Among the many advantages of the ERP technique is its temporal resolution, which enables changes in the processing of a stimulus across the time course of the ERP brain wave to be examined. The ERP technique is also a noninvasive procedure and can be used with virtually identical procedures with participants across the life span. Thus, ERP technology has the potential to provide a powerful tool to study changes in brain–behavior relations and functions across the lifespan.

Research has demonstrated that the ERP technique can effectively study both general and specific aspects of the brain's response to stimuli in the external as well as internal environment (D. Molfese, 1978a, 1978b). For example, the ERP can be used to study an individual's perceptions and decisions during tasks or during a learning situation (D. Molfese, 1983; Nelson & Salapatek, 1986; Ruchkin, Sutton, Munson, Silver, & Macar, 1981), to reflect learning across a brief period of time, such as a 15 min, or during an interactive session lasting 10 min per day for a week (D. Molfese, 1989; D. Molfese & D. Molfese, 1997; D. Molfese, Morse, & Peters, 1990). Because the ERP technique does not require a planned and overt behavioral response from individuals, it is particularly well-suited for the study of early infant and child development. Finally, the ERP has a level of spatial resolution that permits a basis for speculations concerning the distribution of mechanisms across the different brain regions that subserve cognitive functions. Additional information on ERP and other brain response techniques useful for studying cognitive processes is included in D. Molfese, V. Molfese, and Kelley (2001).

Longitudinal studies of brain or behavior in infants and young children have been rare. One such longitudinal study examined the influence of environmental and social variables on cognitive development and included behavioral as well as ERP measures. Social measures included assessments of SES (parental education, occupation, and family income), which were obtained each year, as well as information on parenting practices and family activities, which was obtained from parent interviews and home observations by using the Home Observation for Measurement of the Environment (HOME) Inventory (Caldwell & Bradley, 1978). One analysis of how these environmental and social measures relate to children's performance on intelligence tests was reported by V. Molfese et al. (1997). Preschool measures of the home environment were found to be the single most important predictor of performance on intelligence tests, including verbal subscale scores, at ages 3 through 8 years. SES showed a smaller (but still significant) effect, beginning at age 5 years, over and above the effect of home environment (see Figure 1). In this study, differences were found when the children were grouped as low, medium, and high, using a composite score composed of SES scores plus scores on four subscales from the HOME Inventory (Learning Materials, Stimulation of Communicative Competence, Physical Environment, and Academic Stimulation). Significant differences at 3 through 8 years of age were found between the low and high groups on intelligence test scores and among all three groups from age 5 years through 8 years. For the low-SES/low-HOME group, average IQ scores were low at age 3 and got lower across the study period, unlike the other two groups, whose average IQ scores started higher and remained at a higher level across the study period.

Scores on environment and social measures also have been used to investigate language performance scores of young children. V. Molfese, DiLalla, and Lovelace (1995) investigated the extent to which prediction of preschool language performance of 3- and 4-year-olds could be made using measures of perinatal risk, SES, and home environment. The longitudinal study included 94 children, who had complete data on the variables under study. Performance on the Stanford–Binet Verbal Reasoning subscale was predicted from individual measures of perinatal risk, SES, HOME Inventory, and Bayley (1969) Mental Development Index scores.

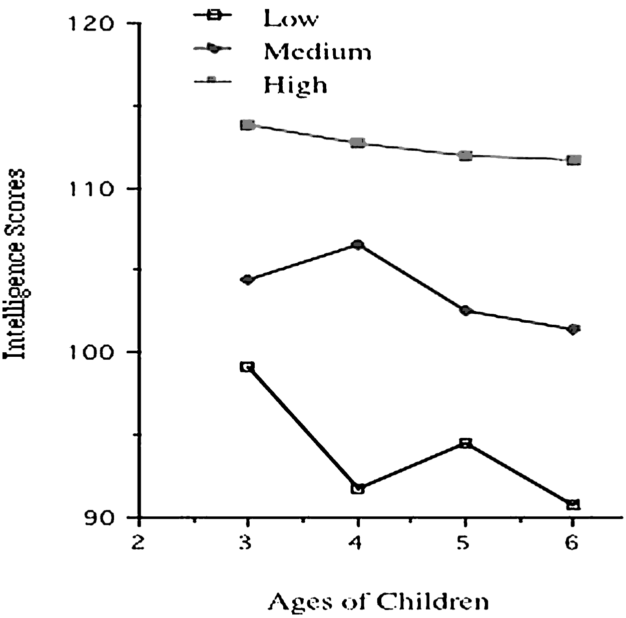

FIGURE 1 Changes in intelligence scores, with age, in three groups categorized by SES and amount of activities in the home.

The best predictors of Stanford–Binet Verbal scores were the child's gestational age at birth, parity (birth order) of the child, and the amount of academic and language stimulation in the home. These four variables accounted for 47% of the total variance. A growth curve study of children from the same longitudinal study was undertaken to determine how environmental measures effect changes from one age to the next in intellectual abilities of individual children. Espy et al. (2001) reported that HOME scores were stable predictors of Stanford–Binet Verbal scores at age 3 years. Changes in verbal abilities between the ages of 3 and 8 years, however, were not found to be related to HOME scores or to SES differences between the children. However, SES was found to be predictive of changes, with age, in nonverbal skills. Children with lower SES scores showed progressively poorer nonverbal skills relative to their higher SES peers. These nonverbal skills (Abstract Visual Reasoning scores) are important for achievement in school and are strongly correlated with verbal abilities. These findings suggest that nonverbal skills represent one potential, but sometimes neglected, component that influences early academic difficulties in children of lower SES. An exclusive focus on the development of verbal- and language-related skills in young children could overlook the importance of also considering nonverbal-skill development.

Activities in the home environment during the preschool period also were examined for their role in the development of reading abilities in the same longitudinal sample (Schaper, Conway, Modglin & Molfese, 2001). This investigation included total scores from the HOME Inventory and a composite score created using the sum of reading-related and speech-related items from the HOME scale. Reading- and speech-related items included activities such as family encouragement for the child to learn patterned speech (songs and rhymes), for the child to read a few words, for conversational opportunities, for the child to learn the alphabet, and so forth. Analyses included total and composite HOME scores when the children were 3 years old, reading scores from the Wide Range Achievement Test (WRAT; Wilkinson, 1993), and school-administered reading achievement scores obtained when the children were 8 and 9 years of age. Scores were available for 72 children. Measures of the home environment and SES were found to be consistent correlates of reading abilities, with correlations for normal readers ranging between .22 and .44, and for poor/dyslexic readers ranging from .25 to .56. A previous study (V. Molfese, D. Molfese, Modglin, & Schaper, 2000) reported that reading scores of 7- and 8-year-olds were related to measures of home environment but not to SES. Results from both of these studies are consistent with the findings of other researchers in showing that it is activities in the home that are correlated with, as well as predictive of, early reading scores (Lonigan et al., 1999; Share et al., 1983; Stanovich, 1988).

The longitudinal study (Molfese et al., 2000) also included ERP measures of speech sounds to determine how the processing of these sounds related to the development of language and language-related skills, such as reading abilities. The purpose of our study was to determine if differences in the participants' environmental and social experiences are reflected in differences in ERP responses to speech sounds, a basic component in the language acquisition process. We hypothesized that the same types of home activities and parenting practices that influence the development of language and reading behaviors would also influence the processing of speech sounds.

METHODS

Participants

Participants in this longitudinal study included 134 children (ranging in age from birth to 13 years old). Reported here are data obtained at 3 and 8 years of age. Sixty-three of these children were females. Overall HOME scores ranged from 26 to 54 at 3 years of age (M = 45.96; SD = 4.96) and 30 to 59 at 10 years of age (M = 52.8; SD = 4.29). Peabody IQ scores ranged from 64 to 134 at 3 years of age

(*M* = 98.8; *SD* = 16.35), and at 8 years of age WISC full scale IQ scores ranged from 72 to 133 (*M* = 107.16; *SD* = 11.49).

Stimuli

Four computer-generated consonant-vowel syllables were used. These stimuli began with an initial consonant transition that was 50 ms in duration followed by a 250 ms steady-state vowel. Each syllable was composed of three formants and varied in two dimensions (Cutting, 1974). The first dimension involved changes in the second formant transition. An initial up-gliding (i.e., rising) second formant transition characterized the consonant-sound portion of the /bi/ syllable, whereas a falling second formant transition characterized the consonant portion of the /gi/ stimulus. The first and third formants of both consonant sounds contained initial up-gliding components for the two syllables. The second feature, formant bandwidth, distinguished the two speech syllables from the two nonspeech sounds. The speech sound versions (normal speech formant) of the /bi/ and /gi/ sounds were composed of three formants with bandwidths of 60, 90, and 120 Hz for formants 1, 2, and 3, respectively. The three formants of the nonspeech versions (sinewave), on the other hand, all had bandwidths of 1 Hz. Rise and decay times were equivalent across sounds. Twenty-five orderings of the four sounds were digitized and presented through a speaker positioned approximately 1 m over the midline of the participant's head. Stimulus presentation was at 80 dB SPL (A), as measured at the ears, for infants, and 75 dB SPL (A) for the children.

Home Environment Measure

The HOME Inventory was used to obtain information about child-centered activities in the home and parenting practices. The HOME was administered when children were 3 years old, and it involved interview questions that were answered by a parent (usually the mother) as well as observation items related to physical aspects of the home. The Early Childhood HOME (EC HOME) was used with families of 3- to 6-year-old children and consists of 55 items (Caldwell & Bradley, 1978). The scale is composed of 8 subscales: Learning Materials, Stimulation of Communicative Competence, Physical Environment, Warmth and Acceptance, Academic Stimulation, Modeling, Variety in Experience, and Acceptance of Child. The EC HOME total score and a subscale score, composed of the 16 items most related to reading and language activities in the home, were used in the analyses reported later. Reading and Language item numbers used were 7, 8, 9, 10, 12, 13, 14, 15, 16, 27, 28, 29, 34, 37, 41, and 48.

Procedures

The participants were tested at birth and subsequently at or around their birthdays each year. At each testing, a similar ERP procedure was followed. The ERP technique involved placing silver-silver-chloride electrodes at specific scalp locations. ERPs then were recorded to a randomly ordered series of speech and nonspeech sounds. Six electrodes were placed over the left and right sides of each infant's head at the frontal temporal and parietal scalp locations and were referred to linked ear references. These placements included two electrodes placed over the left and right temporal areas, respectively, as specified by the Ten-Twenty System (Jasper, 1958); a third electrode placed at the left frontal area, a point midway between the external meatus of the left ear and Fz; a fourth electrode placed at the right frontal area, a position midway between the right external meatus and Fz; a fifth electrode placed at the left parietal area, a point midway between the left external meatus and Pz; and a sixth electrode placed at the right parietal area, a point on the right side of the head midway between the right ear's external meatus and Pz. Thus, these electrode placements were over the left frontal, temporal, and parietal areas of the brain and the corresponding areas over the right hemisphere. These placements were used to assess left versus right hemisphere responses. (Responses within each hemisphere concerning general language perception areas are commonly thought to be localized to the left temporal and parietal language-receptive regions of the brain as well as to the language production areas of the frontal lobe.) The electrical activity recorded from these scalp electrode positions was referred to electrodes placed on each earlobe and linked together. Additional electrodes at a canthal position and at a supraorbital site relative to the right eye were used to monitor eye artifacts. Electrode impedances were under 5 k ohm, and they did not vary more than 1 k ohm between electrode sites on the scalp or the two ear reference electrodes, according to measurements made before and after the test session.

Infants were tested while in a bassinet reclined at a 40-degree angle throughout the test session. Children were tested while seated. Once all electrodes were in place and the impedances measured, the stimuli were presented while the participant was in a quiet, awake state. Continuous monitoring of the ongoing EEG and electromyographic (EMG) activity, along with behavioral observation, was used to monitor the participant's state and determine when stimulus presentation should occur. During periods of motor activity, stimulus presentation was suspended. Testing was then resumed when motor activity returned to an acceptable level.

The ongoing EEG during the test session was amplified 10,000 times, using modified Tektronix differential amplifiers with the band pass flat between .1 and 30 Hz. These amplified signals were then recorded onto cassette tape using a Vetter C-8 FM tape recorder. The analog FM tapes were then played back off-line and the auditory ERP portions of the EEG signal were digitized using a Macintosh Plus microcomputer and the Evoked Potential Analysis and Collection System©

software package (Molfese, 1988). On each trial an ERP was digitized separately for each electrode site, stimulus event, and infant. Each ERP consisted of 70 data points, sampled at 5-ms intervals and collected sequentially over a 700-ms period beginning at stimulus onset. These digitized values were then stored, and subsequent analyses were performed off-line following completion of the testing session.

Information on family background was provided by the parents, who completed questionnaires while their child participated in the ERP testing. Information was obtained on parental education, occupation, and income. The HOME Inventory was administered during the visit to each child's home; the visit was scheduled within 1 week of the laboratory testing sessions at age 3.

RESULTS

ERP data were obtained for each participant at birth, 3 years, and 8 years. At each age, artifact rejection was carried out on the ERP data from each electrode, so as to eliminate the ERPs contaminated by motor movements and eye artifacts from further analysis. If an artifact (operationally defined as a shift in the voltage level in excess of +/–40 uV) occurred on any one electrode channel during the 65-ms-pre- or 700-ms-post-stimulus periods on any trial, all of the ERPs collected across all of the electrode sites for that trial were discarded from subsequent analyses. This procedure, which was based on the peak-to-peak amplitudes, resulted in rejecting less than 15% of the trials for each infant. Rejection rates were comparable across the four sounds. Following artifact rejection, the single-trial data were then averaged separately for each electrode site and sound. Thus, 24 averages were obtained for each participant at each age and were then analyzed using standard peak amplitude and latency measurements.

Environmental Influences on Brain Responses

Mean scores on the HOME obtained at of age 3 years were used to separate the 134 children with complete data into two groups: 64 children with total scores at or above 47 on the HOME (*high* group) and 70 with scores below 47 (*low* group). A discriminant function using two amplitude and latency measures derived from the ERP, elicited in response to consonant-vowel speech syllables, yielded a single function ($\chi^2 = 14.5$, $df = 2$, $p < .001$) that correctly classified 66% of the children in the *low* group and 66.7% of the children in the *high* group. By age 3 years the amplitude of the P1 (P1 = first large positive peak, *M* latency = 105 ms) waveform appeared larger for the *high* group, whereas the N1-P2 (N1 = first large negative peak, *M* latency = 220 ms; P2 = second large positive peak, *M* latency = 365 ms) complex showed a larger amplitude waveform for the *low* group. Additionally, the amplitude of the P2-N2 (N2 = second large negative peak, *M* latency = 460 ms) complex appeared to be smaller for the *high* than for the *low* group (see Figure 2). Further inspection of the ERP responses of the two groups of children to speech and nonspeech sounds showed similar effects of larger N1-P2 amplitude responses for the *low* group, as illustrated in Figures 2 and 3, for the speech and nonspeech stimuli, respectively. These amplitude differences were particularly evident at frontal electrode sites across both hemispheres. For example, the N1 peak amplitude was clearly smaller for the *high* than for the *low* group in response to all consonant speech sounds at all frontal electrode sites (Figure 3). A similar difference between the groups could be seen at left- and right-hemisphere parietal sites as well. In contrast, this difference was not as notable for the nonspeech sounds (Figure 4), where the effect was most readily seen at right hemisphere temporal and parietal sites.

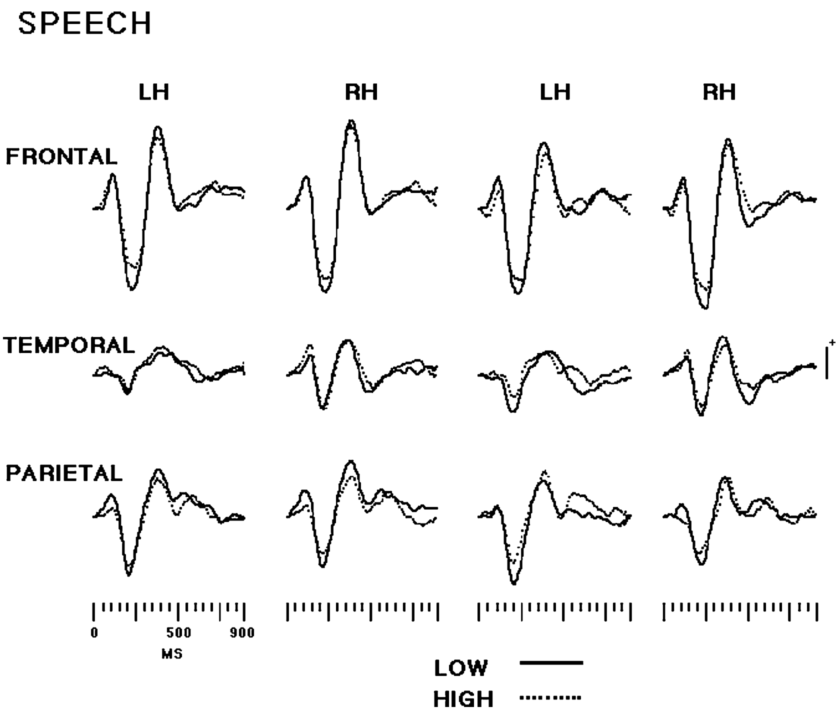

FIGURE 2 Group-averaged ERPs recorded over left hemisphere (LH) and right hemisphere (RH) frontal, temporal, and parietal regions of 3-year-old children. The ERPs were elicited in response to speech syllables. The high-stimulation group (HIGH) had higher HOME scores than the low-stimulation group (LOW). ERP duration is 700 ms. Calibration marker is 2.5 μV with positive polarity up.

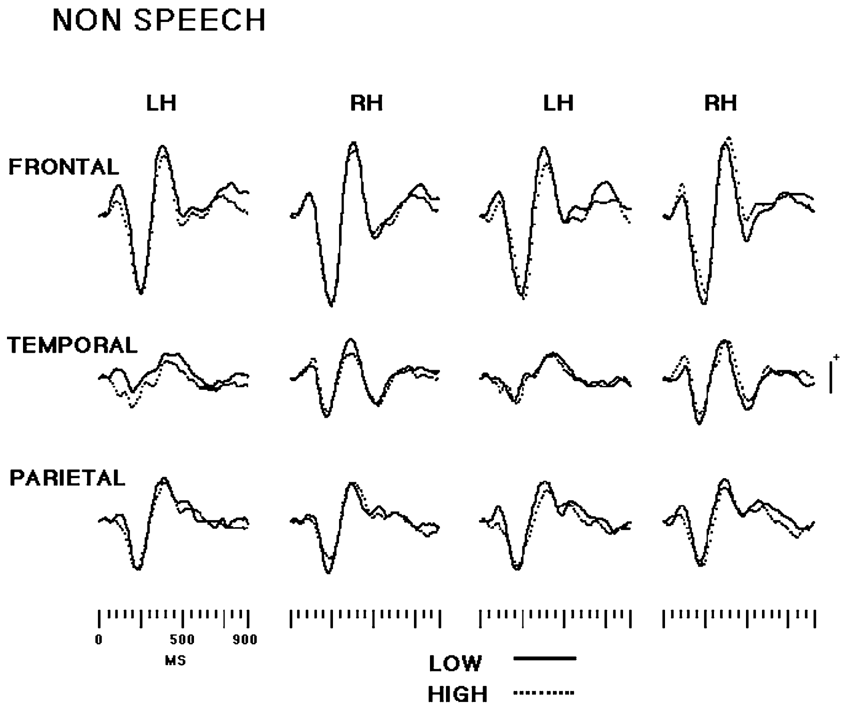

FIGURE 3 Group-averaged ERPs recorded over left hemisphere (LH) and right hemisphere (RH) frontal, temporal, and parietal regions of 3-year-old children. The ERPs were elicited in response to nonspeech analogs of the speech syllables. The high-stimulation group (HIGH) had higher HOME scores than the low-stimulation group (LOW). ERP duration is 700 ms. Calibration marker is 2.5 μV with positive polarity up.

The relationship between ERPs and HOME scores for 8-year-old children was consistent with the earlier findings with the 3-year-old children. A discriminant function yielded an overall classification accuracy level of 78.6%, ($\chi^2 = 27.2$, $df = 5$, $p < .0001$) that classified correctly 77.2% of the children in the *low* group and 81.6% of the children in the *high* group. As suggested by an examination of the ERP waveforms, the best models used a combination of ERPs obtained in response to both speech and nonspeech sounds. As illustrated in Figure 5, there continued to be marked differences in the ERP waveform patterns between the *high* and *low* groups of children. Such differences were notable in the early P1 component whereby the peak amplitude appeared lower for the *high* than for the *low* group. Although some differences could still be noted at N1, more marked differences appeared at subsequent peak latencies that involved P2, N2, and P3. These differences are further illustrated in Figures 6 and 7. The magnitude of the

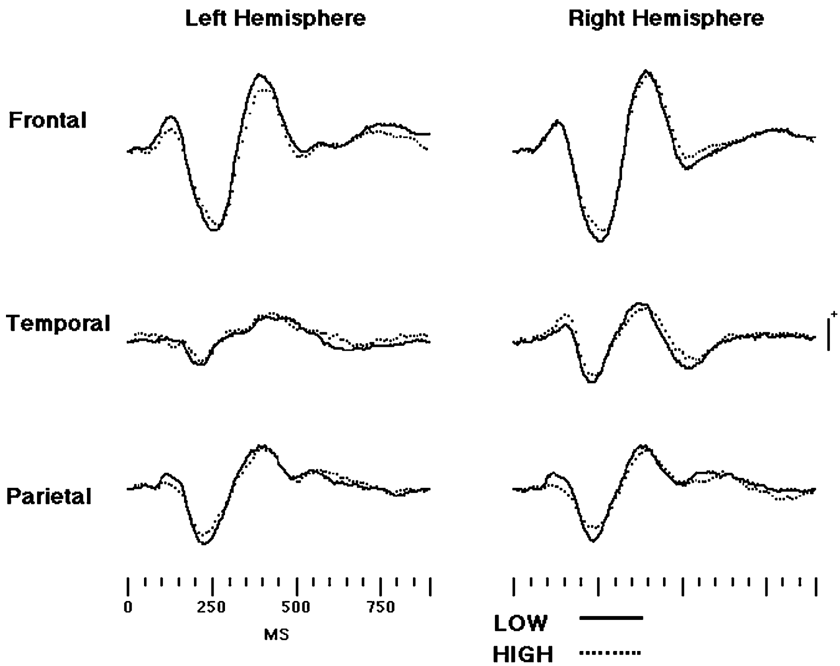

FIGURE 4 Group-averaged ERPs recorded over left and right hemisphere frontal, temporal, and parietal regions of 3-year-old children. The ERPs were averaged across speech syllables and nonspeech analogs. The high-stimulation (HIGH) group had higher HOME scores than the low-stimulation group (LOW). ERP duration is 700 ms. Calibration marker is 2.5 µV with positive polarity up.

peak amplitude differences appeared most marked in this age group. Multiple peak differences appeared throughout the waveforms across electrode sites and across stimulus types (speech and nonspeech).

DISCUSSION

The fundamental model described here is concerned with whether parenting practices and the experiences and opportunities available in the child's environment influence not only the development of behaviors (reflecting cognitive abilities), but also the way the brain processes speech sounds, a component important for language reception and reading. Evidence from our longitudinal study shows group differences in brain responses to speech and nonspeech stimuli. These group differences appear to be related to differences in parenting practices as well as to the type and amount of activities occurring in the child's home.

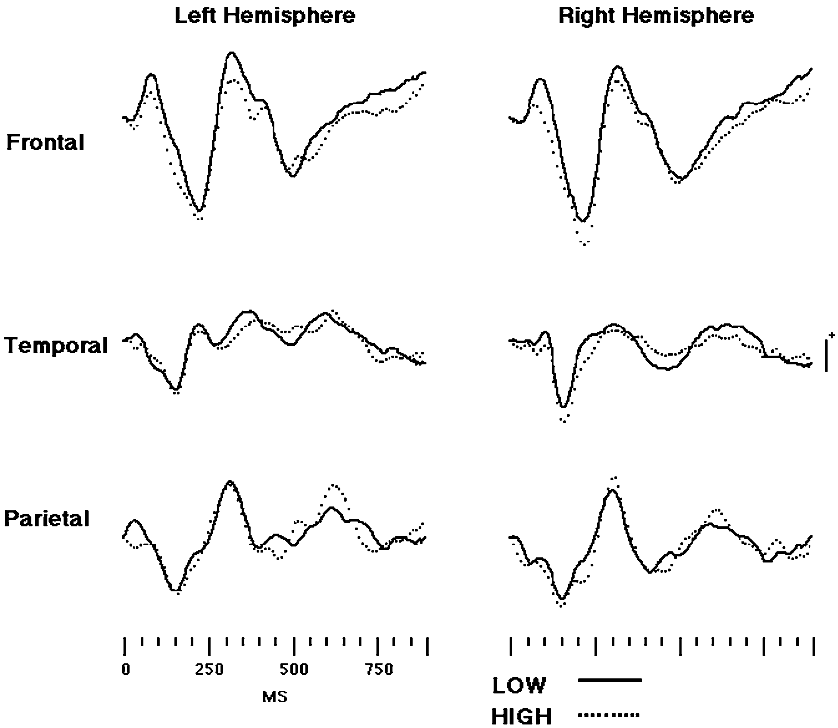

FIGURE 5 Group-averaged ERPs recorded over left and right hemisphere frontal, temporal, and parietal regions of 8-year-old children. The ERPs were averaged across speech syllables and nonspeech analogs. The high-stimulation group (HIGH) had higher HOME scores than the low-stimulation group (LOW). ERP duration is 700 ms. Calibration marker is 2.5 μV with positive polarity up.

There are two important findings. First, although the ERP responses of the 3-year-old children reflect responsiveness to speech and nonspeech sounds, the discriminant differences between the groups were based on responsiveness to the speech sounds and not the nonspeech sounds. For the 8-year-old children, however, both the speech sounds and the nonspeech sounds generated effective discriminant models. These differences among age groups in the ERP responses to speech and nonspeech sounds may reflect continuing developmental changes in speech discrimination abilities. That this might be the case is reflected in the second important finding, differences in the amplitude of the ERP waveforms. For the 3-year-olds and 8-year-olds, the amplitudes of key ERP waveform components were smaller for the group of children receiving high levels of home environment stimulation compared to those for the low-stimulation group. We believe that differences in ERP waveform amplitude reflect processing effort. With

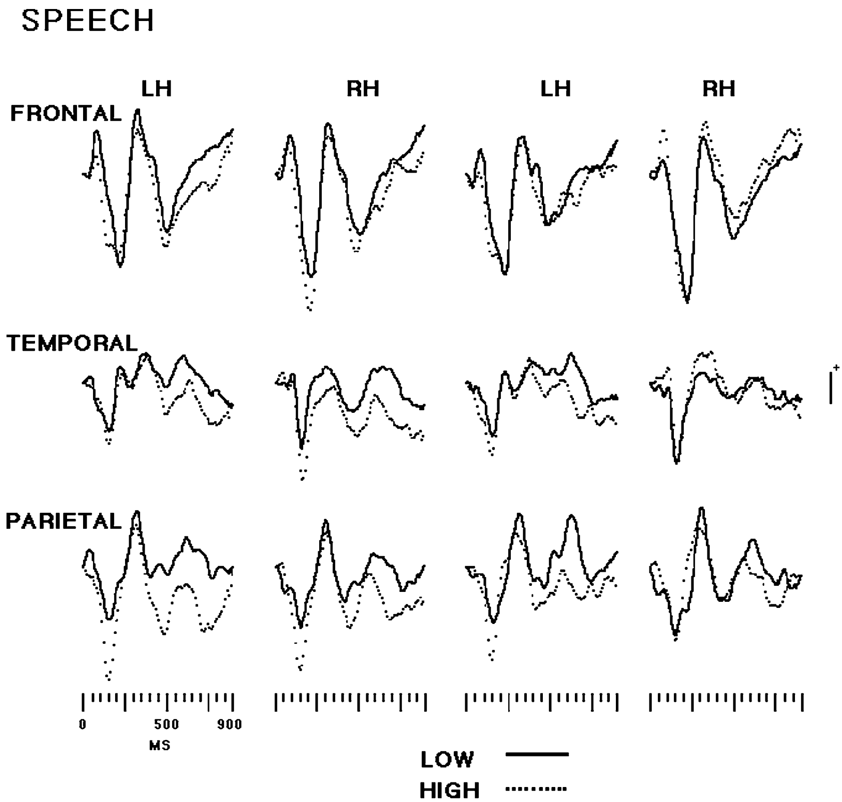

FIGURE 6 Group-averaged ERPs recorded over left hemisphere (LH) and right hemisphere (RH) frontal, temporal, and parietal regions of 8-year-old children. The ERPs were elicited in response to speech syllables. The high-stimulation group (HIGH) had higher HOME scores than the low-stimulation group (LOW). ERP duration is 700 ms. Calibration marker is 2.5 μV with positive polarity up.

age, the brains of the 3- and 8-year-old children should reflect less effort in processing speech and nonspeech sounds, given their more advanced language skills and greater exposure to their language environments. At this point one would expect that speech perception abilities have become more automated and consequently require less effort for the child's brain to process this material. It is noteworthy that this decrease in ERP amplitude is primarily true for children living in stimulating home environments. Perhaps automation of the speech perception process is at a more advanced level in children with more language experience.

Similar group differences in waveform components have been found in children differing in reading abilities (D. Molfese & V. Molfese, 2002), in which

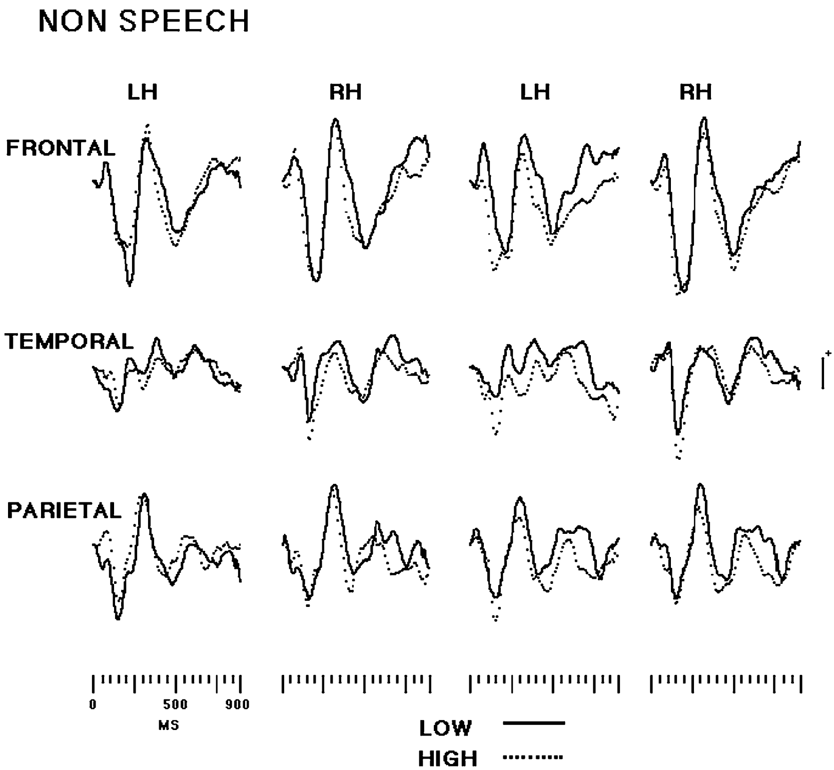

FIGURE 7 Group-averaged ERPs recorded over left hemisphere (LH) and right hemisphere (RH) frontal, temporal, and parietal regions of 8-year-old children. The ERPs were elicited in response to nonspeech analogs of the speech syllables. The high-stimulation group (HIGH) had higher HOME scores than the low-stimulation group (LOW). ERP duration is 700 ms. Calibration marker is 2.5 μV with positive polarity up.

differences in both the latency amplitude of the waveforms were noted between groups of normal-reading versus poor-reading or dyslexic children. In this study, ERP responses were elicited to speech and nonspeech stimuli, and differences between brain waveforms recorded at birth and at 8 years of age were compared. Both the latency differences and the amplitude differences found in this study may reflect differences in processing-time resources assigned to activities such as speech perception. The additional processing-time resources needed by children in the poor- and dyslexic-reading group may mean that these children have fewer processing resources to devote to other aspects of the tasks, compared to normal-reading children. Thus, the processing differences in the ERP responses to speech sounds may influence the development of other abilities that build on speech perception skills, such as language and reading skills.

A similar model may explain the role of the environment in the development of cognitive skills in young children. For children who exhibit early differences in brain responses to speech and nonspeech, the environment may play an important role in enabling these discrimination skills to be used as foundation skills necessary for later language and reading. For children who less readily discriminate between speech and nonspeech sounds, due to either biological differences based in prenatal events or early prenatal experiential differences, the environment may also play an enabling role, although the less-stimulating environments may fall short of what is needed. More research is needed on the role that specific aspects of the environment play in the development of the brain's responsivity to speech stimuli. More research is also needed to determine how experiences in the home and out-of-the-home environments influence the brain's processing skills and cognitive skills.

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