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Honors Thesis

ABSTRACT

The role of biological components as related to language processes has received increased attention in recent years. Evidence from a variety of different methodologies has indicated the presence of early hemisphere differences in young infants. Yet the relationship between such early differences and later language development has remained unclear although several recent reports suggest a marked relationship between the two. The present paper examined the relationship between such lateralized responses in young infants and performance on the Peabody Picture Vocabulary test at three years of age.

A Relationship Between Auditory Evoked Responses To Speech Sounds Recorded At Birth and Vocabulary Size As Measured By The Peabody Picture Vocabulary Test Administered At Three Years Of Age

Recently, there has been much speculation as to the ability of assessment measures to predict later language performance. If an infant's potential for learning language could be measured, then correction of developmental problems could be instigated earlier and, thus, allow an improved chance for success in such endeavors. Many of the behavioral studies to date have used a variety of perinatal measures to predict later langauage development. These measures have included factors such as the prenatal characteristics of the mother, labor and delivery events, the postnatal status of the infant, scores on the Brazelton Neonatal Assessment Scale (Brazelton, 1973), and demographic characteristics. These studies

The influence of perinatal measures on specific types of mental development, such as language performance, has been examined in only a few of studies (Field, Dempsey, & Shuman, 1981; Siegel, 1982; Bee, Barnard, Eyres, Gray, Hammond, Spietz, Snyder, & Clark, 1982). Unfortunately, the accuracy in predicting subsequent development has not been very high. Some of the research has examined development in later infancy (4-18 months) and compared that to language performance at two or three years of age (Siegel, 1981,1982; Nelson, 1973; Ramey, Campbell, & Nicholson, 1973). The results of these studies have been slightly better in predicting later developmental scores. However, replicability of the findings has been

Studies involving evoked brain responses have provided information on the structure and functioning of the brain and development of hemispheric involvement in cognitive and intellectual abilities (for reviews see Calaway, Tueting, & Koslow, 1978; Corballis, 1983; Molfese, 1983; Segalowitz, 1983). Much of this research has focused on the relationship between the brain and language. For example, Molfese and Molfese have provided investigations into the identification of electrophysiological correlates of a variety of speech-perception cues across and within a number of developmental periods. Place of articulation and voice onset time (VOT) are two of the perceptual cues that have been studied using these procedures. Results have shown that brain wave patterns recorded from different areas of the scalp change as a function of place of articulation (Molfese & Molfese, 1979a, 1979b, 1980; Molfese, 1978b, 1980, 1983; Molfese & Schmidt, 1983). In studies involving adults, the early portion of the AER varies reliably between the two hemispheres when discriminating between two different consonants, but a later portion of the AER differentiates only over the left hemisphere. The AERs elicited by speech syllables reliably produce changes in two portions of the waveform in response to different syllables. Initially, as seen in the early portion of the AER waveform, both hemispheres simultaneously discriminate between different consonant sounds. The first consonant discrimination reflected by the AER patterns, then, appears to be bilaterally distributed across the two hemispheres. Approximately 200 msec later in time, however, a second change in the AER waveform occures only over the left hemisphere which again discriminates between the two consonant sounds. VOT, a different speech cue, elicits a similar pattern of early bilateral responses and later lateralized changes in the AER waveforms. However, with the VOT cue the lateralized response occurs over the right hemisphere rather than the left hemisphere (Molfese, 1978b;1980; Molfese & Hess, 1978). Several papers have reported similar findings with infants (Molfese & Molfese, 1979a; 1979b; 1985a). However, the temporal pattern of first bilateral and then lateralized responses is reversed from that found in adults. For example, Molfese and Molfese (1985a) report that initial consonant discrimination occur in the left hemisphere of newborn infants. This inital lateralized response was then followed later in time by a bilateral response which also discriminated between the two consonants. In summary, then, research findings indicate that both young infants as well as adults demonstrate lateralized and bilateral discrimination of place of articulation cues as reflected in different portions of the AERs.

Do these lateralized and bilateral patterns of responses to speech stimuli provide implications for later language performance? Such a hypothesis is conceivable when considering Lenneberg's (1967) idea that lateralization is a biological sign of language. In the first attempt to directly address this question, Molfese and Molfese (1985b) evaluated the predictive validity of demographic variables, behavior scales, and auditory evoked responses for identifying developmental deviations for particular children in language abilities. Of all the measures employed, however, only the perinatal electrophysiological measures appeared to have high predictive accuracy. Infants whose brain responses to speech sounds reflected abilities to discriminate between speech stimuli and in hemispheric responsiveness were the better performers on language test administered at 3 years of age. A regression procedure indicated that the predictive accuracy achieved using the AER factor scores exceeded by far the predictive abilities of other perinatal measures.

In a follow-up study which utilized a different analysis procedure, Molfese & Molfese (1985a) again found that early discrimination abilities were related to later language development. Infants' brain wave responses to speech and nonspeech stimuli were recorded shortly after birth. Three years later the verbal subscale of the McCarthy Scales of Children's Abilities was administered to the children. The auditory evoked responses (AERs) of the children who scored above 50 on the McCarthy scale were able to discriminate between consonants alone and consonants in differing vowel environments, and could also discriminate between variants of the speech and nonspeech stimuli. These children seemed to have more sensitive nervous systems which note finer distinctions and, so, have an advantage in the process of language development.

A study by Molfese & Searock (1986) also examined the correlation between early brain waves and later language performance. Differences in language performance of 3-year-olds were predicted by the infants' brain responses to vowel sounds at one year of age. The brain responses of the infants who three years later would possess more advanced language skills, discriminated between more speech sounds than the brain responses recorded from the children who would later develop weaker language skills. Moreover, the right hemisphere responses possessed a greater advantage in discriminating the vowel sounds than the left hemisphere for children who

Molfese and Molfese (1985a, 1985b) and Molfese & Searock (1986) used the McCarthy's Scales of Children's Abilities to assess later language

Peabody Picture Vocabulary Test (Dunn, 1965) as a measure of later language skill. As in the case of Molfese and Molfese (1985a), auditory evoked responses were recorded at birth and then comparisons were made with the language scores obtained at three years-of-age. Analyses then were employed to assess whether a relationship did exist between the AER measures taken at birth and the PPVT scores obtained 36 months later.

METHODS

Subjects

Sixteen Caucasian infants who were part of a longitudinal sample were selected on the basis of the willingness of their parents to allow them to participate. These infants were tested within the first 36 hours of birth. The specific characteristics of this group include an average birth weight of 3334.68 g (SD = 608.7), a mean gestational age of 38.6 weeks (SD = 1.54 weeks), a mean Obstetrical Complication Scale score (Littman & Parmelee, 1978) of 106.2 (SD = 23.2), and a mean Brazelton Neonatal Assessment Scale (Brazelton, 1973) score of 10.7 (SD = 3.3). All infants were tested on the verbal subtest of the Peabody Picture Vocabulary Test (Dunn, 1965) when they were within one week of their third birthday. The average PPVT score was 51 for the 16 infants. For the 8 infants who scored above 51, the mean score was 74.75 (SD = 18.72), whereas the mean was 27.25 (SD = 20.6) for the 8 infants who scored below 51 on the test. *T*-tests of these characteristics indicated that the groups differed on the PPVT scores, *t*

(14) = 4.83, *p*<.01, but the two groups did not differ statistically on birth weight, gestational age, obstetrical complication, Brazelton scores, Bayley mental scores at 6 months, Bayley mental scores at 12 months, or socioeconomic variables (parental education and occupation, family income level) (all *p*>.05).

Stimuli

The stimuli selected for the present study included the four stimuli from the Molfese and Molfese (1979a) study. These materials had been shown to generate both bilateral and lateralized stimulus related effects as well as the more general hemisphere non-stimulus related effects. In addition, eight related stimulus items were added in order to test the generalizeability of the findings for consonants across different vowel sounds. The entire stimulus set thus consisted of six computer-synthesized, consonant-vowel speech syllables, each composed of three formants with bandwidths of 60, 90, and 120 hz (for formants 1, 2, and 3, respectively), and six nonspeech control stimuli composed of three sine waves matched to the center frequency for each of the three formants of the speech syllables. The stimuli were constructed on the Haskins Laboratories parallel resonance synthesizer by James Cutting (1974). All stimuli contained an initial 50 ms rapid-frequency transition followed by three steady state formants which were 250 ms in duration. Rise and decay times were matched at 4 ms across stimuli. All stimuli were identical in peak intensity and duration. The amplitude relationships among the component tones of the nonspeech stimuli corresponded to the amplitude relationships of the formants in the speech stimuli. The six speech syllables were [bi, bae, bau, gi, gae, gau]. The six speech and six nonspeech stimuli were ordered into 16 different blocked random orders for each infant. These orders were recorded on one channel of a stereo tape using a cassette stereo tape deck (model JVC-2). The interstimulus interval varied randomly from 4 to 8 s in order to reduce expectation and habituation effects. a 16 ms pulse synchronized with the onset of each stimulus was recorded on the second channel of the stereo tape and served as a signal to a PDP 11/34 computer to initiate digitizing of the AER data for each stimulus.

Stimulus Identification Information

The 12 stimuli for this study has been previously tested in an identification task with 10 undergraduate college students. The students listened to 10 repetitions of each stimulus presented in a random order. The speech stimuli were identified correctly 572 of 600 presentations (95.3%). The nonspeech stimuli were identified in terms of the speech stimuli of 68 of 600 trials (11.3%).

Procedures

Infants were tested individually within 36 hours of birth in a room adjoining the hospital newborn nursery. Scalp electrodes were placed at temporal locations over the left (T3) and right (T4) hemispheres and referred to linked ear electrodes (Jasper, 1958). Two additional electrodes were placed on the forehead, one supraorbital and one canthal to the right eye, to monitor eye movements and muscle artifacts. A final electrode was placed on the forehead and served as a ground to the isolation amplifier system. Mean electrode impedances were 1.5 KOhms before testing and 1.5 KOhms after the test session. All electrode impedances were within 1 KOhms of each other. The electrodes were connected to Analogue Devices

Isolation Amplifiers (Model 286J powered by an Analogue Devices Power Supply Model 925) which, in turn, were connected to modified Tektronix Differential Amplifiers (Model AM502) with the bandpass flat between .1 Hz and 30 Hz. Gain settings were at 50,000. AERs elicited by the stimuli were recorded on an FM tape-recorder (Vetter Model C-8) for later off-line data analysis. Amplifier, FM recorder, and computer channels were counterbalanced across subjects. The stimuli were presented to each infant through an 8-Ohm speaker positioned 1 m above the infant's head and equidistant from each ear. Infant EEG activity and behavioral state, monitored throughout the testing session, determined when stimuli were presented to the infant. Stimuli were only presented to the infant during quiet, awake state as determined by both behavioral and EEG indices.

At three years of age, the verbal subscale of the Peabody Picture Vocabulary was administered to the children.

RESULTS

Based on other analyses with a similar age population (Molfese & Molfese, 1979a; 1979b;1985a), 88 data points over a 704 msec period beginning with stimulus onset were selected from each AER for further analyses. This period was selected because most of the synchronized activity of the AER elicited by the speech and nonspeech stimuli had concluded at the end of the 704 msec post-stimulus onset period. Individual auditory evoked responses were digitized at 8 msec intervals for a 704 msec period following stimulus onset. These digitized values were stored on-line during the data recording session by a DEC PDP 11/34 minicomputer. Subsequent analyses were performed off-line after the testing session had been completed. Artifact rejection was carried out on the AER data for each electrode to eliminate from further analyses the AERs contaminated by motor movements. If an artifact occurred on any one electrode channel during the 704 msec post-stimulus period, all of the AERs collected across all of the electrode sites for that trial were discarded from subsequent analyses. Artifact rejection (mean =4.5% of the trials were rejected) based on amplitude limits and signal averaging were carried out off-line after the testing session had been completed. Following artifact rejection, the single trial data were then averaged separately for each electrode site and stimulus condition. In this manner, 384 averaged AERs were obtained for the 16 infants.

The final data set to be used in the subsequent analyses described below consisted of 384 averaged AERs which were each made up of 88 data points beginning at stimulus onset and continuing at 10 msec intervals for 704 msec. For each infant, 24 averages were obtained. These included averages for the six speech and six nonspeech CV syllables for the two

Principal Components Analysis--ANOVA

This analysis sequence followed the procedures outlined and used successfully in previous studies (Brown, Marsh, & Smith, 1979; Chapman, McCrary, Bragdon, & Chapman, 1979; Chapman, McCrary, Chapman, & Martin, 1980; Donchin, Tueting, Ritter, Kutas, & Heffley, 1975; Molfese, 1978a; 1978b; Molfese & Molfese, 1979a; 1979b; 1980; Molfese & Schmidt, 1983;

Ruchkin, Sutton, Munson, Silver, & Macar, 1981; Sutter, 1970). The rationale for the use of this procedure is that it has proven successful in first identifying regions of the AER where most of the variability occurred across AERs and subjects and, second, in then determining if the variability characterized by the different factors were due to systematic changes in the independent variables under investigation. The PCA procedure behaves somewhat similar to a factor analysis with the exception that it constructs the factors on the basis of variances instead of correlations (Rockstroh, Elbert, Birbaumer, & Lutzenberger, 1982, page 63). The PCA procedure itself is blind to individual experimental conditions and generates the same solution regardless of the order in which the AERs are entered. It does, however, assign weights (factor scores) for each individual AER, which directly indicates the extent to which that area of the AER characterized by a single factor increased or decreased in size relative to other AERs at that same latency. These factor scores later serve as the input to an analysis of variance which is used to determine if the regions of variability identified as factors by the PCA did or did not change systematically as a function of some experimental manipulation. Once the PCA identifies where within the AERs most of the variability occurred, the ANOVA is used to identify the cause of this variability. The Analysis of Variance accomplishes this task by determining whether the variability reflected in the factor scores assigned for each factor to each averaged AER differed as a function of changes in the independent variables. This procedure directly addresses the question of whether the AER waveshapes in the region characterized by the most variability for any one factor changed systematically in response to the different stimulus conditions as recorded from the different electrode sites over each hemisphere.

The 384 averaged AERs, each consisting of 88 data points which covered the 704 msec period following stimulus onset, were input to a principal components analysis (PCA) with correlational matrix and employing a varimax rotation procedure (BMDP4M, Dixon, 1981). The time points of each AER waveform between certain latencies (time points or variables) which varied across a number of different cases or AERs served as the variables in the present analysis. Factors meeting the Cattell Scree Test criterion were retained for further analysis (Cattell, 1965). In this manner, six factors accounting for 67.92% of the total variance were identified. These factors were then rotated using the normalized varimax criterion, which improved factor distinction while preserving orthogonality. These six factors and the group-averaged AER (or centriod) are presented in Fig. 1.

INSERT FIGURE 1 ABOUT HERE

The centroid was characterized by a series of waves or components which reached peak amplitudes (either positive or negative) at different times following stimulus onset. These included a positive peak that was reached at 88 ms following stimulus onset (P88), which was followed immediately by a second positive peak at 120 ms (P120). A large negative deflection occurred next which reached its maximum negative point 224 ms after stimulus onset (N224). Positive peaks at 360 ms (P360) and 408 ms (P408) followed. The final portion of the centroid was marked by a N560

72 ms for Factor 1 was the region which the factor analysis identified as varying across a large number of the waveforms collected in this study. This factor accounted for 20.43% of the total variance in this study. Factor 2 (13.91% of the total variance) was marked by a peak latency of 560 ms. A peak latency of 432 ms characterized Factor 3 (12.15% of the total variance) while a latency of 192 ms marked Factor 4 (10.18% of the total variance). Factor 5 (6.22% of the total variance) had a peak latency of 648 ms, and 5.03% of the total variance was attributed to Factor 6 which had a peak latency of 336 ms. The ranges, peak latencies, and total variance accounted for are summarized in Table 1.

INSERT TABLE 1 ABOUT HERE

Independent analyses of variance were performed using the factor scores generated by the PCA analysis for each factor as the dependent variable (BMDP08V,Dixon, 1981). A factor score or weight was derived by the PCA for each averaged AER submitted to the PCA for each factor. In the present study, 384 individual averaged AERs were input to the PCA. Consequently, 384 factor scores were calculated for each of the seven factor scores where each set reflected the contribution of a single factor to the original AERs. Six independent analyses of variance were performed, with one analysis for each factor. The first analysis of variance was conducted on the factor scores for Factor 1, the second for the factor scores of Factor 2, etc. Since the factors derived in the present study were orthogonal, independent analyses of variance for each factor were appropriate. Nevertheless, only effects beyond the $p < .01$ level are reported in this paper in order to further reduce the likelihood of Type I error. Planned and post-hoc analyses all involve the conservative Scheffe procedure.

The analysis of variance design included a single between-subjects measure (with two levels) that was based on a median split which separated the infants who 3 years later scored above 50 on the Peabody Picture Vocabulary Test from those infants who later scored below 50. This factor, then, consisted of a HIGH PPVT group and a LOW PPVT group. The remaining factors of the analysis of variance were repeated measures for the two consonant sounds ([b vs. g]), the two formant structures (speech vs. non-speech), the three vowel sounds ([i, ae, au]), and the two electrode positions (left hemisphere vs. right hemisphere). The effects outlined are reported first as they relate to the group differences and then hemisphere effects.

Group Differences

Two regions of the AER, one at the beginning of the waveform (between 5 and 160 msec) and one at the end of the waveform (between 600 and 700 msec) were found to vary systematically between the LOW and HIGH groups. First, a GROUP X HEMISPHERE, $F(1,14) = 11.33$, $p < .0046$; and a GROUP X FORMANT X VOWEL X HEMISPHERE interaction, $F(2,28) = 5.76$, $p < .0080$

The GROUP X HEMISPHERE interaction indicated that the left hemisphere responses differed between the LOW and HIGH groups, $F(1,14) = 19.39$, $p < .0009$. In addition, hemisphere differences were noted in the AER

The GROUP X FORMANT X VOWEL X HEMISPHERE interaction revealed a number of differences between the two language groups. First, the left hemisphere electrode site of the LOW group discriminated the speech vowel [ae] from [i], F(1,28) = 28.799, p<.0001, and from [au], F(1,28) = 15.33, p<.0008. For the nonspeech sounds, differences were only noted over the right hemisphere electrode sites. Here, the right hemisphere discriminated [ae] from [i], F(1,28) = 8.23, p<.0077, and [au], F(1,28) = 5.60, p<.0237. Second, the pattern of left and right hemisphere discrimination for the HIGH group differed from the LOW group in that only the right hemisphere of the

Several between hemisphere differences were noted for both the LOW and HIGH groups at this latency for specific stimuli. The two hemispheres of the LOW group responded differently to the speech vowel [ae], F(1,28) = 19.35, p<.0003, and the nonspeech equivalent of the vowel [au], F(1,28) =

A GROUP X VOWEL X HEMISPHERE effect was noted for Factor 5, F(2,28) = 5.74, p< .0082, which characterized a region of variability between 600 and 700 msec following stimulus onset. Posthoc tests of this interaction indicated that for the LOW group (1) the left hemisphere responses discriminated [au] from [i], F(1,28) = 12.23, p<.0038, and [ae], F(1,28) = 7.04, p<.0181; (2) and the left and right hemispheres responded

Hemisphere Differences

A Main effect for HEMISPHERES characterized Factor 4, F(1,14) = 8.38, p< .011, and indicated that the AERs recorded from the left and right

DISCUSSION

Based on the analyses presented here, it appears that vocabulary size at three years of age may be related to vowel sound discrimination at birth. Two regions of the newborn brain response, one between 5 and 160 msec, and the other between 600 and 700 msec, varied as a function of the child's vocabulary size three years later. Overall, it appears that children with larger vocabularies later in life show no between hemisphere discrimination

The two groups of children also differed in terms of the hemisphere regions which discriminated between the different vowel sounds. Both the left and right hemisphere AERs of the LOW group discriminated between the different vowel sounds between 5 and 160 msec following stimulus onset. The left hemisphere discriminated between the vowels which were characterized by normal speech formant bandwidths while the right hemisphere discriminated between those with nonspeech formant

These results differ in a number of ways from the results reported earlier by Molfese and Molfese (1985a). They had noted that children with higher performance measures on the language subtest of the McCarthy Test of children's Abilities demonstrated left hemisphere lateralized discrimination of consonant sounds with speech formant structure while the right hemisphere discriminated between the nonspeech controls for these stimuli. In addition, this discrimination between consonant sounds occurred between 88 and 240 msec. Thus, the key stimulus features identified by Molfese and Molfese which discriminated between children with different levels of language performance were consonant sounds. Furthermore, this discrimination occurred later in time than that found for vowel sounds in the present study. One possible reason for such differences could be found in the nature of the language tests themselves. While the Peabody Picture Vocabulary Test provides one measure of the size of a child's vocabulary, the language subtest of the McCarthy test provides a much broader test of language skills -- word knowledge, pictorial memory, opposites analogy, verbal memory, and verbal fluency. Thus, the AER differences between the present study and that of Molfese and Molfese (1985a) could be due to the differences in the language measures used and the relevancy of different types of brain responding to these measures.

As in previous studies, a general hemisphere difference was noted which discriminated between the left and right hemisphere of all of the

In summary, it appears that AER procedures can be used with newborn infants to identify children who three years later may develop larger or smaller vocabularies. As in the case of Molfese and Molfese (1985a), relationships were identified between the ability of the newborn infant's brain response to discriminate between different sounds and the later emergence of language skills.

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APPENDICES

FIGURE 1: The PPMD Centroid + 6 Factor Loadings generated by the Principal Components Analysis (PCA).

C-MAG = 6
F-MAG = .5
H-SCALE = 4

DATE = 05/06/88
TIME = 06:02:42

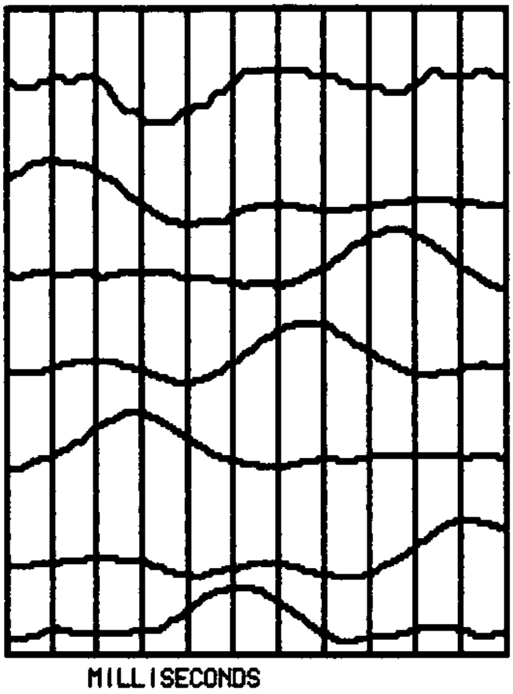

TABLE 1. The range within which the waveform varied, the maximum point of this variability following stimulus onset, and the percentage of variability accounted for by each of the six factors derived by the PCA.

Factor #	Variability Range (in msec)	Peak Latency (in msec)	Percentage of Total Variance
1	5 - 160	72	20.43
2	488 - 624	560	13.91
3	368 - 496	432	12.15
4	128 - 256	192	10.18
5	600 - 700	648	6.23
6	272 - 400	336	5.03