The Role of the Auditory Environment in the Development of Speech Production Abilities During Infancy

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1. The Role of the Auditory Environment

The role of the auditory environment in prelinguistic speech development has been controversial since at least 1958 when Brown first proposed the "babbling drift hypothesis" (5). The hypothesis that babble progressively approximates the characteristics of the ambient language has been studied primarily by comparing the characteristics of babble with the presumed characteristics of the adult speech produced in the child's environment, with particular emphasis on sounds which are excluded in the adult language, and sounds which are exclusive to the adult language (in comparison with a second language, usually English). Thus far the results have been somewhat contradictory. Locke (5) reviewed studies covering 15 different language environments, and concluded with confidence that the auditory environment does not influence speech production until the age of 18 months. Other studies strongly suggest that the auditory environment may have a significant impact on speech before the end of the first year.

Recent advances in research regarding the role of the auditory environment in speech development have been made possible by an improved description of the infant's auditory environment, a better understanding of infant speech production abilities, and more sophisticated analyses of both infant and adult produced speech. Often the infant's auditory environment is described by reference to phonetic analyses of adult-produced, adult-directed speech (e.g., radio monologues and telephone conversations). A more complete conceptualization of the infant's auditory environment must take into account the infant's auditory abilities and attentional preferences, aspects of the environment which may mask or modify linguistic input, and characteristics of speech heard by the infant, including self-produced speech, adult-produced infant-directed speech (i.e., motherese), and adult-produced adult-directed speech.

This research has also been hampered by a failure to consider the interaction of the auditory environment with the infant's developing motor abilities. For example, some studies have examined cross-linguistic differences in voice-onset-time and fundamental frequency contours (5). However, there is little variation in these acoustic characteristics either within or between infants, and there is reason to believe that these parameters are particularily difficult for young infants to control.

Finally, the bulk of this research has involved phonetic analyses of both infant and adult speech. Phonetic analysis of infant speech has been criticized on a number of grounds: it is subject to listener biases; similarities among samples are emphasized while differences are obscured; only segmental aspects of speech are described; description of vocalizations which are not grossly speech-like are impossible; and it assumes, unrealistically, that infant vocalizations are composed of the same auditory and articulatory features that characterize adult produced phonemes (2).

The problems listed above have been avoided in more recent research with both cross-linguistic and hearing impaired samples. For example, de Boysson-Bardies et al. (3) described a unique method for determining the phonetic characteristics of the infant's linguistic environment; in this study the adult phone frequencies were taken from the adult models for words produced by 20 month old children, and then compared with phone frequencies in prelinguistic speech samples taken from younger children. This procedure increased the probability that the adult repertoires represented what adults say to infants, rather than the more typical sampling procedures which represent what adults say to each other. In addition, these comparison repertoires are more likely to reflect the infant's hearing abilities and attentional preferences. Comparative analysis of the consonant repertoires of 9 to 16 month old infants learning French, English, Japanese, and Swedish found reasonably good correspondence for place and manner of articulaton, word final consonant use, and vocalization length. de Boysson-Bardies and her colleagues (1) have also found striking differences in vowel formants between samples collected from 10 month old babies learning French, English, Cantonese, and Arabic.

Acoustic analysis has also had a profound impact on the study of speech development in hearing impaired children. Oller (6) cites the traditional belief that the age of onset and quality of babbling produced by hearing impaired infants is the same as for normally hearing babies. However, an acoustically based metaphonological analysis reveals that the onset of canonical babbling is significantly delayed for these children. Kent et al. (4) studied the speech produced by twin boys, one with normal hearing and one with profoundly impaired hearing, during the period 8 through 15 months of age. Acoustic analysis revealed that the hearing impaired baby's vowel space became increasingly restricted with age, while the vowel space of the normal hearing baby changed shape to resemble that of the adult speaker of English.

2. Otitis Media and Infant Speech Development

The studies cited above deal only with severe to profound hearing impairment. It is not known whether the more subtle and fluctuating hearing impairment that is associated with otitis media with effusion (OME) has similar effects on speech development during infancy. It is known that OME is especially prevalent during the period 6 through 18 months of age and that children with a history of chronic OME are at risk for speech, language, and learning difficulties. In addition, studies show that the risk for speech and language delay is especially high when the episodes of OME begin during the first year of life (7).

We are currently engaged in research designed to examine the impact of OME on infant speech production abilities. Such studies are necessary if we are to develop: models to explain the relationship between OME and speech and language delay; measures to predict which infants will experience speech and language delay secondary to chronic OME; and treatment programs to prevent speech and language delay in such children.

We are recruiting 6-month old infants with no prior history of hearing impairment or otitis media ("OME-free" group) and 6-month old infants who have had one or more ear infections at or before 6 months of age ("OME" group) through physicians, audiologists, and community health nurses. Each infant in the study has a normal prenatal, perinatal, health, and developmental history and comes from an English-only speaking family with no history of speech, language, or learning disability.

Continued membership in the assigned group (i.e. "OME" or "OME-free") is dependent upon the results of tympanometry at each assessment: infants in the OME-free group will be required to maintain normal tympanometric results throughout the period of study, while infants in the OME group will be required to demonstrate abnormal tympanometric results during at least one of the assessments. Early age of onset is generally associated with increased risk for chronic OME, and consequently it is likely that infants in the "OME" group will demonstrate abnormal middle ear status on more than one occasion between 6 and 18 months of age.

At each of the ages 6, 9, 12, 15, and 18 months the infant recieves a complete standard audiology assessment including otoscopy, assessment of warble-tone and bone conduction thresholds for frequencies between 250 and 6000 Hz using visual reinforcement audiometry, and tympanometry . Following the audiology assessment the infant's vocalizations are recorded for approximately 30 minutes. Phonetic and acoustic analyses are being used to determine a phonetic complexity score and canonical babble ratio for each sample, and the F2/F1 ratio for each vowel contained in each sample. Developmental changes in these measures will be compared across the 2 groups.

The figure below shows some prelimary data for two infants currently enrolled in the study. Baby A, a boy, had normal hearing and middle ear function one week prior to taping and no history of OME. Baby B experienced 3 ear infections, according to parent report, prior to the age of 6 months. He had elevated thresholds and flat tympanograms one week prior to taping but normal hearing and middle ear function one week after taping subsequent to antibiotic treatment. Baby A was taped at age 5 months 2 weeks, while Baby B was taped at age 6 months 3 weeks. The speech samples were analyzed by first segmenting all of the infant's vocalizations into utterances, defining the utterance as a vocalization bounded by adult speech, 1 second of silence, or an audible inspiration. Each utterance was then classified as speech-like or non-speech, and then each speech-like utterance was further classified as canonical or noncanonical (6). The frequency of the first and second formants of each vowel contained in a canonical syllable was determined using autoregression analyses and fast fourier transforms on samples digitized at a sampling frequency of 20 kHz. The figure below plots the resulting F1 and F2 value for each vowel. Baby B is clearly producing a more restricted set of vowels in relation to Baby A, showing a less mature pattern of vowel production ability, despite being almost 5 weeks older than his normal hearing peer.

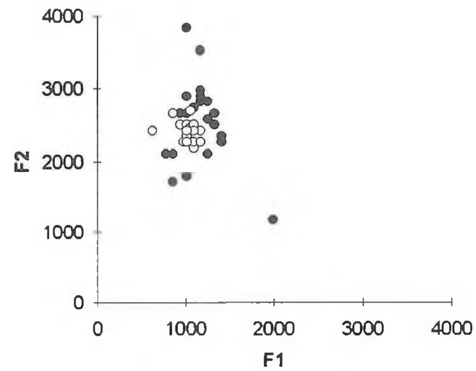

Figure 1. F1/F2 plot for vowels produced by Baby A (closed circles) and Baby B (open circles) at age approximately 6 months.

3. References

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