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LATERAL DIFFERENCES IN THE NEWBORN INFANT'S RESPONSE TO SPEECH AND NOISE STIMULI

by

MADELINE HAMMER

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Abstract

LATERAL DIFFERENCES IN THE NEWBORN INFANT'S RESPONSE TO SPEECH AND NOISE STIMULI

by

MADELINE HAMMER

Adviser: Professor Gerald Turkewitz

To determine whehter infants process auditory stimuli equivalently when presented to both ears and whether white noise and speech stimuli produce similar or differential patterns of asymmetrical responding,lateral eye movements and changes in heart rate were measured and compared under conditions in which a taped speech stimulus was presented either independently to each ear or simultaneously to both ears and in which a white noise stimulus was presented simultaneously to both ears. Simultaneous stimulation of the two ears resulted in systematic lateral eye-turning, with turning to the right produced by simultaneous speech stimulation and turning to the left produced by simultaneous white noise stimulation. Speech stimulation applied separately at either ear resulted in ipsilateral eye-turning with no significant difference in the effects of stimulation at the left and stimulation at the right. Simultaneous white noise stimulation resulted in significantly more cardiac acceleration than did simultaneous speech stimulation. Although simultaneous speech stimulation produced significant accelerative responding and unilateral presentation at either side did not, no difference in cardiac response was found between simultaneous speech stimulation and speech stimulation at either side. It was found that the systematic lateral eye movements in one direction to simultaneously presented speech stimulation could not be accounted for by differential responsiveness to unilaterally presented stimulation, suggesting that the preponderant lateral turning in one direction was a consequence of competing input to the two ears. The cardiac and eye-turning findings also indicated that the eye-turning behavior to simultaneous stimulation represented an orientation toward the more effective sound source. These results are taken to suggest that the newborn infant processes speech sounds more effectively at the right ear and white noise sounds more effectively at the left ear and that the type of differentiation found in adults' processing of various auditory stimuli may have its anlage in the newborn infant.

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CHAPTER I

INTRODUCTION

Speech-related auditory functioning in infants

A number of recent studies of auditory processing during infancy have suggested that the neural mechanisms necessary for speech perception may be functional very early in life. Several of these studies suggest that the newborn infant is particularly sensitive to frequencies within the speech range and to patterned or speechlike sounds as compared to constant signals. Studies by Eisenberg and her coworkers (see Eisenberg, 1970; 1976) have suggested that low and high frequency sounds have different functional properties for the newborn infant, that signals in the carrier range for speech (the average fundamental frequency of adult speech is approximately 120Hz for males and 240Hz for females) are particularly effective and that patterned stimuli such as tonal sequences and synthetic speech sounds are quite potent and evoke highly specific and differentiated modes of response. Hutt, Hutt, Lenard, Bernuth and Muntjewerff (1968), recording the electromyographic activity of the newborn infant in response to presentation of 70, 125, 250, 500, 1000 and 2000 Hz sine and square waves and of male and female recordings of "baby", found infants to be most responsive to square wave sounds (which generate broad band acoustic frequencies) with low frequency fundamentals and to natural speech. In a following study, Lenard, Bernuth and Hutt (1969) recorded cortical evoked responses to some of the same acoustic stimuli as well as to low and high frequency narrow band and broad band noise sounds. They reported results similar to Hutt, et al. and in addition discounted band width as well as rise time of the signal as possible sources of differential effectiveness. Lenard, et al. suggested that their findings supported Eisenberg's thesis that the newborn infant's auditory system is differentially tuned to the carrier frequencies of language and also indicate that it is not just energy but structure within a frequency range to which the newborn is particularly responsive. Butterfield and Siperstein (1972) found that newborn infants altered their sucking behavior to decrease their exposure time to noise and to increase their exposure time to vocal-instrumental music. Moreover, while their responses were equally strong to both singing voices and combined vocal-instrumental music, they showed no reliable increase in response to instrumental music, suggesting that the human voice is a particularly potent stimulus for the newborn infant. Finally, Condon and Sander (1974) filmed the body movements of infants ranging in age from 12 hours to 14 days during presentation of speech and other types of sounds. On the basis of microanalysis of their sound films, the authors conclude that as early as the first days of life, the infant's body movements are synchronized with meaningful units of adult speech but not with other types of sounds.

In addition to the above studies with newborn infants, a number of acoustic cues which have been identified as providing a basis for the perception of consonant-vowel (C-V) syllables in adults have been utilized to examine discrimination of speech sounds in infants one month of age and upwards. Considerable progress in this area in the 1970's is related to the development of sophisticated speech-generating equipment which allows control and systematic variation of relevant acoustic parameters and to the application of heart rate and non-nutritive sucking habituation-dishabituation paradigms as behavioral indices of discrimination in young infants. The evidence indicates that young infants can discriminate between phonemic contrasts which are presumably identical in all but one aspect. For instance, a number of studies suggest that infants discriminate synthetically produced phonemic contrasts /ba/ and /pa/ or /da/ and /ta/ which differ in the timing of the onset of the first formant[1] relative to that of the second formant (Eimas, Siqueland, Jusezyk, and Vigorito, 1971; Trehub and Rabinovitch, 1972; Eimas, 1975 b; Lasky, Syrdal-Lasky, and Klein, 1975; Streeter, 1976). In adults these differences are found to be sufficient for the identification and discrimination of stop consonants which differ according to the onset of voicing (VOT). Still other studies have found that infants discriminate synthetically produced phonemic contrasts /ba/, /da/, and /ga/ which differ in the direction and extent of the second formant (F_2) transition (Morse, 1972 ; Eimas, 1974 a; Miller and Morse, 1976). These cues are found to be sufficient for the identification and discrimination of stop consonants which differ according to place of articulation. Other studies have

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[1] In the production of speech, sounds are produced by the vocal cords of the larynx and filtered by the chamber or vocal tract above the larynx. The filtering process produces concentrations of resonating frequencies referred to as "formants" that are a function of the size and shape of the chamber. The frequencies of these formants over time can be displayed on a sound spectograph and are labeled in ascending frequency order: first formant, second formant, etc.

revealed that infants can discriminate intonational contrasts (Morse, 1972), /ra/ - /la/ contrasts (Eimas, 1975 a), fricative cue contrasts /sa/ - /va/ and /sa/ - / a/ (Eilers and Minifie, 1975), isolated vowels and vowels in a consonant-vowel context (Trehub, 1973; Swoboda, Morse, and Leavitt, 1976).

Some of the studies suggest that not only are infants able to discriminate the above contrasts, but appear to do so in a manner which parallels adult speech perception. Thus, if adults are asked to label randomly presented C-V syllables which are systematically varied along a critical acoustic cue continuum (i.e. VOT and F_2 transition), they will identify the stimuli within a critical boundary as one syllable and across that boundary as another syllable. Furthermore, they will only discriminate pairs of these stimuli which they have labeled as members of different phonetic categories. Applying these findings toward the examination of speech discrimination in infants, several studies suggest that infants are able to discriminate sounds well when the C-V syllable pairs presented are classified as different phonemes by adult listeners. Moreover, infants do not show evidence of discrimination under conditions in which the sound-pairs are within the same adult phonetic category, even though the absolute acoustic difference in the primary cue for the sound-pairs is presumably identical in both conditions (within and across-category). One of the earliest studies of this kind was undertaken by Eimas, *et al.*, 1971 using a habituation-dishabituation conditioned high amplitude sucking procedure (HAS). The investigators found that one and four month old infants could discriminate the synethic syllable sounds /ba/ and

/pa/ differing in VOT and that discrimination was reliably better in the across than in the within-category condition. Eimas (1975 b) replicated these findings utilizing different phonemic pairs (/da/ and /ta/) and different VOT values.

Further support for the view that infants are able to discriminate speech sounds in a manner which parallels adult phonemic discrimination are the studies which suggest that infants respond differently to acoustic signals which cue specific phoneme contrasts when they are presented in isolation or within a speech context (Morse, 1972; Eimas, 1974; 1975 a). For instance, Eimas (1974) reported that when the F_2 transitions that cued the /d / - /g/ contrasts are presented in isolation to the infant, they are discriminated continuously, and when presented in a speech context, they are discriminated categorically. Finally, evidence for infant parallels to adult speech discrimination has been suggested by a recent study of vowel discrimination. In contrast to consonants, vowels are generally discriminated continuously by the adult listener. Swoboda, Morse, and Leavitt (1976) suggested that infants as young as 8 weeks also discriminate /i/ and /I/ vowel contrasts continuously (within- and between- phonetic category contrasts were discriminated equally well).

While these similarities to features of adult phonemic perception are impressive, the conclusion that the infant and adult behaviors are determined by the same underlying mechanism is premature. Firstly, whether the mechanisms underlying the infant's discrimination of consonant-vowel syllable contrasts are specifically phonemic, categorical but not specifically phonemic, or based upon acoustic differences is still open to question. A number of researchers (Stevens and Klatt, 1974; Butterfield and Cairns, 1974; Eilers and Minifie, 1975; Eisenberg, 1976) have suggested that the infant's "categorical" discrimination of phonemic contrasts differing in VOT may be accounted for by a number of purely acoustic variables which operate differentially along the continuum of the VOT dimension (i.e. the absence or presence of an F_1 transition or of a noise source). Butterfield and Cairns (1974) have suggested that there may also be alternative acoustic bases for the infant's categorical discrimination of the phonetic contrasts differing in place of articulation. Morse (1976) notes that subsequent to the generation of synthetic speech stimuli, while the critical parameters such as VOT or F_2 transition are well specified, few investigators have analyzed their synthetic continuum for frequency or intensity related discontinuities which may have been unintentionally introduced by syntheses. The possibility therefore exists that the infant discrimination findings may be accounted for by various unknown, purely acoustic variables.

Butterfield and Cairns (1974) have also criticized the interpretation of results of the HAS studies as indicating categorical discrimination because one cannot infer an inability to discriminate (i.e. in the within-category contrasts) from failure to show post-shift recovery of a voluntary response (HAS).[1] However as Morse (1976) notes,

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[1] Moreau, Birch, and Turkewitz (1970), Turkewitz, Moreau, Birch, and Davis (1971) and Turkewitz, Birch, and Cooper (1972) have found that different responses (e.g. heart rate, finger movements, lateral conjugate eye movements) have different patterns of habituation to the same auditory stimulus and that these responses are not equivalent indicators of the effectiveness of any one stimulus. Thus utilization of different response indicators might reveal discrimination of within-category consonant changes.

the consistency with which infants in the HAS studies fail to show post-shift recovery of within-category changes and the replication of the HAS findings utilizing a relatively involuntary response, heart-rate deceleration (Miller and Morse, 1976; Till, in Morse, 1976) do suggest that young infants treat between- and within-category contrasts differently. Morse suggests however that the lack of recovery to a within-category change may be due to constraints of the paradigms on memory processes and that it may be possible for a paradigm to be developed which would reveal continuous discrimination of consonants in infants. Indeed, Morse raises the possibility that the simple distinction between auditory and phonetic levels of processing may have limited meaning in infant speech perception and may actually represent a continuum of processing. This prospect is not unlikely considering that the infant's phonetic discrimination of speech sounds as revealed in the infant studies is of a much more limited nature than that established in adult research. For instance, the conclusion that adult listeners perceive synthetic speech stimuli categorically is based on studies in which many pairs of stimuli have been presented and only those pairs of stimuli which cut across the adult's categorical boundary were accurately discriminated. This is not feasible in infant research and thus we are unable to know whether the infant's discrimination gradients around the category boundary approximate the sharp gradient of the adult listener (Butterfield and Cairns, 1974). The infant's categorical discrimination of consonants as established in the studies is also limited to the discrimination of consonant-vowel syllable contrasts in which the vowel environment is held constant (i.e. /ba/ vs. /pa/). In contrast, adults display abstract phonetic identification as well; they are able to identify consonants under conditions in which the particular acoustic cues which signal a given consonant are dramatically different (e.g. vary as a function of vowel context, position in the syllable, sex of speaker, etc.). Fodor, Garrett, and Brill (1975) attempted to examine this abstract phonetic invariance in infants 14 to 18 weeks of age in a conditioned head-turning paradigm utilizing natural speech stimuli /pi/, /pa/, /pu/, /ki/, /ka/, /ku/. Fodor *et al*. observed that the infants gave more conditioned head-turns to the pair that contained the same initial consonant than to the pair that contained different ones. Since they employed natural speech sounds, however, the infants' differential response may have been due to acoustic cues (which were more similar in the same-consonant condition) rather than to phonetic identification.

Lateralization of auditory functioning

Another characteristic of speech receptive functioning in children and adults is that this function appears to be lateralized. For instance, dichotic listening tasks have consistently shown asymmetry (a right-ear advantage) in processing speech sounds (e.g. Kimura, 1961 a) and speech disturbances in adults are strongly associated with left-temporal lobe lesions (e.g. Zangwill, 1960). Moreover, anatomical evidence has indicated morphological asymmetry of the cerebral hemispheres in the temporal lobe language region (Geschwind and Levitsky, 1968) and it has been suggested that the structural and functional asymmetries observed are related phenomena (Yeni-Komshian and Benson, 1976; Witelson, 1976). A less consistent and different pattern of lateralization has been shown for nonspeech auditory functions. Although there are many questions remaining, as indicated above, as to whether speech signals undergo phonetic processing in infancy, the studies of infant speech discrimination and of neonatal responsivity to speech-related auditory stimuli do suggest the presence of an auditory processing mechanism in early infancy that is particularly if not exclusively[1] relevant to the processing of speech signals. The question therefore arises as to whether such a mechanism may be operating unequally in the two hemispheres (or subcortically) during infancy and whether infants appear to treat speech and nonspeech auditory stimuli differentially in terms of patterns of lateralized response to these signals.

Evidence for the presence of left-right differentiation of the cerebral hemispheres for language functions in adults has been derived from various techniques. Anatomical evidence indicates that in adults the planum temporale (a portion of Wernicke's speech area) is visibly larger in the left hemisphere than in the corresponding area in the right hemisphere in 90% of adult cases (Wada, Clark and Hamm, 1975). Clinical studies have consistently found a strong positive relationship between left temporal lobe lesions and aphasia in adults (Zangwill, 1960; Kimura, 1961b; Milner, 1962; Geschwind, 1970) whereas lesions to the right hemisphere are not typically associated with language disturbances. Experiments

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[1] There is some evidence to suggest that specialization of the left hemisphere in the adult may involve detection and/or analysis of complex acoustic properties such as temporal order (e.g. Halperin, Nachsan, and Carmon, 1973; Cutting, 1974 a,b). Although these particular acoustic properties may be functionally crucial in determining phonetic structure, they may engage the same processing mechanism in a nonspeech context as well.

with split-brains (Gazzaniga and Sperry, 1967) and with anesthetization of the left or the right hemisphere through intracarotid injection of sodium amytal (Wada and Rasmussen, 1960) have also indicated left hemisphere specialization for language processing (e.g. temporary aphasia is more closely associated with left hemisphere anesthetization).

In the normal adult population, evidence for lateralization of language functions in the brain has been provided by use of a technique involving competition between input to the two hemispheres (dichotic listening, Kimura, 1961a), by evoked potential recording techniques (e.g. Molfese, Freeman and Palermo, 1975) by examination of patterns of EEG activity associated with speaking and listening tasks (e.g. Wood, Goff, and Day, 1971), by a technique involving tachistoscopic presentation of verbal and nonverbal material to the left or right visual field (e.g. Geffen, Bradshaw, and Wallace, 1971). In general most studies utilizing these converging techniques indicate specialization of the left hemisphere for the processing of verbal material and of the right hemisphere for the processing of auditory-nonverbal and visuo-spatial material. A number of concepts such as analytic vs. gestalt processing (Bever and Chiarello, 1974) or focal vs. diffuse processing (Semmes, 1968) have been suggested as determining factors underlying these differential functional asymmetries, but these concepts remain speculative.

Until recently, the bulk of the evidence on the development of lateralization has been interpreted as suggesting that structurally determined differentiation in auditory speech processing emerges with the development of language and maturation of the brain and that it is plastic until after puberty (Zangwill, 1960; Lenneberg, 1967). This interpretation was derived from clinical data on children who have incurred brain lesions to the right hemisphere or left hemisphere at various ages. For instance, Basser (1962) reports equivalent delays in the onset of speech in children who incurred massive brain lesions to the right hemisphere or to the left hemisphere before the age of two. After the onset of speech and before ten years of age,temporary disturbances in speech occur to a greater extent following damage to the left hemisphere than to the right hemisphere. After puberty, permanent speech disturbances are almost exclusively associated with left hemisphere lesions. Interpretation of these findings as reflecting an increase in lateralization with age has recently been criticized by Kinsbourne (1974) and by Hécaen (1976),[1] who suggest that the reduced recovery with increase in age is related to a decrease in the compensatory potential of other areas of the brain.

Nonclinical evidence of hemisphere specialization in children has most frequently been provided by use of the dichotic listening task technique. Studies utilizing this technique have suggested that hemispheric differentiation in the processing of speech (and nonspeech auditory) stimuli is present soon after the onset of language (Kimura, 1963; Knox and Kimura, 1970; Nagafuchi, 1970; Ingram, 1975). The dichotic listening task involves the simultaneous presentation of different auditory stimuli at each ear. The greater accuracy in the reporting of certain types of auditory material presented to one ear over the other ear is assumed to reflect the superiority of the opposite hemisphere in processing that material. In the auditory system,

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[1] See Appendix A

although each hemisphere receives input from both ears, the crossed connections are more numerous than are the uncrossed ones (Rosenzweig, 1951; Boca, Calearo, Cassinari, and Migliavacca, 1955). It has been suggested (Kimura, 1961a, b) that when stimuli are presented dichotically, the crossed pathways suppress the ipsilateral ones ensuring functional prepotency of the contralateral ear-to-hemisphere connections. In the case of dichotically presented speech stimuli, left hemisphere specialization for language processing would result in a right-ear-advantage (REA) since the right ear speech pathway is direct, while the left ear speech pathway traverses an indirect route from the left ear to the right hemisphere and across the corpus callosum to the left hemisphere. More direct evidence that the dichotic task does indeed reflect such a hemispheric specialization of function comes from studies of the effects of unilateral temporal lobe lesions (Kimura, 1961b), unilateral intracarotid injection of sodium amytal (Kimura, 1973) and surgical disconnection of the cerebral hemispheres (Milner, Taylor and Sperry, 1968) on recognition of verbal stimuli presented to the ear contralteral to the lesioned or anesthesized hemisphere and/or to both ears.

Kinsbourne (1973) has proposed an attentional model to explain the ear advantage which also assumes hemispheric specialization as a basis, but he does not propose structurally determined prepotency of the crossed pathways and degrading of the signal across the corpus callosum. Instead he proposes that each hemisphere serves the contralateral one-half of space. Depending upon the nature of the task, one hemisphere will be activated (e.g. left hemisphere for speech input) and turn attention toward the opposite side. At the same time activation of the other hemisphere will be inhibited. Studdert-Kennedy (1975) has cited a number of studies which indicate that perceived spatial orientation and involuntary attention do play a role in determining ear advantages (p. 124-125).

Utilizing the dichotic listening task, Kimura (1961a, 1963, 1964, 1967), Knox and Kimura (1970), Milner (1962), and a host of other researchers (see Eisenberg, 1970, p. 20) found that adults and children as young as three years demonstrate a right ear superiority in identifying verbal stimuli and a left ear superiority in identifying nonverbal (i.e. melodies) auditory stimuli. Although Kimura initially identified the principal dimension determining the hemisphere which would process an auditory input as being a meaningful-nonmeaningful one, more recent evidence (Shankweiler and Studdert-Kennedy, 1967) has caused her to view the determining factor as being more uniquely related to human speech (Kimura, 1973). Shankweiler and Studdert-Kennedy found that dichotic presentation of nonsense consonant-vowel syllables (the smallest segment of the acoustic signal required for consonant identification) produces a right ear superiority while dichotic presentation of isolated vowels produces left ear superiority or equivalent processing in both ears. Since the task did not require either recall of a stimulus list or competition between semantically meaningful items, the differences were explained in terms of the parameters which differentiate speech ("encoded") from nonspeech ("unencoded") acoustic stimuli and the existence of a special left hemisphere neural mechanism for the decoding process involved in the perception of speech sounds.[1]

Porter and Berlin (1975) present a more comprehensive view of the processes involved in the right-ear advantage reported in numerous dichotic competition[2] studies. The authors suggest that different levels of processing are tapped in different studies and, depending upon the task requirements, the REA might reflect lateralization of semantic or other complex linguistic mechanisms, of linguistic short-term and long-term memory processes, of vocal tract control, etc. The situation presented by dichotic presentation of pairs of nonsense C-V syllables may involve relatively early maturing low level central perceptual processing. Results of a number of studies have suggested that in this type of task an important part of the dichotic interaction occurs at an auditory level and that the advantage accrueing to the right-ear stimulus may be seen even before the stage at which the phonetic message is extracted from the signal.

Using their level of processing model, the authors are also able to reconcile some of the conflicting findings in studies examining the development of the dichotic REA. Some of these studies suggest a developmental increase in the REA (e.g. Satz, Bakker, Teunissen, Goekel, and Van Der Vlugt, 1975) while others do not (e.g. Kimura, 1963). Porter and Berlin suggest that those studies which did not reveal a developmental increase in REA tapped early maturing auditory and phonetic processes (as in studies where

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[1] See Appendix B

[2] Some studies have indicated an REA for monaurally presented complex linguistic messages or tests requiring recall of monaurally presented word or syllable lists.

single pairs of nonsense-syllables were presented). This analysis is of particular relevance in light of evidence suggesting that some aspects of phonetic processing may be functional in early infancy.

However even those dichotic studies which tap low level perceptual processes may, in the child and the adult, inadvertently involve a higher order processing of speech information. Nonsense C-V syllables are linguistically meaningful to children and adults and there may be an implicit understanding by these subjects that the task requires that linguistic distinctions be made. It is possible that the hemispheric differences reported are related to these factors rather than to the mere physical properties of the speech or nonspeech sounds. This possibility is supported by recent studies of cortical auditory evoked responses in adults during presentation of various auditory stimuli. In one study, differential neural events are found to occur in the left and right hemispheres which are related to the meaningfulness of the stimuli to the subject (the use made of the stimuli by the subject as determined by prior instuctional set) rather than to the speech or nonspeech character of the stimuli (Matsumiya, Tagliasco, Lombroso, and Goodglass, 1972). Studies by Wood, Goff, and Day (1971) and by Wood (1973) have found differential neural events within the left hemisphere itself to the same acoustic signal (/ba/) depending on whether the subject is required to make a linguistic or a nonlinguistic distinction in analyzing a stimulus. In a recent review of studies of hemispheric specialization in commissurotomized adult subjects, Nebes (1974, p. 12) has suggested that "it is not just the type of perceptual stimulus or the mode of readout used which determines which hemisphere is dominant but rather the type of information processing required to solve the given problem."

To the extent that these information processing functions are absent in the newborn, the specialized left hemisphere mechanism for the perception of speech sounds may be absent as well. Bever (1968) has presented arguments in favor of such a thesis, suggesting that since cerebral dominance for speech appears to be specifically related to speech processing strategies which are acquired, "cerebral dominance develops (at least in part) in response to external experience" (p. 1).

Nevertheless, laterally differentiated mechanisms may exist during early infancy which are precursors of those found for later speech processing functions. They may, for instance, be based upon acoustic properties of stimuli rather then semantic, syntactic or memory processes. Recent data from several sources have in fact suggested the presence of left-right structural and behavioral asymmetry in early infancy in relation to speech processing. Thus Wada, Clark, and Hamm (1975) and Witelson and Pallie (1973) report anatomical differences in the planum temporale (a portion of Wernicke's speech area) of the newborn infant, that area in the left hemisphere being visibly larger than the corresponding area in the right hemisphere. There is also evidence that newborns and older infants respond to speech stimuli with a larger amplitude evoked potential (AEP) in the left hemisphere and to nonspeech auditory stimuli with larger AEP in the right hemisphere (Molfese, et al., 1975; Molfese, Nunez, Seibert, and Ramanaiah, 1976). Similar results were obtained for adults with both the anatomical analysis and evoked potential recording techniques. Finally, Entus (1975), combining the dichotic listening procedure with the HAS habituation-dishabituation paradigm, has reported that infants between the ages of 22 and 140 days display an adult pattern of asymmetry for dichotically presented speech and nonspeech stimuli. Greater recovery of the HAS response was found to changes in speech stimuli at the right ear and to changes in nonspeech stimuli at the left ear.

When considered in relation to the studies which suggest that as early as one month infants show fine speech discriminative abilities and perhaps discriminate phonemic contrasts in a categorical manner, [1]these indications of early functional and structural asymmetries are impressive. The anatomical evidence of neonatal structural asymmetry of the hemispheres in the area of the planum temporale has also been demonstrated by Teszner _et al_. (Hécaen, 1976). The behavioral evidence of early functional asymmetry, however, should not be taken as conclusive. Haith and Campos (1977) cite a number of recent studies with adults which have failed to link evoked potentials to lateralization. Attempts to replicate the Entus findings have

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[1] It is important to emphasize that finding of categorical discrimination for speech sounds in infants does not necessitate corresponding lateralization of functional representation. Thus, some degree of phonemic discrimination has been reported in animal studies (Kuhl and Miller, 1974; Morse and Snowdon, 1975), yet the species studied do not the structural and functional asymmetries evidenced by humans (e.g. Yeni Komshian and Benson, 1976). However, there are differences between the animal and infant speech discrimination findings: for instance, both Miller and Morse's (1976) human infant study and Morse and Snowdon's (1976) monkey study, utilizing the same paradigm to study categorical discrimination of place cues, found better discrimination of between-category changes than within-category changes in the acoustic cue for place. However, only monkeys exhibited significant within-category discrimination, suggesting that the human infant processes phonetic information in a more specialized way.

thus far been inconclusive.[1] The use of other approaches and procedures may prove more fruitful in examining functional asymmetries in early infancy. The present study was therefore designed to determine whether there exists in the newborn period laterally differentiated mechanisms for processing speech as well as other auditory stimuli by examining direction of eye-turning following simultaneous lateral auditory stimulation.

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[1] Glanville, Best and Levenson (1977) replicated Entus' findings for speech and partially replicated the nonspeech results using cardiac deceleration rather than sucking as their dependent measure. However, Khadem & Corballis (1977), testing infants in the same laboratory with improved controls, reported nonreplication of Entus' speech findings.

CHAPTER II

Methodology

Design and rationale

Although several investigations have indicated that newborn infants are more responsive to complex (white noise) auditory stimuli presented at their right than at their left side (Turkewitz, Birch, Moreau, Levy, and Cornwell, 1966a; Hammer and Turkewitz, 1975) and it has been suggested that these early lateral differences may be important for the subsequent development of hemispheric differentiation (Hammer and Turkewitz, 1974), the evidence has suggested that these differences are in and of themselves relatively shortlived (Turkewitz, Moreau, and Birch, 1966b). Thus it has been demonstrated that the lateral differences are a consequence of the infant's prior asymmetrical posture in which the head is maintained to the right of the body midline. This posture results in partial occlusion of the right ear, with a consequent lower level of ambient auditory stimulation to that ear than to the left ear. Equalizing the level of ambient stimulation to which the two ears are exposed prior to testing by holding the head in a midline position for 15 minutes results in the elimination of the infant's lateral difference in responsiveness to unilaterally presented white noise stimulation (Turkewitz,*et al.*, 1966b). However, there may be more long lasting and possible more centrally determined lateral differences which would not be eliminated by equalizing the level of ambient stimulation to which the two ears are exposed. Such differences might be manifested by presenting competing stimuli at the infant's two ears. Thus, although the adaptation period might make an auditory stimulus equivalently effective when presented separately to either side, simultaneous presentation to both sides might reveal the presence of a dominant side, with infants consistently more responsive to sounds presented to one of the two sides.

The current study, derived from these considerations, was therefore, designed to determine whether relatively long-lasting differences in processing auditory stimuli exist in the newborn infant by examining lateral direction of eye-turn under conditions of competing input to the two ears. Since previous studies (Turkewitz _et al._, 1966a, b) have shown that newborn infants turn their eyes in the direction of an effective sound source, presentation of auditory stimulation to both ears should result in different patterns of directional eye movements, depending on the presence or absence of lateral differences in processing that particular class (e.g. speech/nonspeech) of auditory input. If the auditory input is processed equivalently at the two sides, presenting the same acoustic signal simultaneously at the two ears should result in either inconsistent lateral eye movements, with responses to the right and to the left alternating randomly, or no lateral eye movements, the two equal and opposite eye-turning responses cancelling each other out. If the simultaneously presented stimulus is being processed more effectively at one ear there should be systematic eye-turning, either in one direction or sequentially in opposite directions (e.g. left eye turn followed by a right eye turn).

As indicated earlier, studies utilizing the dichotic listening task have found that children and adults demonstrate a right ear superiority in identifying verbal stimuli and a left or no ear advantage in identifying nonverbal (i.e. melodies, common environmental noises) auditory stimuli. The present study, therefore, employed both a speech stimulus and a complex nonspeech stimulus to examine whether simultaneous presentation of the speech or nonspeech stimulus results in similar or dissimilar patterns of differential processing at the two ears.

<u>The stimuli</u>: Studies which have reported fine discriminative ability in the young infant for speech stimuli have utilized synthetic speech sounds so that the perceptual dimensions of the stimulus could be specified. However, since none of these studies were done on newborn infants (the youngest subjects were a month old), it is possible that a synthetic speech stimulus, in which many of the acoustic features of the naturally-occuring speech sound are eliminated, would not be an effective stimulus for the newborn infant. Although it was recognized that analytic studies utilizing artificial speech sounds would be highly desirable should a lateral difference in processing natural speech sounds be found, it was felt to be desirable for this initial study to increase the likelihood of finding a lateral difference in processing by utilizing natural speech. In fact, those studies which have suggested behavioral responsivity to speech sounds in the newborn infant have used the natural human voice to produce the speech stimuli (Hutt *et al.*,

1968; Condon and Sanders, 1974; Butterfield and Siperstein, 1972). Therefore, a natural speech sound, the words "hi baby" spoken by a female voice and reproduced from a tape loop was used. Since it has been demonstrated that the newborn infant turns his eyes in the direction of an 87 db. white noise sound when presented for one second at either ear (Turkewitz *et al.*, 1966a, b) this stimulus was used in the present study to provide a contrasting complex non-speech sound in analyzing lateral differences in processing. The natural speech sound was of the same duration and was presented at the same peak intensity.

The 15 minute head-holding procedure described above was utilized in the present study to equate for ambient levels of stimulation to which the two ears are exposed prior to testing. The speech sound utilized in the simultaneous stimulation condition was presented separately to each ear as well to assess whether there were lateral differences to unilaterally presented speech sound which were not eliminated by the head-holding procedure. This enabled evaluation of whether possible lateral differences found under condition of simultaneous presentation were based upon competition between input at each ear. Presentation of the speech sound separately at each ear also enabled clearer interpretation of the infant's eye-turning behavior in the two simultaneous stimulus conditions. Thus, the effect of separately presented speech at the right and at the left on lateral direction of eye-turning (i.e. whether it produced predominantly ipsilateral or predominantly contra-lateral eye-turning or a combination of both) would suggest whether possible lateral differences in eye-turning to simultaneous speech represented either an orientation toward one sound or away from the other sound source. This is important because of studies suggesting that while the newborn infant will orient toward a sound of moderate intensity, he will also orient away from sounds of effectively high intensity (Turkewitz, *et al.*, 1966a; Hammer and Turkewitz, 1975). It has been shown in previous studies (Turkewitz *et al.*, 1966b) that an 87 db. white noise stimulus presented separately to the adapted (equated for ambient levels of stimulation) right or left ear results in ipsilateral but not contralateral eye-turning. Similarly, it was expected that ipsilateral but not contralateral eye-turning would be found in the present study to an 87 db. speech stimulus presented separately to the adapted right or left ear. It is, therefore, probable that a white noise or a speech sound of the same objective intensity and duration, when simultaneously presented to both sides would be effectively moderate intensity as well. Systematic eye-turning in one direction under condition of moderate stimulation would represent ipsilateral responding. However, in order to reduce possible ambiguity in the results, the infants' cardiac responses were also recorded. Since the newborn infant's cardiac response to auditory stimuli increases with increases in intensity levels (Bartoshuk, 1964; Steinschneider, Lipton and Richmond, 1966; Turkewitz, *et al.*, 1971), it is possible to use it to determine the effective intensity of a stimulus. Analysis of cardiac changes under the four stimulus conditions (simultaneous speech, simultaneous white noise, speech to the right ear, speech to the left ear) and during catch trials enabled clear interpretation of the infants' eye-turning behavior by assessing the relative effectiveness of the stimulus conditions and the possible summative effects when the acoustic signal is presented simultaneously at the two ears. For instance, if simultaneous speech stimulation resulted in a summative effect, a greater degree of cardiac acceleration would be expected to the simultaneous than to the independent speech stimuli.

Subjects[1]

The infants studied were selected from an available population of full-term infants at the Bronx Municipal Hospital Center and were primarily Hispanic and Black from families of lower socio-economic status. The infants ranged in age from 23.5 to 73.0 (mean = 47.8, S.D. = 14.4) hours at the time of testing. Most of the infants were products of uncomplicated pregnancy and delivery[2] and all were in good condition from birth until testing as determined by:

1. A birth weight of over 2500 grams;
2. A pediatric evaluation as a "well-newborn";
3. One minute Apgar scores of 7 or higher.

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[1] All procedures used in the study were approved by the appropriate clinical committee at Albert Einstein Medical College. Informed consent of the mother was obtained and the study described in detail to each mother both verbally and in the two-page consent form.

[2] There was one case of pre-eclampsia and another of premature rupture of membrane. In both cases there were no complications of delivery.

Pilot testing suggested that a state of moderate activity (i.e. body movement, eye opening, fluctuations in cardiac rate and in recorded eye movement) was required for the infant's lateral responsiveness to speech stimulation. Therefore, on any given day, the infant in the nursery who appeared most alert during the half hour preceding the test session and who met the above health and age criteria was selected.

On this basis nine male and nine female infants were selected for study. Because state in the nursery was not necessarily predictive of state during the test session, infants frequently fell asleep during the testing and in these cases infants were aroused. Two of the female infants fell asleep prior to testing and could not be aroused; the test session was therefore terminated in these cases and the data excluded from the analysis. In addition, the data of one female infant was excluded because technical difficulty with the recording apparatus made the eye movement record unscorable.

Apparatus

The speech stimulus was recorded and reproduced on an Ampex recorder/reproducer console, model #AG-440B. The white noise stimulus was produced on a Grason-Stadler Noise Generator and fed through a Grason-Stadler electronic switch. The duration of the white noise stimulus was preset by a Grason-Stadler interval timer. Both stimuli were amplified with a Hewlett-Packard amplifier, attenuated with a Hewlett-Packard attenuator set, then fed through 6.3 cm. Quam speakers. A Bruel & Kjaer precision sound level meter was used to measure the sound pressure level at the position occupied by the infant's ears.

The laboratory consisted of two sound-attenuated rooms. In the larger of the two rooms infants were tested in a specially designed infant chamber. The chamber, which is 112 x 60 cm., contained a flat bed, adjustable speakers, an adjustable head holder that reduces movements in the coronal plane, and electrodes connected to a polygraph located in the adjoining. The chamber had a shielded light source at its head and foot. The adjoining room contained, 1. The Offner Type R polygraph used to record eye movements, heart rate, onset and duration of the stimulus; 2. the equipment used to produce the white noise stimulus; and 3. the amplifier and attenuator sets. Because of space limitations, the large console Ampex recorder was located just outside the adjoining room.

Procedures

Since experience in our laboratory suggests that the infants are maximally alert approximately one hour prior to the morning (9:30 am) feeding, all infants were tested during this period.

Infants were transported from the newborn nursery to the laboratory in an infant incubator cart and placed in the infant chamber in the supine position. Electrodes were attached at the infant's abdomen and chest to record heart rate and at the outer canthus of each eye to record eye movements electro-oculargraphically (EOG technique enables the recording of lateral eye movements when the infant's eyes are closed as well as when they are open). To prevent interference with recording electrodes, the infant's are movement was partially restricted by tieing paper strips around his wrists and pinning them to his diaper. To restrict head movement in the coronal plane, the infant's head was placed in a head-holder. The speakers, through which stimuli were presented, were positioned on either side of the head and two inches from the infant's ears. The room was then darkened, the chamber light providing dim illumination. Just before testing, the infant's head was maintained in a midline position for 15 minutes to equate for ambient level of stimulation to which the infant's two ears are exposed prior to experimental stimulation (see Design and rationale). In addition to the restriction provided by the head-holder, this was accomplished by the experimenter holding the infant's temples between his hands while standing at the head-end of the chamber. Preceding and following each trial, through the use of hand signals, an observer seated at the foot of the chamber indicated to the experimenter in the adjoining room the state of the infant (quiet, crying, eyes opened or closed).

The white noise stimulus was presented at a total sound-pressure level of 87 db. (re .0002 dyne/cm^2) measured at the position occupied by the infant's ears. The speech stimulus, "hi baby", spoken by a female voice and reproduced from a tape loop, was presented at a peak sound pressure level of 87 db. (re .0002 dyne/cm^2) measured at the position occupied by the infant's ear(s). Both stimuli were presented for a one second duration, with successive trials separated by minimal intervals of 40 seconds. However, since a trial began only after an infant had been quiet (i.e. not crying for at least 15 seconds) and after little or no eye movement for the preceding one second, the interval between trials often exceeded 40 seconds. To provide a baseline for analysis of heart rate and eye movement data under comparable pre-stimulus conditions (i.e. little or no eye movement for one second, no crying for at least 15 seconds), catch trials, during which no stimulus was present, were interspersed in each series of trials. Each series consisted of

1. simultaneous presentation of the speech stimulus to both ears;

2. presentation of the speech stimulus to the right ear;
3. presentation of the speech stimulus to the left ear;
4. simultaneous presentation of the white noise stimulus to both ears;
5. catch trial.

The sequence of presentation was random and different for each subject. Subjects received two to five repetitions of their stimulus sequence depending on the infant's state. Attempts were made to arouse sleeping infants during the test session by turning on the lights, lifting the infant upward and forward from the supine position, jiggling and moving the infant until his eyes fixated on the experimenter's face. If time permitted, stimulus sequences were repeated even when attempts at arousal failed. However, the data from those sequences of trials during which:

1. subjects were judged to be asleep and were not arousable and,
2. during which one or less eye-turns were made in a sequence in the one second preceding or the one and one-half seconds following onset of a trial

were excluded from the analysis.[1]

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[1] This was done because pilot testing had indicated little or no lateral eye-turning responses to unilaterally presented speech stimulation for infants in a regular sleep state. However, since it was not known whether cardiac responsiveness to speech stimulation was affected by the infant's state, the analysis of cardiac change was also performed on all the data; the results were similar (see Appendix C) to those derived from the state-limited data.

Scoring

The aspect of eye movement used as a response indicator was direction of the first conjugate lateral eye movement to occur within one and one-half seconds after onset of the stimulus. Although previous studies (Turkewitz *et al.*, 1971) have found reliable eye-turning responsiveness to white noise stimulation within one second following stimulus onset, pilot testing and recent reports (Eisenberg, 1976) suggested a longer latency in responsiveness to speech stimulation.

All eye movement records were independently scored by two raters, neither of whom knew the stimulus used on the trial for which responses were being scored. Scoring procedures for catch and stimulus trials were identical. To control for scorer bias, the circuit used for recording eye movements was varied so that turns to the right were represented by upward deflections of the pen for some infants and downward deflections for others. The "up" and "down" judgements of scorers were later decoded to indicate appropriate direction of eye movements. On 93 percent of the trials, the two scorers were in agreement as to whether an upward or downward deflection represented a lateral eye movement and whether this movement was the first to occur within the one second prior to or the 1.5 seconds following stimulus onset. On the remaining trials, decisions were made by one of the scorers who rescored the record without knowing the original rating.

The cardiac response measure was heart rate change, defined as an increase or decrease of two or more beats per minute during the third to ninth post-stimulus heart beats over the rate per minute of the seven beats immediately preceding stimulation. The third to ninth cardiac cycle was utilized because prior investigations have indicated a latency of about one second for cardiac acceleration (Steinschneider, Lipton, and Richmond, 1966). The amount of heart rate change was independently scored by two raters, neither of whom knew the stimulus used on the trial for which responses were being scored. When differences between the judgements of the two scorers were two beats per minute (bpm) or less, the scores were considered in agreement. Using this criterion, the interscorer agreement in judging cardiac rate was 91 per cent. In cases where there was a disagreement of more than 2 bpm, decisions were made by one of the scorers who rescored the record without knowing the original rating.

The above heart rate scoring procedures had previously been shown to be maximally sensitive in defining responsiveness to white noise stimuli (Turkewitz *et al.*, 1971). However, since these measures had not previously been used with speech stimuli, beat-by-beat cardiac changes during the third to ninth post-stimulus heart beats were examined for both speech and catch trials to assess whether there was any pattern of heart rate response that might be obscured by the above scoring procedures. Beat-by-beat changes in rate were characterized as acceleration or deceleration responses and patterns of changes were identified and compared for speech and catch trials.

CHAPTER III

Results

Because for some infants data for a given stimulus condition was available on only a small number of trials,[1] there was a possibility of distortion when the data are considered in terms of the percent of trials on which response occurred. All statistical analyses were therefore performed using an index of responsiveness. This index is defined by the formula $\frac{R}{n+1}$ where R= the number of trials in which an infant made a response for a given condition and n= the total number of stimulus trials presented for that condition. Adding one to the denominator reduced the index value more when fewer trials were given and less when more trials were given, thereby reducing inflated response values which could result from a small number of stimulus trials. For descriptive purposes, the data are described in terms of percent of trials on which responses occurred.

Eye-turning responsiveness

To determine whether the conditions of stimulation influenced the eye-turning responses of the infants (see Appendix E

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[1] Although at least 3 repetitions of a stimulus condition was presented to each infant, the state criteria (described on page 28) resulted, for some infants, in fewer stimulus trials of a given condition being utilized in the analysis. The number of usable trials ranged from 1 to 8 for a given condition and infant. See Appendix D for number of trials and eye-turning responses for each condition and infant.

for means and standard deviations), separate Friedman two-way analyses of variance by ranks were performed for turns to the right and left. These analyses indicate that the occurrence of both of these types of responses was strongly influenced by the conditions of stimulation, Turns to the right: $\underline{X}_r^2$ (4) = 14.17, $\underline{p} < .01$; Turns to the left: $\underline{X}_r^2$ (4) = 18.13, $\underline{p} < .01$.

Inspection of Figure 1 suggests that these differential effects are in part related to the direction of stimulus presentation. When speech was presented at either the right ear or at the left ear there was preponderant turning in the direction of the sound source. Thus eye-turning to the right was elevated when the speech stimulus was delivered at the right ear and eye-turning to the left was elevated when the speech stimulus was presented at the left side.

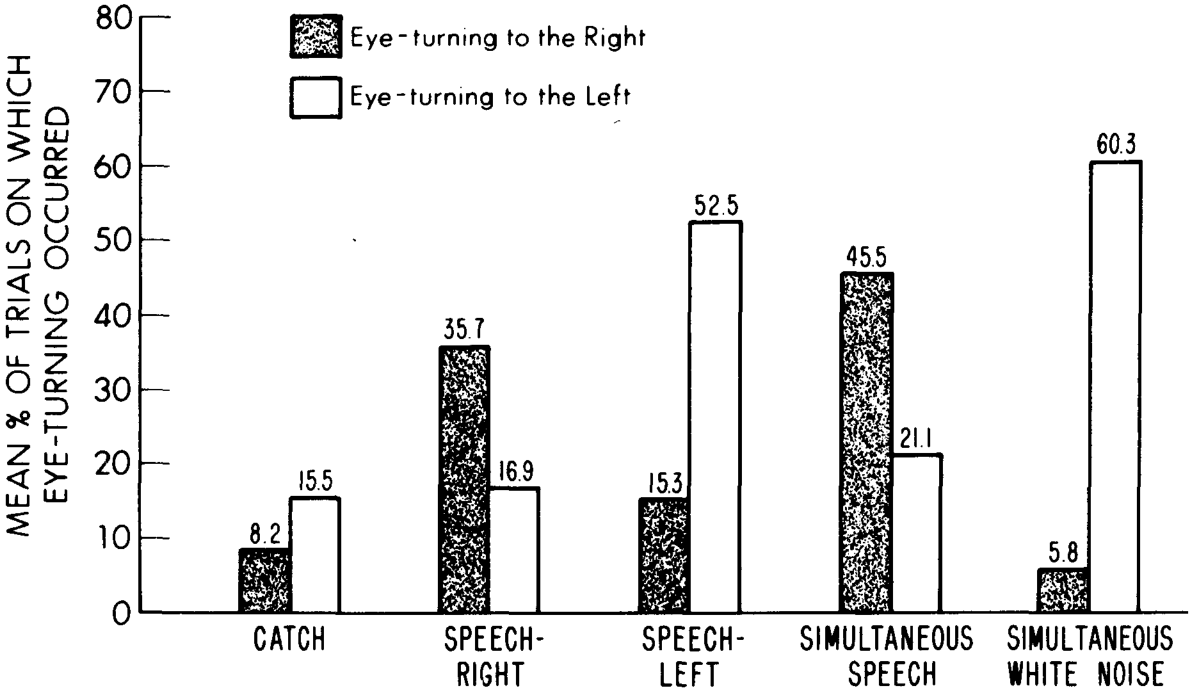

Figure 1. Relationship Between Stimulus or Catch Condition and Percentage of Trials on which Eye-turning to the Right or Left Occurred.

Comparison of eye-turning responses on the two separate speech presentation conditions with catch trials indicated significant ipsilateral and no contralateral responding to both speech applied at the right side and speech applied at the left side. Eye-turning responses to the right occurred on 35.7% of trials in which speech was presented at the right and on only 8.2% of catch trials. The difference was highly significant, $\underline{T}$ (11) =3, $\underline{p} < .005$, one-tailed, Wilcoxon matched-pairs test. When speech was presented at the left, eye-turning responses to the left occurred on 52.5% of the trials as compared to only 15.5% of catch trials. The difference was also significant, $\underline{T}$ (15) =16.5, $\underline{p} < .01$, one-tailed, Wilcoxon matched-pairs test. In general, subjects exhibited the same pattern of response: Nine infants made more eye-turning responses to the right on trials in which the speech stimulus was delivered at the right, while only two infants were more responsive on catch trials. When speech at the left was examined, twelve infants made more left eye-turns than on catch trials, while only three infants were more responsive on catch trials (see Table 1).

Table 1

Number of Subjects Showing Greater, Less or Equivalent Ipsilateral Responsiveness Under Conditions of Speech Presented at Either Side as Compared to Catch Trials.

	> Catch	< Catch	=	Total
Speech-right	9	2	4	15
Speech-left	12	3	0	15

In contrast to the findings of reliable ipsilateral responsiveness under conditions of separate speech presentation at either side, the data do not indicate any effect of the two separate speech stimulation conditions on contralateral eye-turning. The frequency of turns to the left to speech presented at the right and in the absence of stimulation was not appreciably different, occurring on 16.9% of speech-right and 15.5% of catch trials. Similarly, turns to the right occurred on 15.3% of speech-left trials and on 8.2% of catch trials. The differences were not significant, $\underline{T}$ (9) = 20, $\underline{p} > .05$ for speech-right; $\underline{T}$ (8) = 8.5, $\underline{p} > .05$ for speech-left, one-tailed Wilcoxon matched-pairs tests. The absence of an effect on contralateral eye movements indicates that the lateral speech stimulation produced a specific ipsilateral eye-turning response rather than a general increase in the incidence of lateral eye-movements.

The preceding analysis indicates that speech presented at the right and at the left both resulted in ipsilateral but not contralateral eye-turns. It is possible, however, for infants to show different degrees of ipsilateral responsiveness. Since any such difference could affect the interpretation of systematic lateral eye-turns in the simultaneous speech condition, the degree of ipsilateral responsiveness in the two conditions of separate presentation was compared. The infants made ipsilateral responses on 35.7% of the speech-right trials and 52.5% of the speech-left trials. The difference was not significant, $\underline{T}$ (13) = 26, $\underline{p} > .05$, Wilcoxon matched-pairs test. Although the difference was not significant (N = 14, x = 3, p = .092, Sign test), most infants did however, appear to be more responsive to speech presented at the left than at the right. As can be seen in Table 2, ten infants showed this pattern while only three infants were more responsive to speech presented at the right than at the left.

Table 2

Number of Subjects Showing Greater, Less or Equivalent Ipsilateral Responsiveness Under Condition of Speech Presented at the Left as Compared to Speech Presented at the Right.

	> Speech-right	< Speech-right	=	Total
Speech-left	10	3	2	15

Prior analysis indicated that the direction of the stimulus affects the direction of the response. Inspection of Figure 1 suggests that the direction of the response is also affected by the nature of the stimulus. Thus, under condition of simultaneous white noise presentation, eye-turning to the left was markedly elevated, whereas under condition of simultaneous speech stimulation, eye-turning to the right was elevated. On simultaneous white noise trials, eye-turning responses to the left occurred on 60.3% of trials, whereas such responses occurred on only 15.5% of catch trials. The difference was highly significant, T (13) = 10, p = .005, one-tailed, Wilcoxon matched-pairs test. In contrast, for both simultaneous white noise and catch trials, eye-turning responses to the right were infrequent, occurring on only 5.8% of simultaneous white noise trials and 8.2% of catch trials. The difference was not significant, $\underline{T}$ (5) = 5.5, $\underline{p} > .05$, one-tailed, Wilcoxon matched-pairs test.

This pattern was reversed under condition of simultaneous speech stimulation: For both simultaneous speech and catch trials eye-turning responses to the left were infrequent, occurring on only 21.2% of simultaneous speech trials and 15.5% of catch trials. The difference was not significant, $\underline{T}$ (11) = 26, $\underline{p} > .05$, one-tailed, Wilcoxon matched-pairs test. In contrast, eye-turning responses to the right occurred on 45.5% of simultaneous speech trials, whereas such responses occurred on only 8.2% of catch trials. The difference was highly significant, $\underline{T}$ (11) = 3, $\underline{p} < .005$, one-tailed, Wilcoxon matched-pairs test.

The results indicate that the infant's eye-turning to the right and to the left were differentially affected by the two simultaneous stimulus conditions. This was further supported when the effects of the two simultaneous stimulus conditions were directly compared. Thus, simultaneous white noise stimulation resulted in significantly more eye-turning to the left than that during simultaneous speech trials, $\underline{T}$ (11) = 1, $\underline{p} < .01$, Wilcoxon matched-pairs test, and simultaneous speech resulted in significantly more eye-turning to the right than did simultaneous white noise, $\underline{T}$ (11) = 0, $\underline{p} < .01$, Wilcoxon matched-pairs test. These differential effects are also evident in the consistency with which subjects exhibit one pattern of response for simultaneous white noise stimulation and the reverse pattern for simultaneous speech stimulation.

As can be seen in Tables 3 and 4, the large majority of the infants were more responsive in terms of eye-turning to the left on simultaneous white noise trials than on either catch or simultaneous speech trials and a majority were more responsive in terms of eye-turning to the right on simultaneous speech trials than on either catch or simultaneous white noise trials.

Table 3

Number of Subjects Showing Greater, Less or Equivalent Eye-Turning Under Conditions of Simultaneous Presentation of White Noise or Speech as Compared to Catch Trials.

Simultaneous Condition	> Catch	<Catch	=	Total
White Noise:				
Turns to Left	11	2	2	15
Turns to Right	3	2	10	15
Speech:				
Turns to Left	7	4	4	15
Turns to Right	9	2	4	15

Table 4

Number of Subjects Showing Greater, Less or Equivalent Eye-Turning Under Condition of Simultaneous Presentation of White Noise as Compared to Simultaneous Speech Presentation.

Simultaneous WN	> Simultaneous Speech	< Simultaneous Speech	=	Total
Turns to Left	10	1	4	15
Turns to Right	0	11	4	15

The primary analyses indicated that simultaneous white noise and speech stimulation resulted in consistent and opposite patterns of lateral eye movements. However, when turning to the right and to the left were compared within each of simultaneous stimulus conditions,[1] the results were somewhat equivocal; There was significantly more eye-turning to the left than to the right during simultaneous white noise stimulation, T (12) = 3.5, $p < .01$, Wilcoxon matched-pairs test, but no difference during simultaneous speech stimulation, T (11) = 17, $p > .05$, Wilcoxon matched-pairs test. As can be seen in Table 5, the results reflect, in part, the consistency with which subjects displayed greater turning to the left than right under condition of simultaneous white noise stimulation and an inconsistent pattern of lateral eye-turning under condition of simultaneous speech stimulation.

Table 5

Number of Subjects Showing Greater, Less or Equivalent Eye-Turning to the Right as Compared to the Left under Conditions of Simultaneous White Noise or Speech.

Turns to Right	> Turns to the Left	< Turns to the Left	=	Total
Simultaneous White Noise	1	11	3	15
Simultaneous Speech	6	5	4	15

These results suggest greater lateralization for white noise than for speech. In order to evaluate this more directly, the data

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[1] To explore the possibility of a lateral difference bias in the absence of stimulation, eye-turns to the right and left during catch trials were compared; Analysis revealed no difference between the two turning responses in the absence of stimulation, T (8) = 12.5, $p > .05$, Wilcoxon matched-pairs test.

were analyzed in terms of the number of infants who display the "typical" pattern of lateralization under the two conditions. Typical is defined as $L > R$ eye-turning for simultaneous white noise and $R > L$ eye-turning for simultaneous speech. For simultaneous white noise, atypical = $R > L$ and for simultaneous speech, atypical = $L > R$. The number of infants who displayed the typical as compared to atypical pattern of lateralized response was greater for white noise (11: 1) than for speech (6: 5), as can be seen in Table 5. However this difference was not significant, $\underline{p} = 0.138$, Fisher exact probability test.

Simultaneous white noise and simultaneous speech eye-turning data were also analyzed in terms of degree of lateral differentiation as measured by: $\frac{R - L}{R+L+1}$ for speech and $\frac{L - R}{L+R+1}$ for white noise. A ratio or right-left difference to total number of responses was required because all infants did not make an equal number of responses. One was added to the denominator in order to reduce the inflated response values which could result from a small number of responses on the index. When the infant's differentiation index for simultaneous speech and white noise was compared, the difference was not found to be significant, $\underline{T}\ (13) = 36.5$, $\underline{p} > .05$, Wilcoxon matched-pairs test. The data were also analyzed utilizing the differentiation index but without regard to sign. This was done because one or both conditions could result in bidirectional lateralization, with some subjects more responsive to the left and others to the right on the same condition. The difference between the two conditions was not found to be significant, $\underline{T}\ (13) = 27.5$, $\underline{p} > .05$, Wilcoxon matched-pairs test.

Summary of the eye-turning analysis:

The results indicate that the stimuli influenced the eye-turning responses of the infants and that the direction of the response is affected by the direction of stimulus presentation and by the nature of the stimulus, i.e. white noise or speech. Thus:

(1) Presentation of speech either at the right ear or at the left ear produced turning in the direction of the sound source. This specifically ipsilateral response was equivalent for speech-right and speech-left conditions.

(2) Simultaneous presentation of white noise and of speech affected the eye-turning behavior of the infants in opposite directions; simultaneous white noise presentation produced systematic eye-turning to the left while simultaneous speech presentation produced systematic eye-turning to the right. The direction of responses were highly specific in that there was no elevation of turns to the right for white noise or to the left for speech. Although there is some suggestion that the infant's eye-turning is less consistent for speech than for white noise (i.e. under condition of simultaneous WN presentation, there were significantly more eye-turns to the left than to the right, but the two turning responses were not significantly different under condition of simultaneous speech presentation), no differences in degree of lateralization were found when the two conditions were directly compared.

Cardiac response

The data indicate that cardiac acceleration but not deceleration was influenced by the conditions of stimulation (see Appendix E for means and standard deviations). A Friedman two-way analysis of variance by ranks failed to indicate any effect of conditions of stimulation on cardiac decelerative responsiveness, $\underline{X}_{\underline{r}}^2$ (4) = 5.29, $\underline{p} > .05$. Since the measure of cardiac change utilized in the study (see scoring section) had not previously been used in defining responsiveness to speech stimuli, beat-by-beat cardiac changes during the third to ninth post-stimulus cardiac cycle were also examined for speech trials vs. catch trials to assess whether there existed any pattern of cardiac response to the speech stimulus which might have been obscured by the particular measure utilized in the study. No such pattern emerged from the beat-by-beat examination.

In contrast to the above findings, the data indicate that cardiac acceleration was influenced by the conditions of stimulation. The mean per cent of trials on which acceleration occurred is presented in Figure 2. As can be seen in the figure, in the absence of stimulation and on speech-right and speech-left trials, accelerative responses were infrequent. On simultaneous speech trials, the frequency of cardiac responses was moderate, and under condition of simultaneous white noise stimulation, it was high. A Friedman two-way analysis of variance indicated that the difference among conditions was highly significant, $\underline{X}_{\underline{r}}^2$ (4) = 13.67, $\underline{p} < .01$.

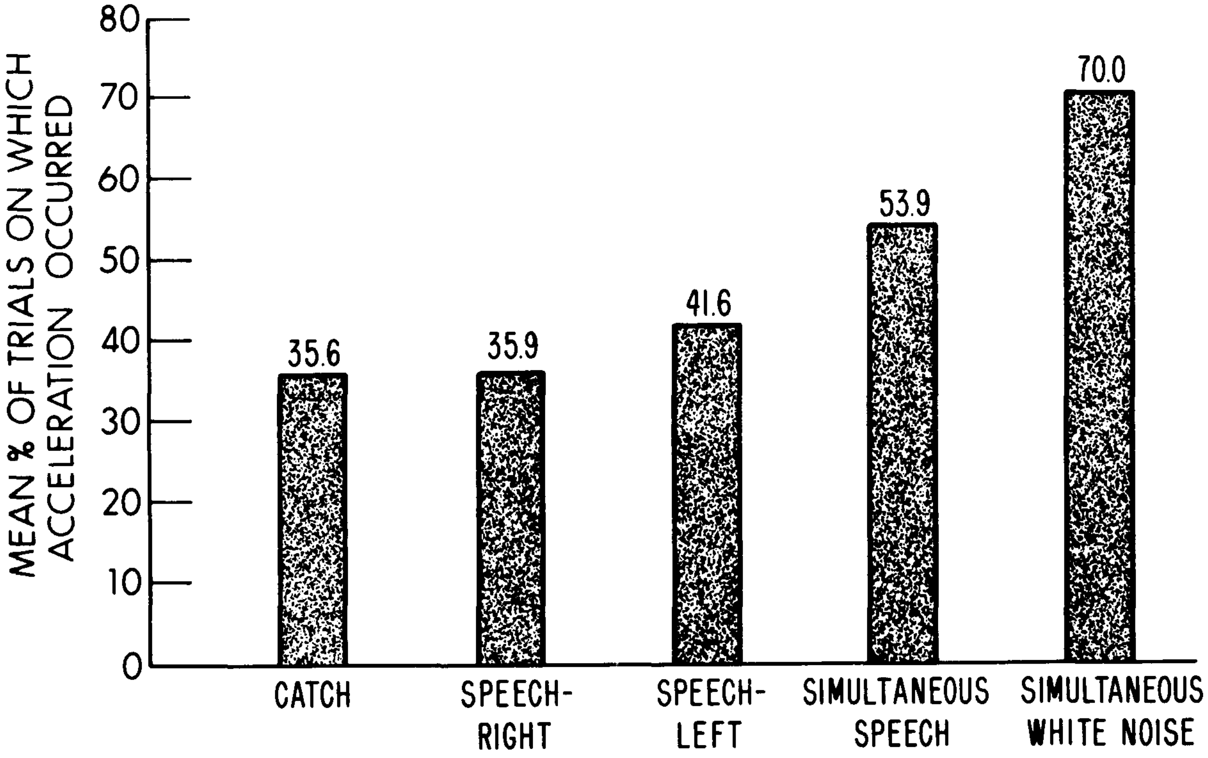

Figure 2. Relationship Between Stimulus or Catch Condition and Percentage of Trials on which Cardiac Acceleration Occurred.

When each of the four stimulus conditions was compared to catch trials, Wilcoxon matched-pairs tests revealed that only the two conditions on which stimuli were simultaneously presented at the two ears produced significant increases in cardiac acceleration, T (13) = 9.5, $p < .005$ for simultaneous white noise; T (14) = 23.0, $p < .05$ for simultaneous speech; T (14) = 28.0, $p > .05$ for speech-right; T (13) = 29.0, $p > .05$ for speech-left, one-tailed Wilcoxon tests. Although the results indicate a significant effect of simultaneous presentation of speech and none for the separate speech presentation conditions, no significant difference in the index of responsiveness was found between simultaneous speech stimulation and speech stimulation at either side, T (12) = 30.5, $p > .05$ for speech-right; T (13) = 32.0, $p > .05$ for speech-left, Wilcoxon matched-pairs tests.

When cardiac acceleration was compared under the two simultaneous stimulus conditions, responsiveness was significantly greater under conditions of simultaneous white noise stimulation than of simultaneous speech stimulation, T (12) = 13.0, $p < .05$, Wilcoxon matched-pairs test.

Sex differences

Analysis of the data did not reveal any differences between male and female infants. No significant differences between the sexes were found with regard to turns to the left or to the right or with regard to cardiac acceleration or deceleration responses under any of the five conditions (see Appendix F for U values).

Latency in eye-turning responses

Although previous studies have found the first second following stimulus onset to be maximally sensitive in defining responsiveness to white noise stimulation, pilot testing and recent reports (Eisenberg, 1976) suggested a longer latency in eye-turning responsiveness to speech stimulation; a longer interval, 0-1.5 seconds, was therefore utilized in this study. In order to examine the effect of utilizing this longer interval, the frequency of first lateral eye movements to occur within the first second following stimulus onset (0-.99 seconds) was compared with the frequency of first lateral eye movements to occur within the 1-1.5 seconds following stimulus onset. The per cent of trials on which the first lateral eye movement occurred within the first interval or within the second interval following stimulus onset is presented in Table 6. As can be seen in the table, even when the fact that the second interval is only one-half the first is taken into account, there is a greater frequency of eye-turning response during the first than during the second interval in all four stimulus conditions. When the data were examined in the context of the obtained results, i.e. differential effects of conditions of stimulation on direction of eye-turning, it appears that the two intervals are differentially sensitive in detecting eye-turning responses to speech and white noise stimulation. Prior analyses indicated that the response to simultaneous white noise stimulation was eye-turning to the left. When this response was examined, it is apparent that the overwhelming majority of responses occur during the first second following stimulus onset. In contrast,

Table 6. Mean Per Cent of Trials Per Second on which Turns to the Right and to the Left Occurred in the First (0-.99 seconds) and Second (1-1.5 seconds) Intervals Post-Stimulus.

	Catch		Speech right		Speech left		Simult. Speech		Simult. WN	
	1	2	1	2	1	2	1	2	1	2
Turns to the right	6.0	4.4	28.0	15.4	10.6	9.4	36.4	18.2	4.2	3.4
Turns to the left	7.7	15.6	15.5	3.4	37.1	30.8	18.4	5.4	58.0	4.4

in each of the three speech conditions, eye-turning during the second interval appeared to contribute appreciably to the directional response associated with the different speech conditions. Thus, for turns to the right to speech presented at the right, turns to the left to speech presented at the left, and turns to the right to speech simultaneously presented to both sides, a substantial proportion of the responses occurred during the second interval, suggesting a more variable and longer latency for the responses to speech than to those for white noise.

CHAPTER IV

Discussion

The results of the present investigation were that under conditions of simultaneous input to the two ears, speech stimulation resulted in eye-turning to the right and white noise stimulation resulted in eye-turning to the left. Current and previous (Turkewitz, *et al*, 1966b) findings also indicate that the eye-turning response to unilaterally presented speech or white noise stimuli[1] is an ipsilateral one. These findings suggest that the response observed in the current study under conditions of simultaneous stimulation represents an orientation toward the side on which the sound is more effectively processed, with modulated speech processed more efficiently at the right ear and a broad spectrum white noise processed more efficiently at the left ear.

The finding that simultaneous white noise stimulation results in a significant increase in eye-turning to the left corroborates earlier findings (Turkewitz and Feiffer, 1976) and provides additional support for the conclusion that the infant processes the white noise stimulus at his left ear more efficiently than at this right ear. Difficulty in interpreting the Turkewitz and Feiffer study result from their findings that

[1] The stimuli were presented at the same objective intensity as under simultaneous presentation and followed a fifteen minute adaptation procedure.

the white noise stimuli presented at the left and right ears separately did not have equivalent effects on eye-turning; Failure to eliminate peripherally determined lateral differences in responsiveness following an adaptation procedure was thought to be the consequence of having utilized a shorter duration of the midline procedure that had previously resulted in the elimination of right-left difference in responsiveness. In the current study this problem was avoided by using a longer adaptation period. The current findings of equivalent effects of right ear and left ear speech presentation on the infant's ipsilateral eye-turning behavior indicate that the adaptation procedure was effective.

The absence of a difference in responsiveness to speech presented separately at the left and right ears also suggests that the right ear advantage for the speech stimulus and left ear advantage for the white noise stimulus are a consequence of the competition situation and do not reflect the kind of peripherally determined lateral differences obtained in previous investigations. Moreover, the finding that the infant makes different responses to simultaneous white noise and simultaneous speech also argues against any simple peripherally determined effect which would be expected to operate in the same direction for both stimuli.

As has been previously noted, studies have indicated that newborn infants will orient their eyes toward sounds of moderate intensity and away from sounds of effectively high intensity (Turkewitz, et al., 1966a; Hammer and Turkewitz, 1975).

It was therefore essential to an interpretation of the results of simultaneous stimulation to determine whether right eye turns represented turns toward the stimulus at the right or away from the stimulus at the left. Although, in the current investigation, unilateral presentation of speech resulted in toward-turning, it is possible that simultaneous presentation of speech at the same sound pressure level had a summative effect, effectively increasing the intensity of the stimulus and thereby producing away-turning. Analysis of the cardiac data revealed systematic cardiac acceleration to simultaneous speech stimulation but not to speech presented independently at the right or at the left. However, there was no significant difference between cardiac responsiveness to simultaneous speech presentation and speech presented at either the right or left. These results suggest a minimal or no summative effect of simultaneous speech presentation, making it unlikely that simultaneous speech was effectively intense resulting in away-turning.

The finding of significantly more cardiac acceleration to simultaneous white noise than to simultaneous speech suggests that the white noise stimulus may have been more potent for the newborn infant[1], which is consistent with Bench's findings (1976) comparing tonal stimuli, voice and a broad-spectrum noiseband at various sound pressure levels. The evidence nevertheless suggests that the noise stimulus was within the range of effectively moderate

[1] See Appendix G for possible bases for the difference.

intensity for the newborn infant. Firstly, previously published findings have reported that the same 87 db white noise stimulus presented spearately to the adapted right and left ears produced toward-turning and no away-turning (Turkewitz, et al., 1966b). Furthermore, the current data indicates little or no summative effect of simultaneous presentation of the speech sound; a strong summative effect of simultaneous white noise presentation is therefore also unlikely. Moreover, previous studies in our laboratories (Turkewitz, et al., 1971; 1972) indicate that white noise stimulation of the left ear at 90 db produces similar levels of ipsilateral eye-turning and cardiac acceleration and no indication of contralateral responding. These results suggest that simultaneous presentation of the 87 db noise stimulus did not shift the effective intensity so as to produce aversive responding (contralateral eye-turning).

While the results of the present investigation indicate lateral differences in the processing of both simultaneous white noise and speech stimuli, lateral differences in processing the white noise stimulus appear to be somewhat more consistent. These findings are the reverse of those found in studies of children and adults where results have been much more consistent with regard to lateral differences in the processing of speech stimuli than of nonspeech stimuli. Although it is not clear whether the findings of the current study are unique to the speech stimulus used, "Hi Baby," or whether they are characteristic of speech stimuli in general, the current findings suggest that changes in the nature of lateral differentiation may occur during early childhood.

The pattern of asymmetry found in the current study, i.e. REA for the speech stimulus and LEA for the noise stimulus, is congruent with that reported in other studies of infants, children and adults; Moreover, the finding of a prominent left ear advantage for processing white noise in the current study supports previously reported finding of a prominent left ear advantage in processing nonspeech sounds in young infants (Entus, 1975) and of a greater right hemisphere advantage in processing nonspeech sounds in young infants than in adults (Molfese, et al., 1975).

In addition to a differential pattern of asymmetry for speech and white noise, observations of the infant's eye-turning behavior in the present investigation suggest other differences in responses to speech and white noise: Firstly, a more variable and longer latency for eye-turning responses to speech than for white noise is suggested, which is consistent with other recent reports (Eisenberg, 1976). Secondly, observations made during preliminary and experimental test sessions suggest that the infant's directional responses to speech stimulation were much more dependent upon an alert or semi-alert state than were such responses to white noise. These observations are consistent with Bench's (1976) findings that less obvious responses, i.e. aspects of the head above the upper lips, to vocal and tonal stimuli were more consistent when the infant was moderately active than when he was asleep but that there was no such state-dependence involved in the infant's response to white noise stimuli. These differences may reflect a difference in the level of the nervous system at which the stimuli are processed since the behavior of awake infants is much more likely to be dominated by cortical functioning. To the extent that the infant's eye-turning responses to speech stimulation (particularly in the simultaneous condition) is dependent on light sleep or wakeful states, as suggested by our observations and Bench's results, this might reflect a dependence upon cortical control mechanisms in processing the speech stimuli whereas the response to white noise stimuli ,which does not appear to be dependent on state, may be determined at lower levels of the central nervous system. Similarly, the longer and more variable latency for eye-turning responses to speech than for white noise is also suggestive of a mechanism for eye-turning response to speech that is more complexly determined.[1] Although the cardiac response to speech does not appear to show this state dependence (see Appendix C), the finding of dissociation between various response indicators in the newborn infant (Turkewitz, et al., 1971) would suggest the possibility of separately organized responses here as well.

Although it has frequently been asserted that the newborn infant is essentially decorticate, recent assessments of the functional and morphophysiological status of the infant's cerebral cortex have indicated substantial maturation at full-term (e.g. Purpura, 1975). It is, therefore, possible that the lateral differences in processing speech may be an early instance of hemispheric differentiation

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[1] It is also possible that the differential latency is peripherally-determined and is related to gross auditory differences between the stimuli such as differences in bandwidth.

whereas the lateral difference in processing white noise may be precortically determined. This possibility is given additional weight by the fact that language and other functions are lateralized at subcortical levels in the adult human (e.g. thalamus, Ojemann, 1975; 1976) as well as at cortical levels.

While these determining factors remain highly speculative, the data on differential patterns of asymmetry, latency and state clearly suggest qualitative differences in response to "hi baby" and white noise. It will remain for future studies to determine whether these differences are related to speech as such and to provide clues as to mechanisms. It has been shown that newborn infants respond differentially to stimuli on the basis of quantitative differences in their effective intensity (Turkewitz, et al., 1966a; Hammer and Turkewitz, 1975). If future analytic studies were to indicate that the differential patterns of response obtained in the current study are based upon qualitative features which differentiate speech from nonspeech, this would suggest that newborn infants may function on a number of more or less advanced levels. On the other hand, it is possible that the differential patterns of response are based upon acoustic properties which are quantitatively different for speech and nonspeech. This latter possibility is intriguing in that opposite patterns of lateralized response to speech-like and nonspeech-like acoustic input could provide a potentially powerful mechanism for subsequent differentiation of speech from nonspeech stimuli and development of responsiveness to qualitative features which differentiate speech from nonspeech.

CHAPTER V

Summary

To determine whether infants process auditory stimuli equivalently when presented to both ears and whether white noise and speech stimuli produce similar or differential patterns of asymmetrical responding,lateral eye movements and changes in heart rate were measured and compared under conditions in which a taped speech stimulus was presented either independently to each ear or simultaneously to both ears and in which a white noise stimulus was presented simultaneously to both ears. Simultaneous stimulation of the two ears resulted in systematic lateral eye-turning, with turning to the right produced by simultaneous speech stimulation and turning to the left produced by simultaneous white noise stimulation. Speech stimulation applied separately at either ear resulted in ipsilateral eye-turning with no significant difference in the effects of stimulation at the left and stimulation at the right. Simultaneous white noise stimulation resulted in significantly more cardiac acceleration than did simultaneous speech stimulation. Although simultaneous speech stimulation produced significant accelerative responding and unilateral presentation at either side did not, no difference in cardiac response was found between simultaneous speech stimulation and speech stimulation at either side. It was found that the systematic lateral eye movements in one direction to simultaneously presented speech stimulation could not be accounted for by differential responsiveness to unilaterally presented stimulation, suggesting that the preponderant lateral turning in one direction was a consequence of competing input to the two ears. The cardiac and eye-turning findings also indicated that the eye-turning behavior to simultaneous stimulation represented an orientation toward the more effective sound source. These results are taken to suggest that the newborn infant processes speech sounds more effectively at the right ear and white noise sounds more effectively at the left ear and that the type of differentiation found in adults' processing of various auditory stimuli may have its anlage in the newborn infant.

Appendix A

Summary of Some of Hécaen's Conclusions Regarding the Ontogenesis of Hemispheric Functional Specialization

Hécaen analyzes twenty-four cases of acquired aphasia in childhood comparing his observations to published clinical and anatomical evidence of both functional and structural asymmetry between the hemispheres early in life. The author's analysis leads him to reconsider Lenneberg's conclusions regarding the ontogeny of cerebral dominance. Taking into account a number of discrepant findings, Hécaen proposes:

(1) the existence of structural lateralization for speech functions extremely early, even prenatally

(2) the need for adequate stimulus during a given period for development of the functional potentialities of the preformed area

In cases of left hemisphere trauma:

(3) the possibility of language displacement to the right hemisphere applying to only a very limited period (i.e. #2 above)

(4) the possibility of an intrahemispheric reorganization by intact "uncommitted" areas which comprise the language zone

(5) the possibility of partial transfer of language representation to the right hemisphere and of reorganization of both hemispheres.

(6) displacement of language representation to a less specialized region, resulting in either functioning at an inferior level or at the expense of other functions which it normally serves.

Appendix B

Consonant vs. Vowel Perception and the Speech-Nonspeech Dichotomy

Liberman, Cooper, Shankweiler and Studdert-Kennedy (1967) have suggested that steady-state vowels are more similar to "nonspeech" acoustic stimuli than are consonants. Adults are able to discriminate among stimuli that represent acoustic variations of the same vowel as easily as equivalent acoustic variations (separated by the same physical steps) across vowel categories (Eimas, 1963). In infants (Eimas, *et al.*, 1971), children (Wolf, 1972), and adults (Liberman, *et al.*, 1967), discriminability of consonants is dependent on category membership. Moreover, sound spectrographic analysis has revealed invariant physical correlates to steady-state vowels along the dimensions of intensity and frequency. The marked lack of correspondence between the acoustic signal and consonant perception, on the other hand, has suggested to Liberman that consonant perception requires a special decoding process in which the incoming continuous speech sound is perceived in discrete categorical units such as a consonant by reference to articulation, which does appear to more closely correspond to the auditory signal. The decoding process, as described by Liberman (1970; *et al.*, 1967) requires a high level of abstraction and a rule-bound construction analogous to the generative grammar proposed by Chomsky. Liberman further explains Shankweiler and Studdert-Kennedy's findings on the dichotic listening task by the existence of a special left hemisphere neural mechanism different from the right for the decoding process involved in the perception of speech sounds.

Appendix C

Results of Cardiac Analysis Using All Data vs. State-Limited Data

Friedman Two-Way Analyses of Variance by Rank:

	All data	State-limited data
Cardiac Deceleration:	X^2_r (4) = 5.60, $p > .05$	X^2_r (4) = 5.29, $p > .05$
Cardiac Acceleration:	X^2_r (4) = 25.93, $p < .001$	X^2_r (4) = 13.67, $p < .01$

Wilcoxon Matched-Pairs Tests for Cardiac Acceleration:

		All data	State-limited data
Catch:	Speech-right	T (15) = 52.0, $p > .05$	T (14) = 28.0, $p > .05$
	Speech-left	T (18) = 50.0, $p > .05$	T (13) = 29.0, $p > .05$
	Simult. Speech	T (16) = 30.5, $p < .05$	T (14) = 23.0, $p < .05$
	Simult. WN	T (18) = 19.5, $p < .005$	T (13) = 9.5, $p < .01$

One-tailed tests

Simultaneous Speech:

Speech-right	T (14) = 17.0, $p < .05$	T (12) = 30.5, $p > .05$
Speech-left	T (16) = 50.0, $p > .05$	T (13) = 32.0, $p > .05$
Simultaneous White Noise	T (16) = 26.5, $p < .05$	T (12) = 13.0, $p = .05$

Appendix D: Number of Trials and Eye Movement Responses for Each Subject and Condition

	Catch			Speech-right			Speech-Left			Simult. Speech			Simult. WN		
		EMs			EMs			EMs			EMs			EMs	
Ss	Trials	R	L	Trials	R	L	Trials	R	L	Trials	R	L	Trials	R	L
1	1	0	0	1	1	0	1	0	1	1	1	0	1	0	0
2	3	0	0	4	3	1	4	0	1	5	1	2	3	0	1
3	3	1	0	4	1	0	5	2	2	6	5	0	4	2	0
4	1	0	0	2	0	0	1	0	1	3	3	0	1	0	1
5	3	0	2	4	1	2	3	0	1	2	0	0	2	0	0
6	3	0	0	4	1	1	5	1	2	3	1	1	3	0	2
7	4	1	0	4	1	1	7	2	4	4	2	2	4	0	2
8	2	0	0	3	0	0	2	0	2	3	0	1	3	0	2
9	3	0	1	4	2	1	4	1	1	5	3	1	3	0	3
10	2	0	0	3	1	0	3	0	1	2	0	0	2	0	1
11	4	1	0	4	2	0	3	0	2	6	1	2	3	0	3
12	5	2	0	5	1	1	4	1	1	5	1	2	4	0	4
13	2	0	2	2	0	1	3	0	1	1	1	0	1	0	1
14	2	0	0	3	1	1	2	1	1	3	0	2	3	0	3
15	6	0	2	8	6	0	5	2	3	6	6	0	8	3	3

Appendix E

Mean Per Cent of Trials on which Eye-turning or Cardiac Responses Occurred and Standard Deviations.

Eye-turning:

		Catch	Speech -right	Speech -left	Simult. Speech	Simult. WN
Turns to Right	$\bar{X}$%	8.2	35.7	15.3	45.5	5.8
	s.d.	14.4	29.5	18.3	41.5	15.4
Turns to Left	$\bar{X}$%	15.5	16.9	52.5	21.1	60.3
	s.d.	30.5	18.4	27.7	22.7	39.6

Cardiac responses:

		Catch	Speech -right	Speech -left	Simult. Speech	Simult. WN
Acceleration	$\bar{X}$%	35.6	35.9	41.6	53.9	70.0
	s.d.	27.3	27.6	28.8	33.1	37.4
Deceleration	$\bar{X}$%	34.6	46.7	37.9	33.4	20.3
	s.d.	32.3	27.4	33.5	11.2	32.4

Appendix F

Sex Differences: Mann Whitney U-Values for Eye-turning Responses to the Right and to the Left and for Cardiac Acceleration and Deceleration.

	Catch	Speech -right	Speech -left	Simult. Speech	Simult. WN
Turns to the right	23.5	15.5	18.5	27.0	26.0
Turns to the left	22.0	22.5	21.0	21.0	17.0
Acceleration	25.0	24.5	26.5	22.0	12.5
Deceleration	24.5	24.5	19.0	22.5	18.0

Appendix G

Possible Bases for the Difference in the Infant's Cardiac Response to "Hi Baby" vs. White Noise

One possible basis for this difference in the current study is that the two kinds of stimuli differed in objective intensity since simultaneous speech was presented at a peak intensity of 87 db. and white noise at a constant 87 db. sound pressure level. Another explanation is that adult listeners perceive patterned and speech sounds as effectively softer (subjects underestimate the SPL to a much greater extent) than constant noise and pure tone signals (Eisenberg, 1970) and this may be true for infants as well. It is also possible that the white noise is not more potent but that the differences in amount of responding are based upon differences in the nature of the response to the speech vs. white noise stimuli. Thus, most studies of newborn infants' cardiac responses to broad spectrum noise stimuli have found an acceleration response (Steinschneider, *et al.*, 1966; Turkewitz, *et al.*, 1971). The nature of the newborn's cardiac response to speech is less well-established. Although Eisenberg (1976) has suggested that infants' (including newborns) cardiac responses to speech sounds are specifically decelerative, the evidence regarding this is thus far equivocal and the data of the current investigation indicate acceleration but no deceleration response to simultaneous speech. Nevertheless, it is possible that white noise produces accelerative responding, while speech stimulation may produce accelerative and/or decelerative responding depending on intensity. If such is the case then speech stimuli at intensities near transition levels might result in predominant acceleration responses but with some deceleration responses as well. Such a combination would result in a reduction in acceleration responses. Although there is no evidence in the current investigation that deceleration responses occurred to the speech stimuli, such an interpretation cannot be ruled out.

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