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The development of auditory figure/ground segregation in young infants.

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THE DEVELOPMENT OF AUDITORY FIGURE/GROUND SEGREGATION IN YOUNG INFANTS

A Dissertation Presented

By

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DEDICATION

To my parents

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ABSTRACT

The Development of Auditory
Figure/Ground Segregation in Young Infants

(February 1, 1979)

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The purposes of the study were: (1) to determine if 12- and 25-week-old infants could detect the addition of their mother's tape-recorded, 5-second greeting to an ongoing background babel of voices, and (2) to determine if a 90° separation of the signal loudspeaker from the background-babel loudspeaker facilitated detection of the signal. A 5-second control signal consisted of extra babel presented in the background babel. Heart rate was recorded and a videotape was made for scoring visual alerting, quieting, head turns to the signal, smiling, vocalizations and fussing.

The results suggested that both the 12- and the 25-week-olds detected the addition of their mother's voice to the background babel as indicated by cardiac deceleration, alerting, and quieting. The control babel produced no response in these measures. Separation of the signal loudspeaker produced a greater cardiac acceleration to the offset of the mother's voice but not a greater deceleration to its onset. Visual alerting and quieting did not increase with separation of the signal from the noise.

There was more head turning, smiling and vocalizing to the mother's voice than to the babel signal, with the older infants showing more of the responses. Smiling and vocalizing tended to be delayed until after the mother's greeting was finished. There was cessation of fussing in the 25-week-olds following the mother's greeting. The head turning, smiling, vocalizing and fussing behaviors occurred very rarely. The results were discussed in relation to the literature, and suggestions for further research were made.

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CHAPTER I

INTRODUCTION

The ability to hear a signal within a noisy backgound, also called auditory figure/ground segregation, is an important auditory skill. Sounds pervade the environment, yet not all sounds are of equal importance to the organism. It is advantageous to be able to discriminate the more important ones. Auditory figure/ground segregation has been studied in adults, but very little is known about the origin and development of the ability.

The purpose of the present study was to determine if infants could segregate auditory figure from ground. The paradigm chosen for study was analogous to that used for studying the so-called "cocktail-party effect" in adults (Cherry, 1953). The task in this situation is to attend selectively to one voice within a context of other competing voices. In infancy, the ability to segregate one message is important in receptive language development, and a deficiency in this ability could impair language learning. In the present study, infants under 6 months of age were observed in order to determine if they could detect the addition of their mother's voice to an ongoing background babel.

A review of the literature suggested that one way adults segregate a signal is by taking advantage of auditory localization when the message and competing voices are spatially separated. Spatial separation facilitates detection in adults. Therefore the present study was an attempt to find (1) whether or not young infants could segregate their mother's voice from a babel, and (2) given that they could, whether or not spatial separation of signal and noise facilitated detection in infants as well as adults. Infants were observed at two ages to see if the ability develops over the first 6 months of life. Heart rate changes were recorded and a videotape was made of behavioral changes. The results are then discussed in light of theories of adult audition and the related infant audition literature.

CHAPTER II

REVIEW OF THE LITERATURE

There are no specific studies of the "cocktail-party effect" (Cherry, 1953) in infancy, although two references are related to it. One allusion to the problem was made by Brazelton (1969) who (based on clinical observations of many infants) suggested that 2-month-olds would orient toward their mother's voice even when others were talking. Bundy (1977) reported pilot data of a study of binaural release from masking in infants. In this situation a tone is embedded within noise to both ears through headphones. Then the tone in one ear is phase shifted so that the signal is 180° out of phase in the two ears. The 4-month-olds were able to use this binaural information to segregate the tone, as indicated by resumption of visual attention to an habituated checkerboard at the time of the shift. The results from these two references indicate that the "cocktail-party effect" warrants further investigation in early infancy.

Due to the paucity of studies of the phenomenon, this review will describe the "cocktail-party effect" in adults and will attempt to lay a foundation for the study of this effect in infants by looking at auditory development. The following topics will be reviewed: auditory figure/ground segregation in adults, maturation of the auditory system in infants, studies of audition in infancy, and studies relating to the heart rate and behavioral responses of infants to sounds.

Auditory Figure/Ground Segregation in Adults

Research with adults has revealed a number of parameters which affect the ability to segregate an auditory stimulus from noise. Thurlow (1971) has reviewed the literature and concluded that whether or not a signal can be detected depends on the relative sound pressure levels (SPL), frequencies, timings, and locations of the signal and noise. In general, the greater the differences between the signal and noise on these parameters, the more likely it is that the signal will be detected. Thurlow emphasizes that there are probably a number of auditory mechanisms producing the effects. The studies have used two types of stimuli: non-speech signals such as tones, and speech.

Non-speech signals. When a signal is obscured by noise it is said to be masked. Monaural masking of tones has been studied with two types of noise: a single pure tone (Wegel & Lane, 1924) and a narrow band of sound (Egan & Hake, 1950; Ehmer, 1959). These studies found a relationship between the relative sound pressure levels of the signal and the noise. Given a situation where the signal was just audible, increasing the noise required the signal to be equally more intense to be heard. The amount of masking is equal to the difference in threshold for a tone with and without background noise. Green and Swets (1966) have suggested that in listening for the tone within noise, the subject is listening for an event with relatively more energy, due to the presence of the tone.

The relative frequencies of the signal and noise influence detection of the signal (Egan & Hake, 1950; Ehmer, 1959; Wegel & Lane, 1924). Tones close in frequency to the masking tone or noise band are more likely to be masked. The masking is caused by the interaction of the sound frequencies close to or the same as the signal's frequency, excluding the phenomenon of "beats." Component frequencies beyond a "critical band" of limits are irrelevant to masking effects (Fletcher, 1940; Scharf, 1961; Swets, 1963). As overall SPL of the stimuli increases, the effect of frequency is more variable. For instance, there is a general effect such that frequencies higher than the critical band are also masked. This effect increases with increasing SPL (Egan and Hake, 1950; Ehmer, 1959; Wegel & Lane, 1924).

Temporal relations are also important in masking. The signal and the noise need not occur simultaneously for masking to be obtained. Both backward and forward masking can occur, depending on the time lag and SPL of the noise burst which follows or precedes the tone (Miller, 1947; Raab, 1963).

The studies discussed so far have involved monaural masking, where the signal and noise are presented to the same ear. When signal and noise are presented to different ears, binaural masking can be obtained, although the effects are usually somewhat smaller (Ingham, 1959; Sherrick & Mangabeira-Albernaz, 1961; Zsislocki, Damianopoulos, Bruining, & Glanz, 1967). Much of the relevant binaural masking research has involved the effect of perceived spatial location differences between the signal and the noise. Langmuir, Schaefer, Ferguson & Hennelly (1944) found that the ability to detect a signal depended on its location with respect to the noise source. Lowest thresholds for detection are found with low frequency signals and marked spatial separation (Hirsh, 1948; Jeffress, Blodgett, & Deatherage, 1962; Jeffress, Blodgett, Sandel & Wood, 1956; Robinson & Jeffress, 1963). Their research supports the hypothesis that phase differences are used to separate the tone from noise. A gain in detection under conditions of certain phase differences is termed a masking level difference (MLD).

Speech signals. Studies using speech signals are different from those using nonspeech signals in that the problem chosen for study is usually not one of detection of the signal, but rather, the intelligibility (reception) of masked speech. There are two categories of speech signal research, those using non-speech background noise and those using speech as masking noise. The perception of speech in the presence of non-speech noise is affected by the same parameters as noise masking of non-speech signals, i.e. SPL, frequency, timing, and spatial location. If the noise has a continuous and uniform frequency composition, the effect of SPL is straightforward. Licklider (1951) has specified the change in threshold for the intelligibility of speech with increasing noise levels. When the frequencies present in the noise are not uniform it is still possible to predict amount of interference with speech perception. This is done by taking an average of the noise levels within each octave band of the frequencies corresponding to the range of frequencies found in speech, (Beranek, 1956; 1957).

Location of the noise source in space relative to the location of the speech signals is also very important in determining amount of interference (Hirsh, 1950; Koch, 1950). The relative disruption decreases with separation of signals and noise, and is due to binaural differences in SPL, time of arrival, and phase (Licklider, 1948).

Besides noise masking of speech from non-speech noise, interference can occur from other messages. The situation where the listener is trying to listen to one message in spite of competing messages is called the "cocktail-party effect" (Cherry, 1953). The "cocktail-party effect" is also subject to the effects of SPL, frequency, timing, and spatial location. In general, any acoustic or linguistic feature which distinguishes one message from another will make it more probable that one will be selected and another rejected (Broadbent, 1958). Louder messages are easier to hear (Egan, Carterette, & Thwing, 1954; Tolhurst & Peters, 1956). If the messages are filtered at different frequencies or spoken by differing voices they are more easily segregated (Broadbent, 1952; Egan, et al., 1954; Spieth, Curtis, & Webster, 1954). The effect of frequency is such that male voices tend to mask male voices more effectively, and female mask female. In addition, because low frequencies usually mask high frequencies with intensities being equal, male voices are more effective at masking female voices than the reverse (Egan, et al., 1954; Spieth et al., 1954). Familiarity of the signal voice aids the listener (Broadbent, 1952; 1958). There is less interference if the messages come from different locations. Location seems to be one of the more powerful cues (Broadbent, 1958; Cherry, 1953; Egan et al., 1954; Plomp, 1976; Poulton, 1953, 1956; Spieth et al., 1954).

Recent research on the masking of speech signals has considered the quality of the speech, as well as its intelligibility. Munson and Karlin (1962) developed one method of speech-quality evaluation, called the iso-preference method. Given a certain level of noise, subjects are asked to rate their preferred level of signal. One interesting finding of their research is that, for a given level of noise, the speech level can be either too high or too low. Also, the more intelligible one of two messages will not necessarily be what a listener will prefer (Beasley, Zemlin, & Silverman, 1972). This research may eventually yield important results relating to infant speech perception, because speech quality is probably important to prelinguistic speech perception. Culp (1974) has shown infants' sensitivity to a talker's voice quality ("harsh" or "pleasant") by their visual attention during the reading of a poem.

One technique used to measure speech quality is Osgood's (1952) semantic differential scaling. Kerrick, Nagel, and Bennett (1969) have used the scale for semantic-differential description of sounds, e.g. loudness and noisiness ratings. The scale might prove useful in operationally distinguishing mothers' speech to babies from speech between adults, as speech to babies seems to have a different quality. Convergent research using acoustical analyses of perceived qualities is needed.

It can be concluded from the adult literature that relative SPL, frequency, sound spectra, timing, and spatial location of a signal and noise are relevant variables to be studied in the development of auditory figure/ground segregation. Discussion of the infant's capacity to perceive these acoustical parameters follows.

Auditory Abilities in Infants

Maturation of the auditory system. At one time it was thought that the newborn was deaf, e.g. Martin & Vincent (1960), or at least had greatly diminished capacity to hear (Aldrich, 1928; Demetriades, 1923). The anatomical development of the ear is nearly complete before the end of gestation, (Patten, 1953). Premature and newborn infants respond to sounds (Hardy, Dougherty, & Hardy, 1959; Richmond, Grossman, & Lustman, 1953; Suzuki, Kamijo, & Kiuchi, 1964; Wedenberg, 1956), and the fetus even responds to sounds in utero (Bernard & Sontag, 1947; Forbes & Forbes, 1927; Peiper, 1963).

In general, the peripheral structures of the ear develop early and growth proceeds caudo-rostrally. At birth the outer and middle ear are formed but growth produces some changes in hearing. The increase in size of the external auditory meatus lowers that particular resonant frequency, which is higher in infants because of the external ear's smaller size. Also, the impedance correction attributed to the middle ear improves with the growth and increased compliance of the tympanic membrane. Robertson, Peterson and Lamb (1968) suggest that the gain in sensitivity due to these changes amounts to only 5-10 dB. Frequently, the functioning of the middle ear at birth is impaired by the presence of fluid and mesenchymal tissue which restricts movement of the ossicles. However, much of this fluid is gone after the first few days of life, and after the first few months it is thought to be completely resorbed (Hecox, 1975).

Bredberg (1968) has studied the development of the sensory cells and nerve supply in the human cochlea. In the 3-month-old fetus the organ of Corti is undifferentiated except for an area near the basal end. Differentiation proceeds in both basal and apical directions from there. Sensory cells are first distinguishable from supporting cells by their darker color after staining. The inner hair cells develop initially, followed by the first, second and third rows of outer cells. The fourth and fifth rows (which are not present everywhere along the basilar membrane) are last to develop, and occur in more irregular patterns. In general, the hair cells are much more regular initially, and become less regular in pattern in the fifth and sixth months of fetal life. Irregularity in pattern is characteristic of the adult form. Bredberg has estimated the average number of outer hair cells to be 13,400, and the average number of inner hair cells is 3,400.

After the hair cells have differentiated there is further development of pillar cells and other supporting tissue. Growth in the fluid spaces occurs beginning in the fifth fetal month. By the sixth fetal month the organ of Corti is developed. Bredberg (1968) found that the fetus, towards the end of gestation, has what seems to be a full complement of hair cells, and none of the children or adults studied by him had damage-free sensory cells and nerves like the fetus had. (His sample was admittedly biased due to terminal illness, previous drug therapy, etc.)

Myelination of the auditory nerve begins in utero and is advanced at birth, second only to myelination of the vestibular system (Peiper, 1963; Yakovlev & Lecours, 1967). Thus, from birth there is rapid neural conduction of acoustic information.

Too little is known about the developmental anatomy of the brain stem to make structural-functional correlations (Hecox, 1975). There is a caudo-rostral progression of myelination of the auditory nuclei. Myelination of the medial geniculate and inferior colliculus is not complete at birth (Rorke & Riggs, 1969). The auditory cortex is immature at birth (Conel, 1963). The earliest fibers to mature are the projections from the medial geniculate. Myelination of these fibers occurs between birth and about 4 years of age. The number of fibers does not change but growth and dendritic arborization do occur. There seem to be no hemispheric differences in anatomy except for the differences in the planum temporale found by Witelson & Paillie (1973) in both newborns and adults. This area is larger in the left hemisphere of both age groups, possibly related to speech perception. The brain waves of the two hemispheres are not synchronized at birth. The fact that the cortex is so immature suggests that binaural integration of sounds may be poor.

Some electrophysiological research has been done on the auditory pathway. However, there are no data on the development of the cochlear microphonic. In newborns, auditory nerve potentials display longer latencies, diminished amplitudes, and higher thresholds than in adults. The responses reach adult values during the first year. The brain stem evoked potential (BEP) (Jewett & Williston, 1971) shows generally longer latencies, diminished amplitude, and higher thresholds than in adults. It is possible to attribute specific parts of the BEP waveform to specific loci in the auditory system. Wave I is attributed to the eighth nerve; it approximates adult performances by the seventh month, postnatally. Waves III and V are attributed to more central processes; they mature between 12-18 months postnatally (Hecox, 1975). One advantage of using the BEP in infant studies is that it seems not to depend on state, as cortical responses do.

Auditory capabilities of the infant. It is well established that the newborn can respond to a number of different parameters of sound. Studies of sound pressure level

(SPL) changes have been concerned with types of responses to different levels and the determination of absolute thresholds. Much of this research grew out of audiometric concerns (Spears & Hohle, 1967). Different thresholds have been established with different types of responses, e.g. 105 dB threshold for auropalpebral response (Wedenberg, 1956); 62.8 dB threshold for respiratory change, (Suzuki et al., 1964); 40-55 dB for heart rate change (Bartoshuk, 1964; Eisenberg, 1965; Steinschneider, Lipton & Richmond, 1966); and 10-17 dB for a BEP (Hecox, 1975). A sharp drop in auditory threshold is seen between three and eight months of postnatal age (Hoversten & Moncur, 1969).

One difficulty with infant threshold studies is that a "no response" does not necessarily mean a lack of detection by the infant. Overt responses do vary considerably, as well. Loud sounds provoke a startle response (Prechtl, 1965) and are more likely to provoke a response than soft ones (Froeschels & Beebe, 1946; Haller, 1932; Stubbs, 1934). The likelihood of a response increases sharply at 60 dB and above (Bartoshuk, 1964; Eisenberg, 1965; Steinschneider et al., 1966); thus most speech is probably audible to the infant. Turkewitz, Moreau, and Birch (1966) suggested that the right and left ears may have different sensitivity, but this finding may be due to the fact that newborns often have their heads turned to the right with the right ear muffled by the bed. Hence, increased sensitivity in the right ear may be a contrast effect. Steinschneider et al. (1966) found an increase in motor and cardiac response with increasing loudness. Bartoshuk (1964) found that the relation between heart rate and SPL between 48 and 78 dB fit a power function. Barnet and Goodwin (1965) did not find a systematic relation between heart rate and SPL, however. Moffitt (1973) found heart rate deceleration with increased SPL in older infants. This finding represents an orienting response to a change in a stimulus previously habituated to, and therefore is not an outright discrepancy with Bartoshuk's (1964) finding of increased heart rate with increasing SPL.

Studies of infant responses to frequency have confirmed that infants do discriminate and respond differentially to them. Infants as young as 1 month of age can discriminate frequency differences as small as 300 Hz (Wormith, Pankhurst, & Moffitt, 1975). Adults are able to perceive a range of 20 to 20,000 Hz under ideal conditions, but are most sensitive to the range of frequencies critical for speech perception (1,000-3,000 Hz), (Keele & Neil, 1965, p. 319). Signals in the critical speech hearing range are also differentially effective at eliciting infant responses (Eisenberg, 1965, 1967, 1969; Hoversten & Moncur, 1969). Low frequency sounds are often soothing (Bench, 1969; Birns, Blank, Bridger, & Escalona, 1965). High frequencies are often distressing (Busnell, 1963; Haller, 1932; Hutt, von Bernuth, Lenard, Hutt, Prechtl, 1968). Sounds of wide bandwidth elicit greater responsivity (Eisenberg, 1965; Hutt, Hutt, Lenard, von Bernuth & Muntjewerff, 1968; and Hoversten & Moncur, 1969). Infants from three to six months of age can distinguish rising and falling intonation (Kaplan, 1969; Morse, 1972).

Infants respond differentially to temporal variations, including duration (Eisenberg, 1965; Keen, 1964; Lipton & Steinschneider, 1964; Stubbs, 1934); repetition rate (Bartoshuk, 1962a; Beadle, 1962); interstimulus interval (Bartoshuk, 1962b; Lipton & Steinschneider, 1964); rise time (Peiper, 1963; Jackson, Kantowitz & Graham, 1971); and are soothed by continuous or rhythmic sounds, as are most adults (Brackbill, Adams, Crowell, & Gray, 1966; Salk, 1962; Tulloch, Brown, Jacobs, Prugh, & Greene, 1964; Weiss, 1934).

Reconsideration of the infant responses to the parameters of sound discussed so far suggests an interesting finding. The SPL (60 dB and above), frequency (1,000-3,000 Hz), band-width (wide), and temporal (continuous and rhythmic) characteristics of sound which are most able to elicit responses from infants are those which characterize human speech. Although it cannot be concluded that infants perceive speech as a special stimulus "innately," it can be said that speech contains those parameters of sound to which infants are responsive. Very young (1-month-old) infants have an ability to process units of speech such as some phonemes in a categorical manner (Eimas, Siqueland, Jusczyk, & Vigorito, 1971; Moffitt, 1971; Morse, 1972). By two months of age, infants can discriminate different voices which were recorded on tape (Boyd, 1972). Infants also learn by four months of age to respond differentially to their mother's and a stranger's voice (LaRoche & Tcheng, 1963) and their mother's voice and its distortion (Turnure, 1971). Also, infants show more quieting and subsequent vocalization to female over male voices (Kagan & Lewis, 1965).

The final ability discussed here is sound localization, which is basic to adult auditory figure-ground segregation. In general, there is conflicting evidence about infants' ability to localize sound. Although some evidence suggests that infants can localize sound soon after birth (Hammond, 1970; Leventhal & Lipsitt, 1964; Wertheimer, 1961), the response has not been found in every study. Aronson and Rosenbloom (1971) found that one-month-olds were distressed by a discrepancy between the location of the mother's face and voice, but their results have not been replicated (McGurk & Lewis, 1974; Condry, Halton, & Neisser, 1977). There is agreement in the Bayley, Gesell, and Cattell Infant Scales that sound localization can be elicited reliably later than 1 month (Bayley, 1969; Cattell, 1940; Gesell, 1925). They suggest that 50% of 4-5-month-olds will turn their head to try to see a hidden object which is making a sound. Ewing and Ewing (1944) and Chun, Pawset, and Forster, (1960), did not find localization of sound until 6 months of age. The ability to search manually for an unseen noisy object develops late in the first year (Freedman, Fox-Kolenda, Margileth & Miller, 1969).

Recent research on sound localization has helped to clarify the issue. Newborns respond to the location of a rattle with a head turn (Muir & Field, in press). However, the response is less frequent at about 2-3 months, increasing around 4 months of age (Field & Muir, 1978). Further work is needed to clarify the reason for changes in the reliability of head turning toward sound between birth and 4 months.

Results of the studies of sound localization which show development of the response within the first half year of life concur with Piaget's (1952) finding with his own children. He maintains that the coordination between vision and hearing is not achieved until 3 months of age. The infant first acquires schemata for "privileged" familiar audio-visual stimuli, such as a face and voice, or a toy that makes a sound. These schemata, which involve audio-visual aspects of the person or object, become "look-and-listen" stimuli. The infant then begins to search for other correlations between sound and image with other less privileged objects, i.e. novel or not familiar ones. Prior to this initial coordination, the infant does not try to look at what he hears, but rather to see while he hears. For Piaget, this accounts for the generalized visual excitation produced by sound before the infant associates sound as a property of a particular person or object.

It can be concluded from the literature on infant audition that they are sensitive to the same acoustic parameters affecting the ability of adults to detect a signal within noise. These parameters are: the relative SPL, frequency, spectrum differences, timing, and spatial location of a signal and noise. This information, combined with the findings of Brazleton (1969) and Bundy (1977) mentioned earlier, suggests that auditory figure/ground segregation would be an interesting topic of study in infancy.

In addition to the consideration of the sensory capacities of the infant, the responses which will be measured must be taken into account. In infant research it is necessary to identify indicator responses which allow us to infer what the infant knows. In the present study, two types of dependent measures were recorded, change in heart rate, and behavioral responses which were recorded on videotape. A review of the literature supporting the use of these response measures with infants follows.

Dependent Measures

Studies of infant responses to sound have used a wide variety of physiological and behavioral measures: e.g., heart rate, respiration change, evoked potentials, startles, quieting, alerting, head turn, smiling, and change in facial expression (Appleton, Clifton & Goldberg, 1975). The present study used heart rate change and several behavioral responses. A review of the use of these measures with infants follows.

Heart rate changes. In their review of the literature, Graham and Clifton (1966) linked the research on the two arousal systems (orienting and defensive) of Sokolov (1963) to the heart rate research of the Laceys (1959, 1967, 1978). Graham and Clifton suggested that the orienting response is accompanied by a heart rate deceleration and an increased receptiveness to the environment. They associated the defensive response with a heart rate acceleration and decreased receptiveness to the environment as the organism mobilizes for action. Graham and Jackson (1970) specified further the differences between the two response systems. The orienting response (1) is elicited by novel stimuli of low or moderate intensity, (2) habituates rapidly with repetition of the stimuli, and (3) occurs at simulus offset, regardless of the stimulus intensity.

In research with infants heart rate deceleration has been associated with attention (Kagan & Lewis, 1965; Lewis, Kagan, Campbell, & Kalafat, 1966; Lewis & Spaulding, 1967; Moffitt, 1973; Wilson & Lewis, 1972). There is evidence for regular decelerations in 2-3-month-olds, the younger of the two ages in the present study (Gray & Crowell, 1968; Hatton, 1969; Lewis, Goldberg, & Campbell, 1969).

Lewis (1975) and Campos (1976) have recently underscored how valuable cardiac responses can be for infancy research. Heart rate can be used when behavioral measures have not yet matured (e.g. Campos, Langor, & Krowitz, 1970). Sometimes the cardiac measures are more sensitive than behavioral measures (e.g. McCall & Melson, 1970).

Campos (1976) has suggested that the bi-directional nature of the heart rate response makes it an especially sensitive tool for studying infant social and emotional development. Stroufe and Waters (1977) agree and point to its usefulness in differentiating overt behaviors which are similar or only subtly distinguishable in aspect. Lewis (1975), Campos (1976), and Sroufe and Waters (1977) note that cardiac change relates to the meaning of a situation for an infant, although Lewis cautions that the response is a vector under the influence of multiple systems and an exact meaning cannot be inferred. For example, an acceleration may be due to anxiety, concentration on problem-solving, or an increase in motor activity. The relation of heart rate to affect is useful in the present study where a socially "significant" stimulus (the mother's greeting) is used.

Behavioral measures. Three categories of behavioral responses were used in the present study as indicating response to sound: alerting, localizing, and social responses. Alerting and localizing indicated detection of the presence and location of the sound, respectively. In the present study, social responses to the mother's voice gave evidence that the infants were indeed segregating a signal, and may have comprehended its social quality, although infants sometimes smile and vocalize to nonsocial stimuli, such as toys.

The category of alerting included behaviors such as looking up and staring, eye widening, and quieting of ongoing motor activity or fussing. Sounds can alert infants to resume visual attention between 3 and 6 months of age (Culp, 1971; Self, 1971). Piaget (1952) noted that sounds elicit generalized looking in infants under 3 months of age, even if specific orienting in the direction of the sound does not occur. Bayley (1969) found that 2-month-olds reliably alert to voices. The age at which infants begin to respond to voices varies from .3 to 2 months of age, with 50% of the infants she sampled showing the response at .7 month.

The category of localizing included head turns to right or left. As was mentioned in the literature on sound localization, infants show a reliable head turn to a sound around 4-5 months of age (Bayley, 1969). Bayley has charted the following course of development of sound localization. First, half of her infants at 2.2 months searched with their eyes to a sound, although not necessarily in the correct direction. The range was from .7 month to 5 months. Second, head turns in the specific direction of a ringing bell were present in half the infants 3.8 months old, with a range of 2 to 6 months. Both Piaget (1952) and Church (1970) found head turn in 2-month-olds to the mother's voice.

Social responses included smiling and vocalizations. Both of these behaviors also develop during the first six months, for voice accompanied by face (Bayley, 1969). LaRoche and Tcheng (1963) found differential smiling to mothers' and strangers' voices between 3 and 6 months. Turnure (1971) found distress in 3- and 6-month-olds when the sight of the mother did not accompany her voice. Babbling also occurs regularly at 3 months (McCarthy, 1954), especially to social stimuli.

Summary of the Review of the Literature

The previous review of the literature suggests the following findings. In adults, auditory figure/ground segregation depends on the relative SPLs, frequencies, timing, sound spectra, and location of the signal and the noise. The previous studies of infant audition indicate that infants response differentially to variations in these parameters. This fact combined with the two references on infant auditory figure/ground segregation suggest that the problem will benefit from study with infants. Both heart rate change and behavioral responses will be appropriate to record as indicator responses in the infants.

CHAPTER III

THE PROBLEM

The purpose of the experiment was to determine if infants could segregate their mother's greeting from a babel of voices. As was mentioned, auditory figure/ground segregation in adults depends on the relative SPL, frequency, timing, and location of the signal and noise. In the present study relative location was systematically varied. The background babel of eight voices was played continually from a loudspeaker directly in front of the infant. At specified intervals the mother's prerecorded greeting to the baby was added from one of two other loudspeakers, either also in front or 90° to the side of the infant. Because spatial separation of signal and noise facilitates detection in adults, it was hypothesized that it would facilitate detection in infants as well. As a control for "right ear advantage," half of the infants had the separated loudspeaker on their right, and half on their left. Heart rate change was recorded and a videotape of behavioral responses was made.

In addition to the mother's greeting, a control signal of extra babel was used. The control is best understood as "babel in babel." It was used because the addition of the mother's voice to the background babel undoubtedly changed the SPL, frequency, rhythm, and location of the ambient sound, despite the masking effect of the background. A simultaneous change in the infant's heart rate or behavior could have been an orienting response to the change in ambient sound rather than segregation of the greeting. Babel added to babel created similar (but not identical) changes in the ambient sound for purposes of comparison. The babel signal consisted of a segment of the background babel equal to the mother's greeting in overall sound pressure level, duration, and location. However, the specific message, frequencies, and rhythm of each mother's greeting were not matched.

Brazelton (1969) claimed that 2-month-olds will orient to their mother's voices even if there are other people speaking at the same time. Therefore, the present study looked for evidence of the discrimination in infants approaching 3 months of age, i.e. 12-week-old infants. The ability to localize sound played an important part in the present study because the relative locations of signal and background were varied. The evidence cited previously in the literature review suggested that sound localization develops during the first 6 months. Accordingly, infants who were 25 weeks old were used in addition to 12-week-olds.

Hypotheses

The hypotheses tested were as follows:

(1) It was hypothesized that the following heart rate and behavioral changes would occur to the mother's voice but not to the added control babel signal:

(a) A heart rate deceleration was expected.

(b) Increases in the duration of alerting, quieting, head turning, smiling and vocalizing were expected to the mother's voice.

(c) Fussing was observed to see if its incidence changed, thereby indicating detection of the signal. The direction of change was not predicted because fussing has been shown to increase to a recording of the mother's voice (e.g. Turnure, 1971), as well as to cease to the sound of a voice (e.g. Brazelton, 1969).

(2) No age differences were expected in response to the mother's voice for heart rate change, alerting, or quieting. Age differences were expected in localizing head turns and social responses (smiling and vocalizing).

(3) Because separation of the signal loudspeaker from the background loudspeaker aids performance in adults, it was hypothesized that it would also aid the infants in the present study.

CHAPTER IV

METHOD

Subjects

The subjects were 32 infants equally divided into two age groups. Half the infants were 12-week-olds (11-13 weeks of age), and half were 25-week-olds (24-26 weeks of age), with an equal number of males and females at each age. In order to obtain 32 infants with complete data, 20 extra subjects were obtained. The reasons for replacement of subjects were as follows: 7 infants fussed and the session was stopped early; 11 infants had heart rate data with artifacts; and the data for 2 infants were lost due to experimenter error.

Parents of infants of the appropriate age were located through newspaper birth announcements, informed of the project by letter, and invited to bring their child to the Psychology Department for the experiment. A framed polygraph record of their infant's heartbeat was given to the parents in appreciation for their participation, and they received a research report with the project results; see Appendix A for samples of the letter and the report. The experimental procedures were approved in advance by the Psychology Department's Committee on the Use of Human Subjects.

Stimuli

Each subject was exposed to two tape-recorded signals, the mother's greeting and the babel signal, as well as the background babel . All signals were presented via loudspeakers. The background babel consisted of a recording of four male and four female voices reading different material aloud simultaneously. It was obtained by having two male and two female voices record two reading sessions on the same tape with a Sony Stereotapecorder SCS TC-252. This tape recorder can re-record over the same section of tape without erasing the initial stimulus; thus the four initial voices produced eight simultaneous streams of speech. The same tape recorder was used to record the mother's voice, which was recorded on a visit to the infant's home prior to the laboratory visit. To obtain the greeting, the mother was asked to try to get her baby's attention by calling the baby for 5 seconds. Whenever possible, the infant was present in the room. An attempt was made to elicit from the mother a greeting which actually did get the baby's attention, preferably including a head turn. The control signal was a 5-second segment of extra babel.

The background babel was played at approximately 60 dB (C), with SPL readings never fluctuating above 63 or 64 dB as measured by a General Radio Type 1565-A Sound-Level Meter. Although it was desired to have a 1:1 signal/

noise ratio in this initial study, there was a problem in that addition of the signal to the background elevated the overall SPL slightly. Because the infant might orient to the overall SPL increase without really segregating the signal, the mother and babel signals SPLs were made to be slightly less than the background levels. Signals which averaged about 55 or 56 dB with fluctuations of 58 or 59 dB were used. They were found not to raise the overall SPL reading of the ambient sound when added to the 60 dB background babel , whereas louder signals did.

Apparatus

The infant sat in an infant seat on a table enclosed above and on three sides, with the mother seated directly behind the infant. (See Figure 1.) Facing the infant was a stage-like 43 x 100 cm opening decorated with multi-colored shapes and mobiles. In the center of the stage, and in front of a curtained backdrop, was a Sony AVC-3200 video camera and a microphone. If the infant faced straight ahead in the infant seat, he or she looked directly into the visible camera lens set at eye level. The colorful display and the camera helped direct the infant's attention toward the front. The microphone transmitted the infant vocalizations.

Mounted on the wall behind the curtained backdrop was the first signal loudspeaker, 140 cm from the infant at

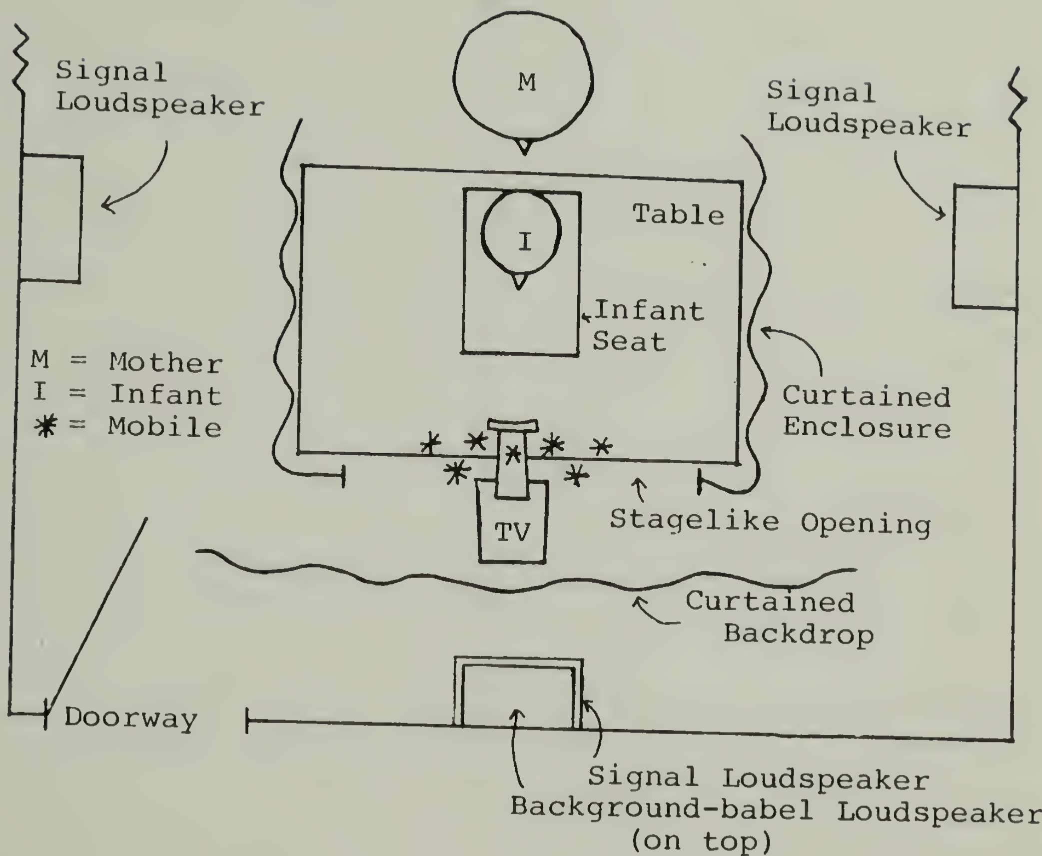

Figure 1: A Schematic Diagram of the Experimental Setting.

eye level. The second signal loudspeaker was also 140 cm from the infant at eye level, but was directly to the side of the infant. Half the infants had the side signal loudspeaker to the right, and half to the left. The loudspeaker which played continual background babel was on top of the front signal loudspeaker. Thus it was above 12 cm above the infant. The vertical separation of the signal and background noise which occurred due to the placement of the front loudspeakers was probably not discriminable to the infants because sound localization within the median plane is very poor even in adults (e.g. Licklider, 1951, p. 1029). The babel was played from the Sony SCS TC-252 Stereotape-recorder on which it had been recorded. The signals were played over two identical AR-7 loudspeakers whose frequency response is essentially flat between 60-12,000 Hz. The infant's vocalizations were amplified by a Realistic SA 100B solid state stereo amplifier prior to being recorded.

The equipment room which contained most of the stimulus and recording apparatus was outside of the second chamber. The video image and the amplified infant vocalizations were recorded on a Sony AV-3650 Videocorder, with DAK videotape. The 5-second mother and babel signals were prerecorded onto identical tape loops which played on a Revox FM tape recorder running at 3 3/4 ips. The tape loops allowed the signal to play repeatedly with an identical interval of 22 seconds between each stimulus onset. The tape loops were changed halfway through the experiment so that each infant received both mother and babel signals. The 5-second signals were amplified by a Pioneer SX-434 Stereo Receiver and directed to the front or side signal loudspeakers throughout the experiment as desired. A TV monitor allowed the experimenter to evaluate the infant's state during the experiment while presenting stimuli from the equipment room.

An electrocardiogram was recorded from three Beckman electrodes placed on the infant's chest. One active lead was placed high on the sternum while the second active lead and ground were placed on the lower ribs about 5 to 6 cm on either side the midline. The signal was first filtered and amplified by a Data, Inc., Instrumentation Differential Amplifier, Model 1124, before reaching the polygraph. The polygraph consisted of a Hewlett-Packard 350-3200A ECG preamplifier, with a Hewlett-Packard 7714-04A power supply and a 7700 Series Recorder. The amplified heart rate signal was recorded on a Vetter C-4 FM Cassette Data Recorder, along with a stimulus pulse signaling the start of each trial. The signal pulse was automatically produced by a custom-built voice-activated relay triggered by the onset of the 5-second voice and babel stimulus and control signals. The voice-activated relay also triggered an Eico 377 Audio Generator, which added a 2000 Hz sine wave to the sound recorded on the Sony Videocorder. The latter enabled audio scoring of signal onset on the videotape because the vocalizations and ambient sound also being recorded didn't afford a discriminable stimulus. Blind scoring of all behaviors except fussing and vocalizations was achieved by completely attenuating the audio channel on the video monitor. Fussing and vocalizations were scored with the observers blind to the stimulus situation but not to stimulus onset.

Experimental Conditions

Each infant received a total of 12 trials. Half of the trials had the mother's voice (M) as the signal, and half had the babel signal (B). Of the 6 trials of each type of voice, half were presented from the front (F) and half were from the side (S). (As was mentioned, half the infants had their side speaker to the right and half to the left.) Thus there were four types of signals: MF, MS, BF, and BS. Each type was presented three times.

The infants were divided into two groups which received different orders of conditions. Either the infant received 6 trials of the mother's greeting before the 6 trials of the babel, or the infant received the babel first. The specific order of front and side trials within each type of signal was determined randomly, with the restriction that half the infants received the first signal from the front, and the other half received the first signal from the side. Order of front-or-side location of first signal was not included in the analyses.

Procedure

Each infant was brought to the laboratory by a parent who was present throughout the experiment. Infants were tested only if awake, quiet, and alert. The background babel was turned on immediately upon the infants' arrival and remained on until the session was over. The recording electrodes were placed on the infant. The parent read a short explanation of the procedures and gave written permission. (See Appendix A for a copy of the explanation and permission form.) An oral description of the experiment had already been given to the parent during the home visit.

The infant was placed in the infant seat, and the double doors to the sound chamber were closed. The two recorders (video and heart rate) were started, and after about 30 seconds the first trial started. The infant's state of arousal was noted and recorded on each of the 12 trials. If the infant became drowsy or began to cry, the session was stopped. However, some fussing was tolerated if it was brief and mild. Parents were informed that they could stop the session any time they wanted without prejudice to them or their child. Each visit lasted about 30 minutes, with about 6 minutes of that being the actual data collection.

Data Reduction

Coding of data.

Heart rate data. A small electrical signal is associated with each heart beat, and it is this 2 mV signal which is amplified and recorded in studies of heart rate. The signal consists of a particular pattern of fluctuation in voltage which is repeated with each beat. See Figure 2 for an example. The large r-wave can be "recognized" electronically and is used to indicate the occurrence of each beat. The heart beat intervals (or times between R-waves), can then be clocked and a measure of heart rate in beats per minute (bpm) computed. For a more detailed discussion of the heart beat signal and its measurement, see Brener (1967).

In the present study, the magnetic-tape recording of the amplified waveform was played through a Hewlett-Packard 2100 computer which timed the intervals between R-waves. A weighted average of heart rate in bpm was computed for each second. The formula for computing the weighted average for heart rate in bpm is presented in Figure x of Appendix B. When the average for each second was computed, all R-R intervals including fractions of an interval which fell within that second contributed to the average. The R-R intervals were weighted in proportion to the time in the second they occupied. For example, two R-R intervals of one half second

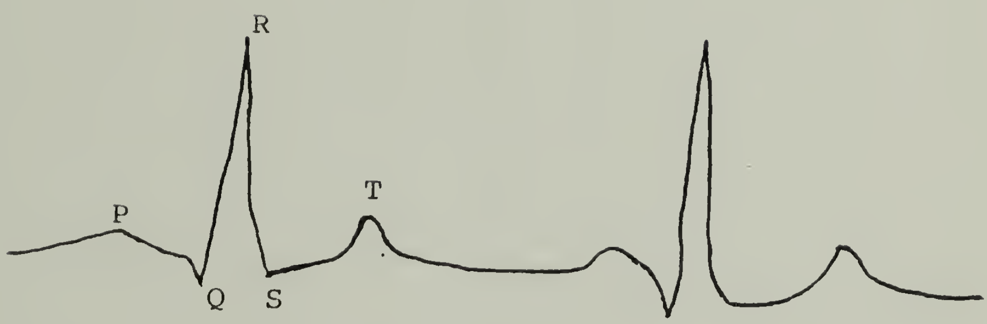

Figure 2: An Example of a Typical Waveform Associated with a Heart Beat: two beats are represented with the components in one of them labeled.

duration each which filled a one-second period exactly would have their values weighted equally. But if one of the R-R intervals occupied more than one half of a second of the one-second period it would be weighted proportionally more in computing the average for that second.

The weighted average R-R intervals were then converted into average heart rate in beats per minute for each second, beginning 3 seconds before each stimulus onset and ending 15 seconds after each stimulus onset. Thus 18 seconds of data were obtained for each trial. Although details of the analysis of the heart rate data will be reserved for later, it should be noted that only 1 of the 3 pre-seconds was used in the analyses, along with the 15 post-seconds. Extra pre-seconds were obtained in the event that an artifact (from movement, etc.) obscured the first pre-second. Only 1 pre-second was necessary for analysis because Clifton and Graham (1968) found that 1 pre-second accounted for as much of the variance in response as the average of 5 pre-stimulus seconds.

Heart rate was recorded for 15 post-stimulus seconds in the present study, even though Graham and Jackson (1970) note that they most often record heart rate for 20 seconds after stimulus onset. They indicate that some flexibility is called for in determining how long each trial should be in any particular study. Fewer seconds were recorded here because the trial length was comparatively short (22 seconds) in order to keep the infants in an optimum state of arousal. Also, the stimulus duration was only 5 seconds and thus enough time (10 seconds) remained after stimulus offset for recording the return to baseline rate, given that a change had occurred. This was followed by 4 seconds of stabilization when no data was obtained. Third, behavioral ratings were obtained for 15 seconds after the stimulus onset, and thus heart rate data was consistent with the behavioral data in this respect. Heart rate data was thus available for 18 of the 22 seconds in each trial.

Graham and Jackson (1970) further suggest that 3 to 4 trials of each type be averaged together to obtain more reliable data for each infant. As was mentioned, the present study averaged 3 trials of each type of stimulus. Graham and Jackson also suggest that when responses to stimulus parameters are of interest, rather than habituation, that different types of trials be interspersed. For this reason, the front and side trials were interspersed. The mother's voice and the babel signal were not interspersed because they were on different tape loops. Blocking them made the procedure simpler.

As was mentioned, 11 infants were eliminated from the study because of artifactual heart rate data. Artifacts occur when other electrical activity, such as that produced by muscle movement, is recorded along with the heart rate signal. When minor artifacts occurred in otherwise good data an average rate in bpm was substituted for that particular second. For example, if heart rate were 150 bpm, then 259 bpm, and then 148 bpm in 3 successive seconds, the 259 bpm figure (physiologically impossible and artifactual) was changed to 149 bpm. The criteria used for changes are listed in Appendix B along with Table 12 which indicates those changes which were made.

In summary, heart rate in bpm was obtained from the electrical heart beat signal for at least 1 second prior to each stimulus onset and 15 seconds post-stimulus for each of the 12 trials for each infant.

Behavioral data. A videotape of each infant was recorded. Types of behavior which were scored as showing detection of a signal within the background babel included visual alerting, quieting, head turns to either the right or left, smiling, vocalizing, and fussing. These responses were operationalized as follows:

(1) Visual alerting

(a) Eye widening, starting from that infant's baseline. It could be due to looking up.

(b) A sudden head movement to a stationary position.

(c) The eyes could either stare or search.

(2) Quieting

(a) The sudden cessation of gross head and body movement.

(b) Some slight digital, facial, or eye movement was permissible, e.g., slight mouthing or moving a digit.

(c) This behavior was also imposed on an average subjective baseline, set in a practice run.

(3) Head turns

(a) It was noted whether they were right or left turns.

(b) Turns had to be greater than 30° to the side.

(c) The return component was included in the turns.

(4) Smiles

(a) Widening of the mouth.

(b) Brightening.

(5) Vocalizatons, pleasure

(a) Coos were included.

(b) A vocalization did not include the short grunts which sometimes occurred with breathing.

(6) Fussing

(a) Fussing or crying.

(b) Distressed facial expressions aided in distinguishing fussing.

(7) Stimulus onset

(a) The onset of the stimulus was noted when it occurred by a 5-second press of the push-button. (The 5-second duration was automatically produced.)

The videotape recorded the entire session with each infant, but only specific time periods were of interest and were, therefore, included in the analyses. Because the signal had a duration of 5 seconds, the time periods used for analysis also had 5-second durations. Four 5-second periods were used, comprising 20 seconds of each 22-second trial. This is different from the heart rate data, where a second-by-second analysis was performed. Second-by-second analysis was possible with the heart rate data because of the continuous,labile nature of the response. The behaviors which were rated were less labile than heart rate change and were also likely not to occur.

The four consecutive 5-second periods used for coding and analyzing the behavioral data were identified as follows: (1) A pre-stimulus period which preceded the stimulus onset by 5 seconds, (2) An onset period corresponding to the 5 seconds when the signal was on, (3) An offset period corresponding to the 5 seconds immediately after the signal ended, and (4) A post-stimulus period of 5 seconds after the offset period. The amount of occurrence of each behavior within these 4 stimulus periods was noted.

The scoring of the behavioral data was accomplished by means of a system of push-buttons which were connected to a clock in a Hewlett-Packard 2100 computer. A push-button was pressed when the observer judged that a particular behavior began, it was held down until the behavior stopped, and then the push-button was released. The beginning and end-times of each behavior were stored in the computer and subtracted to obtain the amount of behavior. The data for the 3 trials of each type of stimulus (MF, MS, BF, and BS) were then averaged so that each subject's data represented the average amount of behavior in each condition. Within each of the four stimulus types, information was coded into the four stimulus periods within a trial. In other words, there were 16 data points for each infant for each of the behaviors. These represented the average occurrence of the behavior within the four stimulus periods for each of the four types of signals (MF, MS, BF, and BS).

The author and a trained Hampshire College undergraduate, Dana Blackmer, observed the videotapes and rated the behaviors. Blind scoring as to the moment of stimulus onset was achieved by completely attenuating the audio channel on the video monitor. Two exceptions to this were the behaviors of vocalizing and fussing which required the audio channel for scoring. However, the observers were blind to the particular stimulus condition of vocalizing and fussing, even though they were aware of the onset of a signal. It should be noted that the author collected the data for each infant, and it is possible that some conditions were remembered during scoring for some infants. However, the scoring of the videotapes was done several months after data collection, and it was not the author's impression that information about order or location, etc., was remembered, as a rule.

Inter-observer reliability was established before the behavior rating began. The two observers scored the behavior of the same infant independently (i.e. they observed the videotape at different times) and a measure of agreement was computed. The measure reflected the percentage of the time that it was agreed that the behavior either was or was not occurring. Infants were chosen for scoring in the reliability test for a behavior only if they exhibited comparatively high levels of that behavior, e.g. an infant who never smiled was not chosen as the subject to be observed for the reliability test of smiling. Coding of data was begun after agreement was 90% or better for each behavior. At the completion of coding of the videotapes a post-test was conducted for each behavior. The results of the pre- and post-tests are in Table 1.

Analysis of data.

Heart rate data. The need for specific ways of viewing and analyzing heart rate data arises from consideration of the nature of heart rate as a continuous, labile response. It is the second-by-second change in heart rate to the presentation of the stimulus which is of primary concern. Interactions of the seconds variable with other var-

TABLE 1

RELIABILITY COEFFICIENTS FOR THE VIDEO BEHAVIORS[a]

Behavior	Pre-test	Post-test
Alerting	.924	.909
Quieting	.938	.933
Right Turn	.965	.979
Left Turn	.983	1.000
Smiling	.984	.938
Vocalizations	.987	1.000
Fussing	.919	.997
Stimulus pulse	.988	.997

[a]Each coefficient reflects the percentage of time that there was agreement that the behavior either was or was not occurring.

iables are also important, because they indicate that the heart rate response was different to the different levels of another variable. Main effects and interactions of variables other than seconds are of lesser importance in the present study, because they indicate only that the averages of the entire 16 seconds of heart rate data were different as a result of the different conditions. For example, if the average heart rate throughout the trials was 150 bpm for the 12-week-olds and only 140 bpm for the 25-week-olds, the main effect for age might be statistically significant. This finding provides little information about the presence or type of response to the stimulus for the two age groups, though it might indicate a state difference between the groups. In the present study it is the response to the stimulus which is of uppermost importance.

There are several other important considerations related to the seconds variable in heart rate data. The statistical meaning of a seconds effect is that two or more of the seconds being analyzed differed from each other. It is possible that a seconds effect could be found, therefore, when the difference did not relate to a psychologically meaningful heart rate response. In conjunction with this, heart rate change involved 16 points of data (for the 16 seconds). Consequently, the degrees of freedom were large, increasing the likelihood of a Type I error. Therefore, in the present study, analyses of heart rate which produced significant main effects and interactions of the seconds variable were always followed up by trend analysis. When a seconds effect was not supported by a significant trend, it was considered unreliable. Trend analysis enabled identification of the form of the function produced by the heart rate change. It also involved fewer degrees of freedom than the original analysis of variance and this tended to control for the inflated possibility of a Type I error due to the 16 data points.

It was decided to test for linear, quadratic and cubic functions. A significant linear trend indicated a uni-directional acceleration or deceleration in heart rate. A quadratic function indicated an acceleration or deceleration which was followed by a return to base level or beyond. An example of a quadratic trend would be a deceleration in heart rate followed by a return to baseline. It might indicate an orienting response to the onset of the stimulus. A cubic trend indicated a heart rate change followed by a return to base level or beyond, followed by yet another change. An example of a cubic trend which could have occurred in the present study might be a deceleration in heart rate to the onset of the mother's voice, followed by an acceleration to supra-baseline levels before stabilization at baseline level. This example could have occurred as an orienting response to the mother's voice, followed by a distressed response to the termination of her greeting and lack of visibility before the heart rate returned to baseline. Other more complex trends (e.g. quartic) were not examined because no hypotheses concerning the psychological meaning of these trends were made. Trend analyses were not performed when there was no significant seconds effect.

The analyses of variance of the heart rate data were of the same general form. There were nine independent variables in all. The between-subject independent variables were: age, sex, order of signal (trials with the mother's voice first vs. trials with the babel signal first), right vs. left-side loudspeaker, and individual subject. The within-subject independent variables were: type of signal (the mother's voice vs. the babel signal), location of signal (front or side), trials, and seconds. The significance level was set a $p < .05$ Each analysis will be described more specifically when it is presented in the Results section.

Behavioral data. Data was obtained for seven behaviors. Only four of those behaviors occurred frequently enough to justify statistical analysis. These four were visual alerting, quieting, and right and left head turns. The findings of the other three behaviors were described as supporting data. These three others were smiling, vocalizing, and fussing. The analyses of variance of the behavioral data were similar but not identical to the analyses of the heart rate data. The between-subject independent variables were: age, sex, order of signal presentation, right vs. left-side loudspeaker, and individual subject. The within-subject independent variables were: type of signal, location of signal, and periods. (Periods correspond to the 5-second stimulus periods described above, e.g. pre-stimulus period.) Again, the criterion significance level for the behavioral data was $p < .05$.

Pilot Study

An initial experiment was conducted with 4 infants, 2 at each age, to determine the response to the mother's greeting and babel signal when no background voices were present. Because of the small number of subjects, the loudspeakers were directly to the front and 90° to the right of the infant, never to the left. Other than the silent background and the omission of left loudspeakers, the procedure was the same as for the experimental study outlined above. Heart rate was recorded.

The results of the pilot study showed heart rate deceleration to the onset of both signals presented in a silent background. The mean change in heart rate for the pilot subjects is shown in Figure 3 as responses to the mother's voice and the babel signal both separately and in combination (see Figure 3). An age (2) x subject (2) x voice (2) x location (2) x trials (3) x seconds (16)

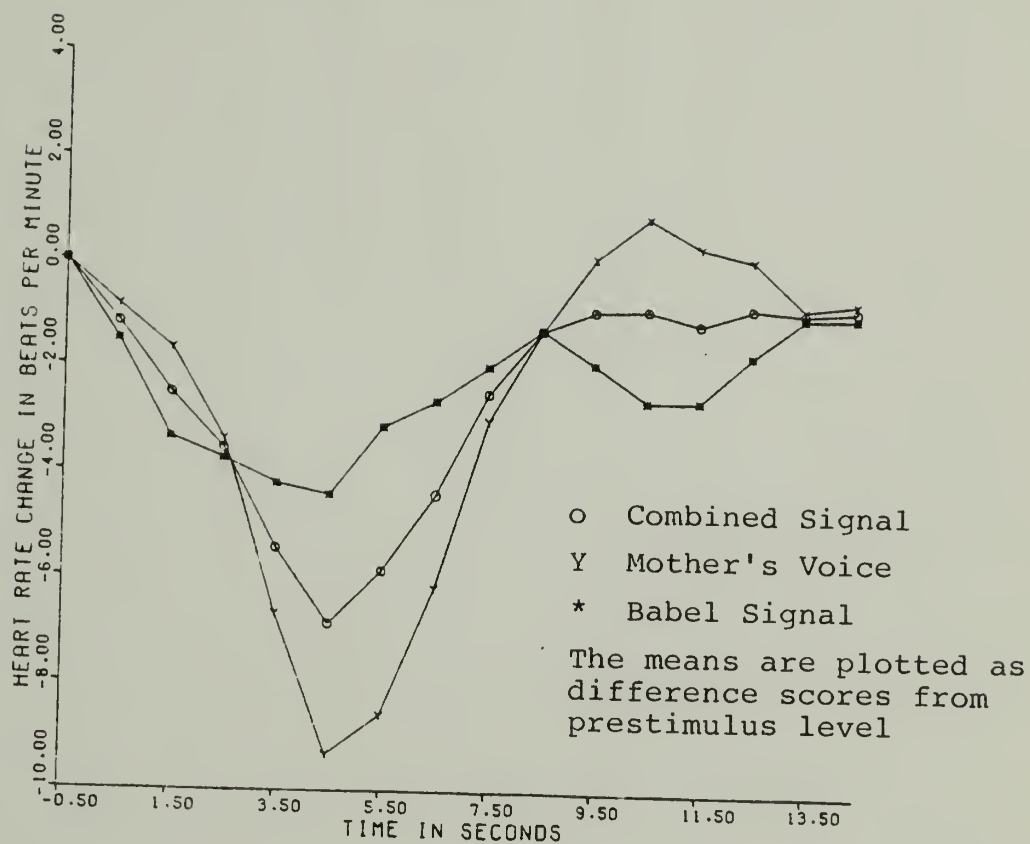

Figure 3: Average Heart Rate Change to Mother's Voice, Babel Signal, and Combined Conditions for the Pilot Subject.

analysis of variance was conducted on the heart rate in bpm for 1 second preceding and 15 seconds following the onset of the 5-second signals (see Appendix C, Table 13). There was a significant effect of seconds, $F\ (15,30) = 4.20$, which was supported by a significant linear seconds effect, $F\ (1,2) = 86.10$. There was also a significant interaction of voice and seconds, $F\ (15, 30) = 3.07$ The interaction was supported by a significant voice x cubic seconds effect, $F\ (1,2) = 44.43$. The interaction suggested that there was greater deceleration to the mother's voice, as can be seen in Figure 3, although an average deceleration of about 5 bpm occurred to the babel signal. There were no age differences (see Appendix C, Table 13).

It should be noted that the heart rate deceleration is 5-10 bpm. The magnitude and direction of this response is similar to that found previously in the literature.

CHAPTER V

RESULTS

The findings are presented with regard to the initial hypotheses for the heart rate data and for each of the rated behaviors.

Heart Rate Data

Preliminary analyses of heart rate change.

The following preliminary analyses were conducted on the heart rate data:

(1) Heart rate was measured immediately preceding stimulus onset for each of the 12 trials. The 12 prestimulus seconds were analyzed in the event that differences in values occurred in baseline heart rate due to age or across trials. Differences in baseline heart rate can occur as a result of changes in the infants' state of arousal. They are important because of the law of initial values (LIV). The LIV holds that the initial value or level of heart rate can affect the magnitude and direction of heart rate change independently of stimulus factors (e.g. Wilder, 1958). For example, if heart rate is initially very fast and a startling stimulus is presented, there may not be as great an acceleration in heart rate as when the

rate is initially slower.

(2) Preliminary analyses of heart rate change were also conducted separately on the between-subject independent variables of sex, order of signal presentation, and right- vs. left-side loudspeaker. These variables were primarily for control purposes and were of lesser interest. Analyzing them separately simplified the main analysis.

Analysis of prestimulus heart rate levels. There were no differences in baseline heart rate levels. The mean prestimulus heart rate level as a function of age and trial is shown in Table 2. These data are for the one-second period prior to the onset of the signals. They are ordered by trial number rather than stimulus type to test for variation in initial level with age over time during the experimental session. An age (2) x subject (16) x trial (12) repeated-measures analysis of variance performed on these data revealed no systematic differences in prestimulus heart rate levels, see Appendix D, Table 14.

Preliminary analysis of heart rate change for male vs. female infants. Mean heart rate change to the mother's voice vs. the babel signal is presented in Figure 4 for males and females. It should be noted that the scale for this and subsequent figures is different than that for the pilot data. An age (2) x sex (2) x subject (8) x voice (2) x location (2) x trials (3) x seconds (16) repeated-measures analysis of variance on these data yielded no signifi-

TABLE 2

THE AVERAGE PRESTIMULUS HEART RATE AS A FUNCTION OF AGE AND TRIAL NUMBER[a]

Age	Trial Number											
	1	2	3	4	5	6	7	8	9	10	11	12
12-Weeks-Old	147.7	146.1	146.8	148.0	148.8	149.3	147.2	150.6	148.5	149.5	149.4	150.4
25-Weeks Old	141.9	141.4	145.4	144.8	146.4	147.1	147.0	146.6	144.4	145.1	143.4	146.4

[a]N=32, equally divided by age.

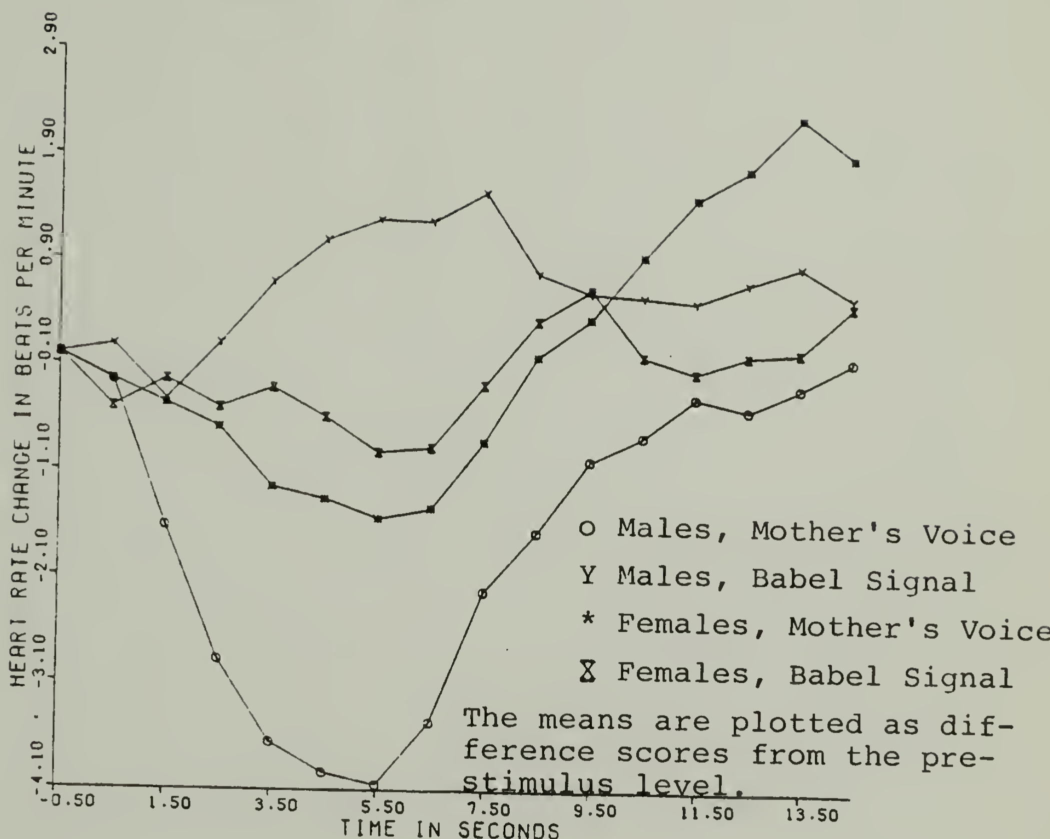

Figure 4: Average Heart Rate Change to Mother's Voice vs. Babel Signal for Males and Females.

cant effects indicating that males and females responded differently to the stimulus conditions. A number of higher-order interactions were significant but were not interpretable; see Appendix D, Table 15, for a summary of all significant effects and interactions involving the variable of sex.

Preliminary analysis of heart rate change for order of signal presentation. Whether the infant received the block of trials with the mother's voice or the babel signal first did not affect the overall response to the two signals. The mean heart rate responses to the mother's voice and the babel signal are presented in Figure 5 for the two groups of infants receiving different orders of presentation of the signals. An age (2) x order (2) x subject (8) x voice (2) x location (2) x trials (3) x seconds (16) repeated-measures analysis of variance on these data revealed no differences in response for the groups receiving different orders of signal presentation; see Appendix D, Table 16, for a summary of all significant effects and interactions involving the variable of order. Several higher-order interactions were significant.

Preliminary analysis of heart rate change for right- vs. left-side loudspeaker. This analysis tested for an effect of the right- vs. left-side location of the side loudspeaker. Location of the side loudspeaker (right vs. left) did not affect the infants' responses to the four types of

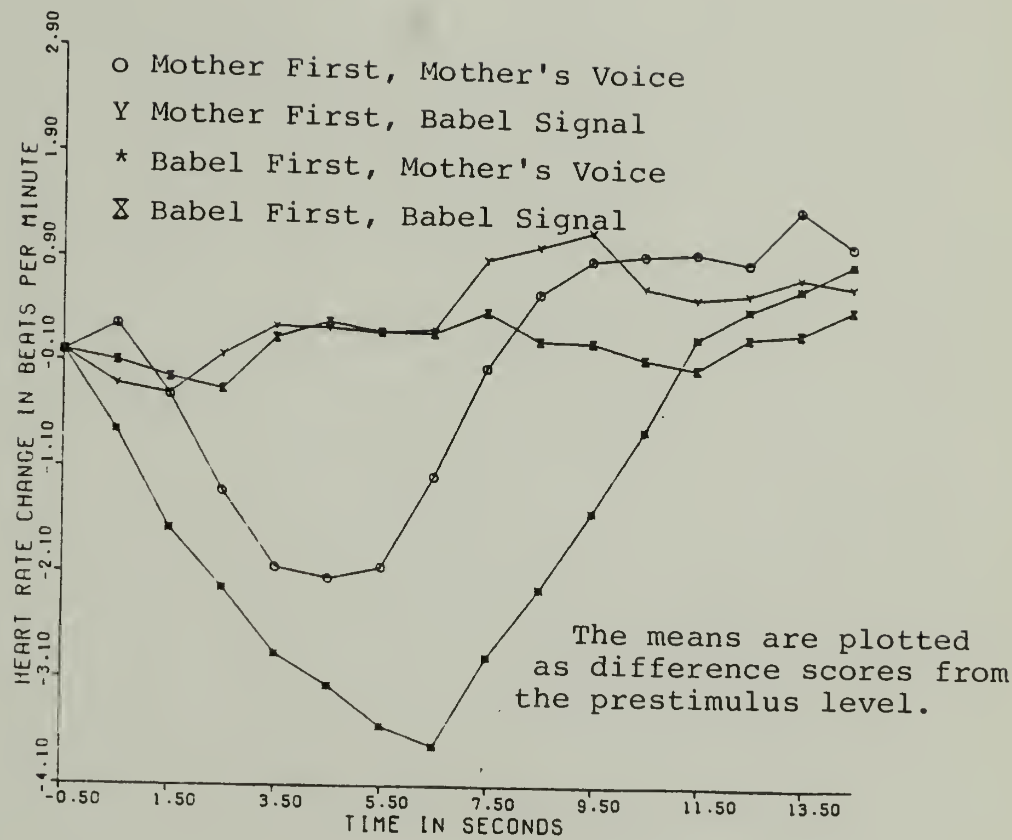

Figure 5: Average Heart Rate Change to Mother's Voice vs. Babel Signal for the Two Groups Receiving Different Orders of Presentation of the Signals.

signals (MF, MS, BF, and BS). The mean heart rate responses to the front and side presentations of the mother's voice are shown for the two side-loudspeaker groups in Figure 6. The mean responses to the front and side presentations of the babel signal are graphed separately in Figure 7. An age (2) x side-loudspeaker (2) x subject (8) x voice (2) x location (2) x trials (3) x seconds (16) repeated-measures analysis of variance was performed on these data and no significant differences were found other than higher-order interactions; see Appendix D, Table 17, for a summary of all significant effects involving the side-loudspeaker variable.

<u>Primary analyses of heart rate change</u>. The primary analysis of the heart rate data compared the changes in heart rate of the 12- and 25-week-olds to the mother and babel signals presented from the front and side loudspeakers. In order to facilitate interpretation of the results, the findings are reported within the context of the specific hypotheses being tested.

<u>Hypothesis 1: Heart rate changes to the mother's voice vs. the babel signal</u>. The first hypothesis was that the infants would show a heart rate change to the mother's voice but not to the control babel signal. The hypothesis was supported. Figure 8 displays a heart rate deceleration of 3 bpm followed by a return to baselevel in response to

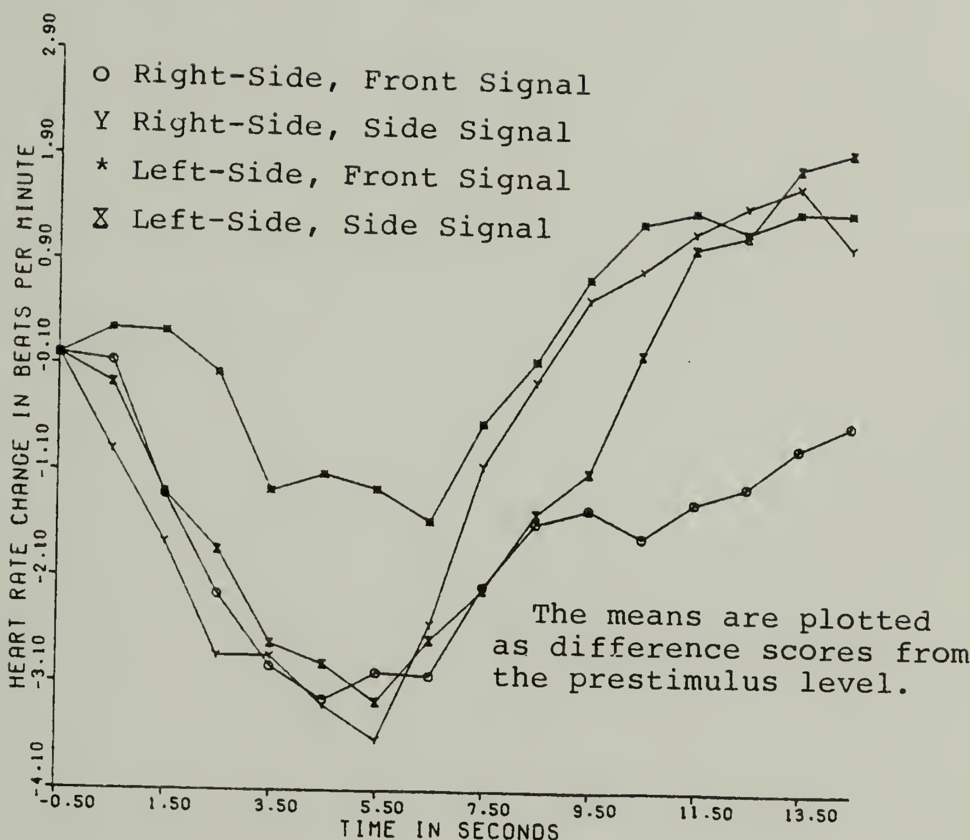

Figure 6: Average Heart Rate Change to Mother's Voice From Front and Side for the Two Side-Loudspeaker Groups (right and left).

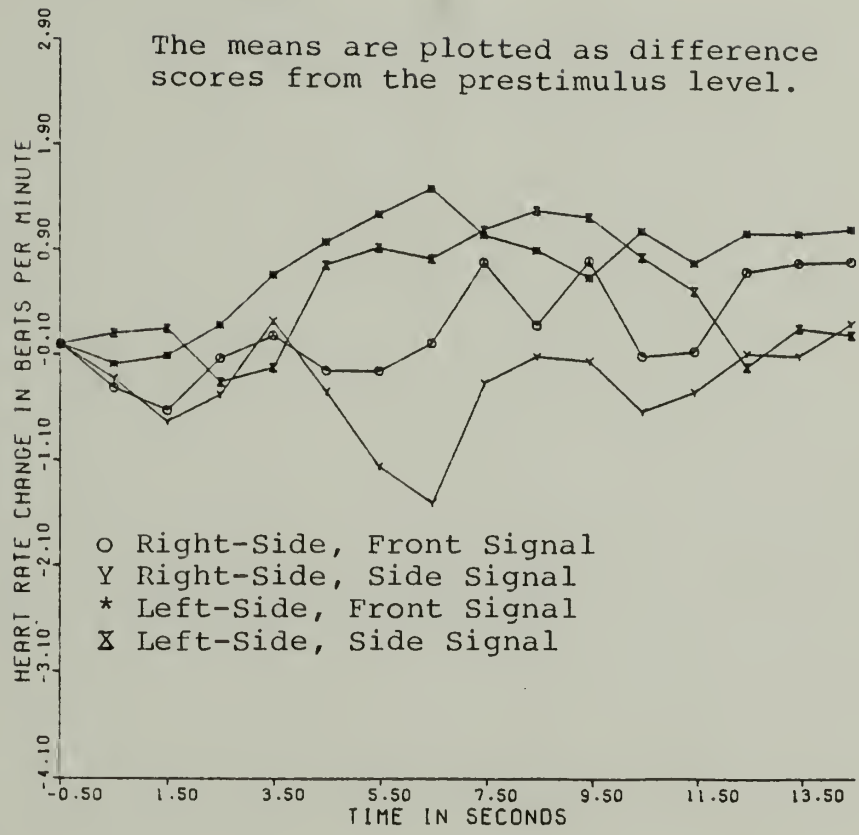

Figure 7: Average Heart Rate Change to the Babel Signal From Front and Side for the Two Side-Loudspeaker Groups (right and left).

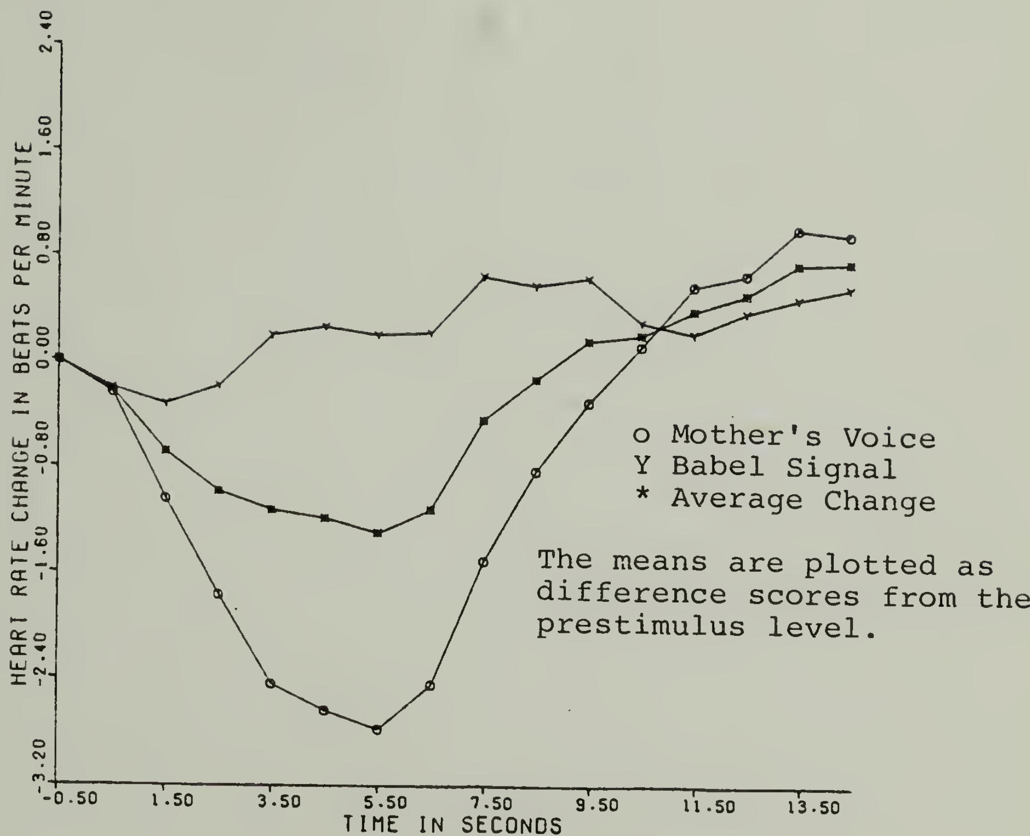

Figure 8: Average Heart Rate Change in bpm to Mother's Voice vs. Babel Signal.

the mother's voice. The average value of heart rate during the trials with the babel signal varied less than 1 bpm over the 16 seconds. Averaged heart rate change to the mother's voice and the babel signal is also presented in Figure 8. An age (2) x subject (16) x voice (2) x location (2) x trials (3) x seconds (16) repeated-measures analysis of variance was performed on these data (see Appendix E, Table 18).

Overall heart rate change differed from what would be expected by chance as indicated by a significant seconds effect, $\underline{F}$ (15, 450) = 5.80, which produced a linear seconds effect, $\underline{F}$ (1, 30) = 11.32; a quadratic seconds effect, $\underline{F}$ (1, 30) = 6.26; and a cubic seconds effect, $\underline{F}$ (1, 30) = 4.51. This effect is graphed in Figure 8 as the average of the response to the two signals.

The second-by-second heart rate changes to the mother's voice and the control babel signal were different, as indicated by a significant voice x seconds interaction, $\underline{F}$ (15, 450) = 4.99 The subsequent trend analysis performed on these data indicated that the voice x quadratic seconds interaction was significant, $\underline{F}$ (1, 30) = 9.92, supporting the interpretation that heart rate decelerated in response to the mother's voice but not to the babel signal. The deceleration in heart rate to the mother's voice was reflected in the lower overall average heart rate during the trials with the mother's voice. The mean heart rate during trials with the mother's voice was 144.6 bpm, whereas during the babel signal it was 148.4 bpm, a difference which was significant, $\underline{F}$ (1, 30) = 12.35.

One important question concerns the relationship of the responses to chance levels of variation. To infer that the response to either signal was detected within the background babel, it was necessary to determine that the response differed from chance. Separate analyses of variance were conducted for the responses to the mother's voice and the babel signal in order to compare each to chance levels. The design for both analyses was an age (2) x subject (16) x location (2) x trials (3) x seconds (11) repeated-measures design. For a listing of the significant effects, see Appendix E, Table 19, for the mother's voice effects, and Appendix E, Table 20, for the effects to the babel signal. The analysis of variance for the mother's voice showed a significant effect for seconds ($\underline{F}$ (10, 160) = 3.17) which was supported by a quadratic trend ($\underline{F}$ (1,16) = 5.97). But heart rate change to the babel signal did not show a significant effect for seconds.

One additional finding of the analysis of variance for the babel signal (Appendix E, Table 20) qualified the conclusion that heart rate change to the babel signal was random. In Figure 9 the average heart rate change in the babel condition is plotted for the 12- and 25-week-olds. It can be seen that the 12-week-olds' heart rate changed

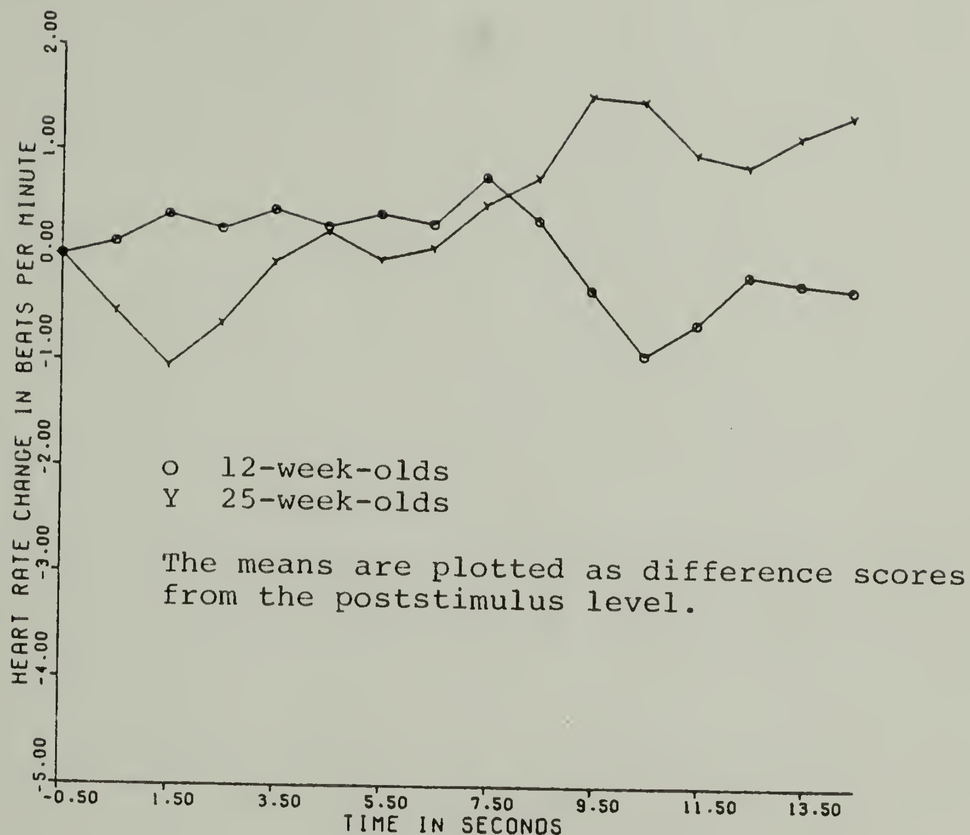

Figure 9: Average Heart Rate Change in bpm to the Babel Signal by Age.

very little for 10 seconds, before dropping 1 bpm. Average heart rate was more variable for the 25-week-olds, although change was gradual and amounted to only 2 bpm altogether. Thus, differences were minimal even though a significant age x seconds effect was obtained to the babel signal, $\underline{F}$ (10, 160) = 2.32, and was supported by an age x quadratic seconds effect $\underline{F}$ (1, 16) - 5.05. (See Appendix E, Table 20.) One possible explanation of the finding is that the older infants detected the babel signal, and the younger did not, with the combined ages showing a significant seconds effect of heart rate change. Further discussion will be reserved for the final chapter.

Hypothesis 2: Age differences in heart rate changes to the mother's voice vs. the babel signal. Part of the second hypothesis predicted that the differential response to the mother's voice and the babel signal for heart rate change would be characteristic of both 12- and 25-week-olds. The mean heart rate change to the mother's voice and the babel signal are presented separately for each age in Figure 10.

Follow-up repeated measures analyses of variance were conducted independently for each age group, see Appendix E, Tables 21 and 22, for 12- and 25-week-olds, respectively. Both of the analyses were of the form: subjects (16) x voice (2) x location (2) x trials (3) x seconds (16). The

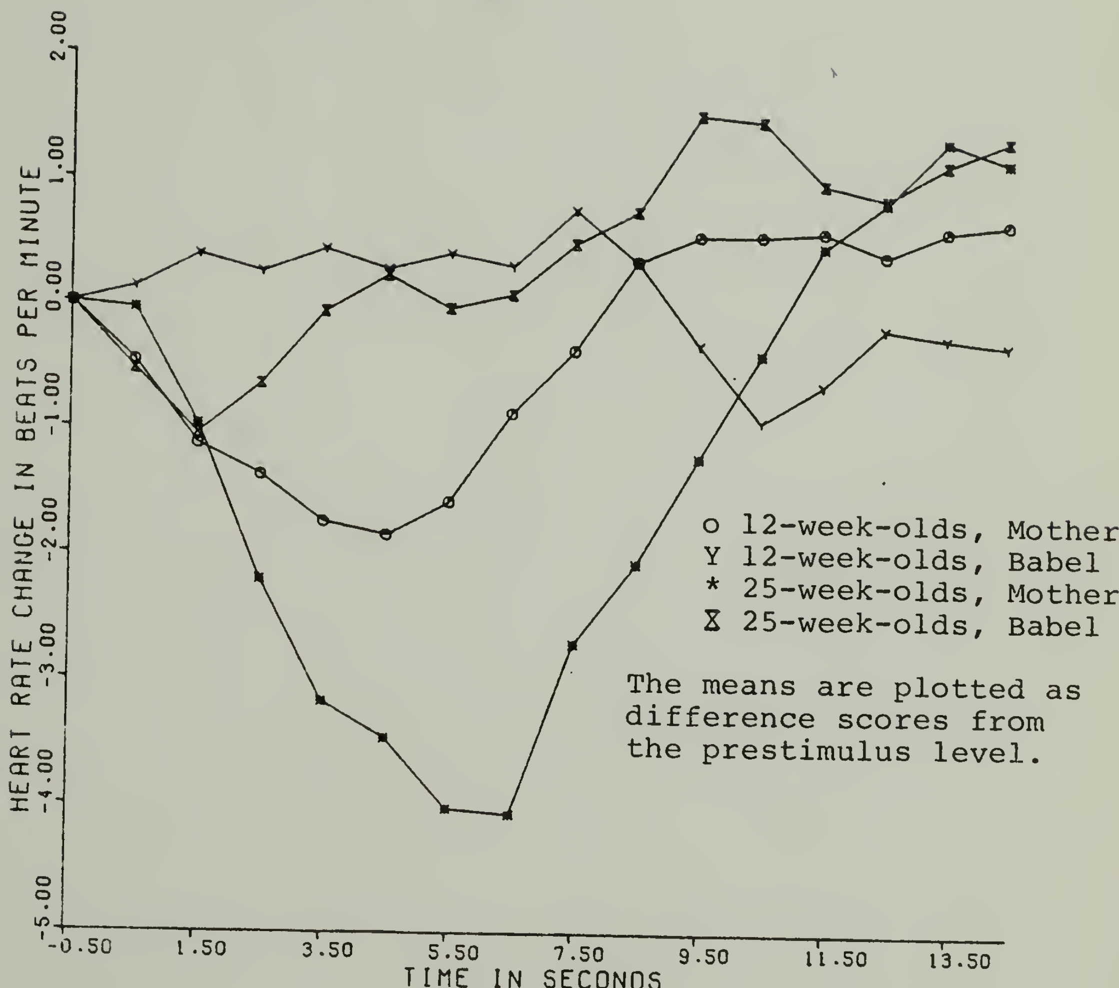

Figure 10: Average Heart Rate Change in bpm to Mother's Voice and Babel Signal for Each Age Group.

voice x seconds effect was significant for both 12-week-olds, (F (15, 225) = 3.86), and 25-week-olds, F (15, 225) = 3.11). Trend analyses revealed that the 12-week-olds showed both a voice x linear seconds effect, F (1, 15) = 11.84, and a voice x cubic seconds effect, F (1, 15) = 6.46. The 25-week-olds showed a voice x quadratic seconds effect, F (1, 15) = 8.92. The average heart rate for both 12- and 25-week-olds separately was different for the mother's voice and the babel signal, see Table 3. The effect of voice for both ages was significant (12-week-olds: F (1, 15) = 4.77; 25-week-olds: F (1, 15) = 7.95).

No overall effect of seconds was found for the 12-week-olds in the separate analysis of heart rate change for that age group, but the significant voice x seconds interaction supported the case that the response to the mother's voice differed from chance levels, and that therefore the voice was detected within the babel background. The 25-week-olds showed an effect for seconds, F (15, 225) = 5.51, which was supported by a linear seconds effect, F (1, 15) = 11.06, and a quadratic seconds effect, F (1, 15) = 6.08.

Hypothesis 3: Heart rate changes to the front vs. the side loudspeakers. It was hypothesized that separation of the signal from the background noise would facilitate detection of the signal. Some of the evidence pointed to this conclusion, although the evidence is qualified. Heart rate change to the mother's voice and the babel signal from the

TABLE 3

THE AVERAGE HEART RATE BY AGE AND TYPE OF SIGNAL[a]

Type of Signal	Age Group	
	12-Week-Olds	25-Week-Olds
Mother's Voice	146.6	142.5
Babel Signal	150.2	146.7

[a]N=32, divided equally by age group.

front and the side is depicted in Figure 11. The deceleration to the mother's voice from the side occurred more quickly and was about 1 bpm greater on the average, than the 2 bpm deceleration to the mother's voice from the front. Responses to the babel signal in both locations varied by less than 1 bpm on the average during the entire trial. A voice x location x seconds interaction reached significant levels of difference, $\underline{F}$ (15, 450) = 2.19, and was supported by a voice x location x linear seconds effect, $\underline{F}$ (1, 30) = 5.77, see Appendix E, Table 18. Examination of Figure 11 suggests that the interaction of voice x location x seconds occurred because there was no response to the babel signal in either location, whereas there was a difference to the mother's voice from front and side, with a greater average response to the side.

Although this is comparable to the finding with adults that spatial separation facilitates detection, the conclusion must be qualified because of the separate supplementary analyses for the mother's voice and the babel signal, see Appendix E, Tables 19 and 20, respectively. Neither signal showed an effect for location x seconds, which is contradictory to the combined analysis of variance's significant voice x location x seconds effect. (One of the two types of signals should have shown the linear effect.)

The contradiction might be explained by the fact that the separate analyses (Appendix E, Tables 19 and 20)

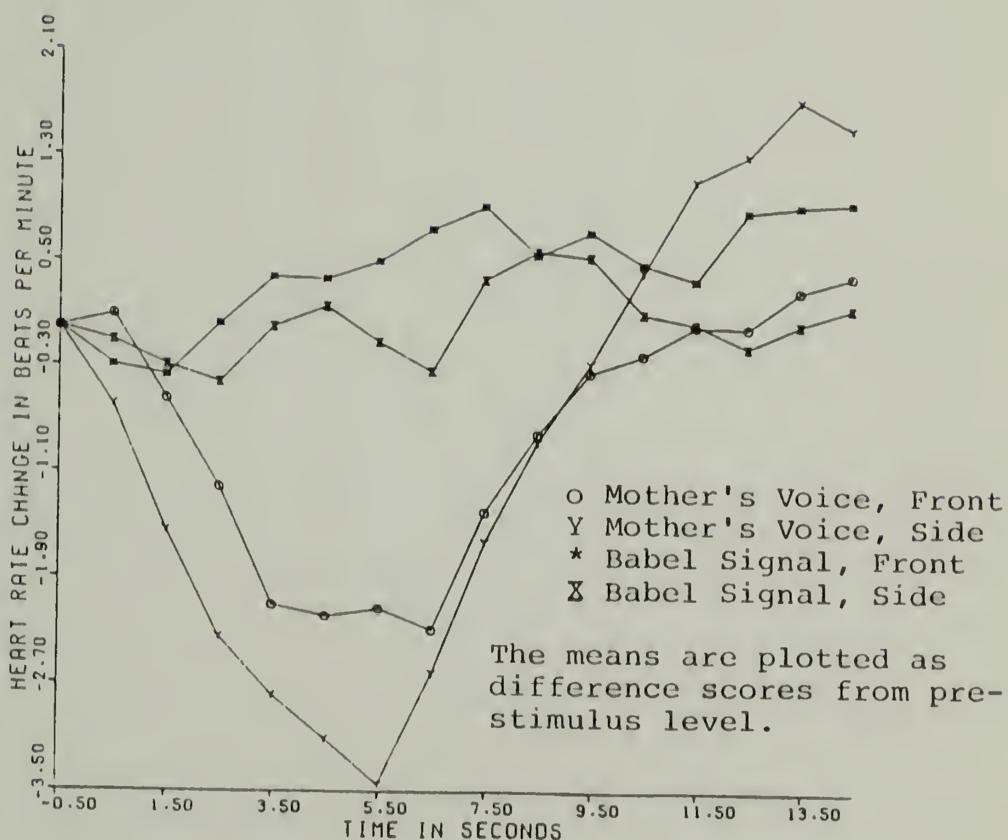

Figure 11: Average Heart Rate Change to Mother's Voice vs. Babel Signal From Front and Side Loudspeakers.

examined only 11 seconds (1 presecond and 10 postseconds) of the trial, whereas the main analysis of variance (Appendix E, Table 18), examined 16 seconds (1 presecond and 15 postseconds). This was done in order to limit the size of the problem for the computer, and also because Graham and Jackson (1970) suggest that the heart rate response usually occurs during the first 10-12 seconds of the trial. Evidently the last 5 seconds were required to maintain a significant effect, perhaps by increasing degrees of freedom. In trying to support a hypothesis, one should not rely too heavily on a heart rate change which needed 5-10 postseconds after the 5-second signal offset to maintain significant levels of difference. Other effects held when the last 5 seconds were dropped.

In order to clarify the finding, two separate analyses of variance were conducted on the front and side trials of the mother's voice, see Appendix E, Tables 23 and 24. There was a significant seconds effect for the mother's voice from the front, $\underline{F}$ (15, 450) = 2.46, which was supported by a quadratic trend, $\underline{F}$ (1, 30) = 4.20. The seconds effect for the mother's voice from the side was also significant, $\underline{F}$ (15, 450) = 8.52, and it was supported by linear, ($\underline{F}$ (1, 30) = 16.16), quadratic ($\underline{F}$ (1, 30) = 12.35), and cubic trends, ($\underline{F}$ (1, 30) = 5.88).

The linear seconds trend which occurred in the voice x location x seconds interaction from the original main analysis would seem to have been due to the linear trend in the heart rate change to the mother's voice from the side as opposed to the front. The quadratic changes (deceleration and return) were thus of sufficiently similar slope not to interact statistically. For this reason, the conclusion that spatial separation facilitated detection is qualified, although it is possible that offset of the mother's voice to the side triggered a linear acceleration in heart rate because it was more easily detected.

The effect of location seemed to be similar for both age groups. No interactions of age and location were significant in the main analysis, with the exception of some higher-order interactions involving trials effects, see Appendix E, Table 18. The higher-order interactions will not be discussed because of the ordering of trials in the present study. Front and side trials were interspersed randomly and thus the 3 trials of each type do not reflect successive presentations.

Behavioral Data

The findings are presented with regard to the initial hypotheses for the following behaviors: visual alerting, quieting, right and left head turns, smiling, vocalizing, and crying. The data for head turning, smiling, vocalizing and fussing will be presented in tables without supporting analyses of variance because of their very low levels of occurrence. As was mentioned, the behavioral measures are the duration of the occurrence of the respective behaviors, not the frequency of occurrence.

Visual alerting.

Hypothesis 1: Visual alerting to the mother's voice vs. the babel signal. The hypothesis that visual alerting would occur for longer periods of time to the mother's voice than to the babel signal was supported, indicating enhanced detection of the mother's voice over the babel signal. The amounts of visual alerting by age and type of signal are presented in Table 4, averaged over trials and subjects within each age, and expressed as percentages of the four 5-second stimulus periods. An age (2) x side-loudspeaker location (2) x order of signal presentation (2) x sex (2) x subject (2) x voice (2) x location (2) x periods (4) repeated-measures analysis of variance on the amount of visual alerting revealed a significant main effect for voice (the mother's voice vs. the babel signal), F (1, 16) = 11.96, see Appendix F, Table 25. It should be noted that the prestimulus differences show a marked effect. Despite this difference there is reason to believe that the effect is real and due to a tonic, rather than phasic change in alerting. The discussion will elaborate this further.

Hypothesis 2: Age differences in visual alerting to the mother's voice vs. the babel signal. It was hypothesized that there would be no age differences in visual alerting to the two types of signals. Responses were found not to vary by age. Again, see Table 4 where the duration percentages of visual alerting are presented for each age group to the two types of signals. Neither the age main effect nor the age x voice interaction was significant (see Appendix F, Table 25).

Hypothesis 3: Visual alerting to the front vs. the side loudspeaker. It was hypothesized that spatial separation of the signal from the background noise would facilitate the detection of the signal, at least for the mother's voice. The front vs. the side location of the loudspeaker did affect visual alerting, but not in the way predicted. See Table 5 where the percentages of visual alerting to the mother's voice and the babel signal from the front and the side are presented for both age groups. It can be seen that there was increased visual alerting for the older infants to the mother's voice presented from the front, rather than the side. The pattern for the babel signal was reversed, with greater percentages of visual alerting to the side condition. The visual-alerting analysis of variance, see Appendix F, Table 25, showed a significant voice x location interaction, F (1, 16) = 5.28. The age x location interaction was also significant, F (1, 16) = 6.69. The younger infants showed more visual alerting to the side condition, whereas the older infants showed more alerting to the front.

TABLE 4

THE AVERAGE DURATION OF VISUAL ALERTING BY AGE AND TYPE OF SIGNAL EXPRESSED AS A PERCENTAGE OF EACH 5-SECOND STIMULUS PERIOD[a]

Age	Stimulus Period			
	Prestimulus	Onset	Offset	Poststimulus
12-Week-Olds				
Mother	44%	42%	44%	41%
Babel	31%	36%	33%	35%
25-Week-Olds				
Mother	49%	53%	55%	53%
Babel	39%	44%	42%	38%

Note 1. Each percentage reflects the average of 6 trials.

[a]N=32, divided equally by age.

TABLE 5

THE AVERAGE DURATION OF VISUAL ALERTING BY TYPE AND LOCATION OF SIGNAL EXPRESSED AS A PERCENTAGE FOR EACH AGE GROUP[a]

Type of Signal	Age Group		
	12-Week-Olds	25-Week-Olds	Combined Age Groups
Mother			
Front	42%	57%	50%
Side	44%	48%	46%
Babel			
Front	31%	40%	35%
Side	37%	42%	39%
Combined Signals			
Front	36%	48%	42%
Side	40%	45%	42%

Note 1. Each percentage reflects the average of 3 trials.

[a]N=32, equally divided by age group.

Other effects of visual alerting. Alerting to the mother's voice vs. the babel signal was different for the two groups receiving different orders of presentation of the two signals. The group which received the mother's voice as the first signal showed alerting 57% of the time to the mother's voice and only 34% of the time to the babel signal. The group which received the babel signal first showed alerting 38% of the time to the mother's voice and 40% of the time to the babel signal. The voice x order interaction was significant, F (1, 16) = 17.48. All other higher-order interactions which were significant have been listed in Appendix F, Table 25, and will not be discussed.

Quieting.

Hypothesis 1: Quieting to the mother's voice vs. the babel signal. The hypothesis that quieting would occur to the mother's voice but not to the babel signal was supported. The percentage of quieting to each type of signal is presented in Table 6 for each age group. An age (2) x side-loudspeaker location (2) x order of signal presentation (2) x sex (2) x subject (2) x voice (2) x location (2) x periods (4) repeated-measures analysis of variance was performed on the amount of quieting; see Appendix F, Table 26, for a listing of all significant effects for that analysis. There was a significant main

TABLE 6

THE AVERAGE DURATION OF QUIETING EXPRESSED AS A PERCENTAGE FOR EACH AGE AND SIGNAL[a]

Type of Signal	Age Group		
	12-Week-Olds	25-Week-Olds	Combined Ages
Mother's Voice	17%	24%	21%
Babel Signal	9%	10%	9%
Combined Signals	13%	17%	15%

Note 1. Each percentage reflects the average of 6 trials.

[a]N=32, divided equally by age group.

effect for voice, F (1, 16) = 15.80.

Hypothesis 2: Age differences in quieting to the mother's voice vs. the babel signal. No age differences in quieting were expected. As can be seen in Table 6, there was more quieting to the mother's voice than to the babel signal for both ages. No main effect for age nor interaction of age x voice was found, see Appendix F, Table 26.

Hypothesis 3: Quieting to the stimuli presented from the front vs. the side. It was hypothesized that there would be more quieting to the mother's voice presented from the side than from the front because the voice would be detected more easily there; but that there would be no difference to the babel signal because it would not be detected. It was found that location did not have an effect. The percentages of quieting to the two signals from the front and side are presented in Table 7. The voice x location interaction in the quieting analysis of variance was not significant, see Appendix F, Table 26.

Other effects for quieting. Several higher-order interactions were significant in the analysis of the quieting data. They were not considered to be interpretable and are not presented, except in Appendix F, Table 26, where they are listed.

Head turning. The data for head turning are presented with regard to the initial hypotheses. A word of explanation is

TABLE 7

THE AVERAGE DURATION OF QUIETING EXPRESSED AS A PERCENTAGE FOR EACH SIGNAL AND LOCATION

Type of Signal	Location of Signal	
	Front	Side
Mother's Voice	22%	20%
Babel Signal	10%	9%
Combined Signals	16%	14%

Note 1. Each percentage reflects the average of 3 trials.

[a]N=32, divided equally by age group.

in order to clarify the response measure. The data which were obtained represent the amount of time (expressed as a percentage) that the infants' head was turned to the ipsilateral and/or contralateral side for each of the four 5-second stimulus periods, e.g. the prestimulus period, and each condition, e.g. MS. The data were averaged over each of the three similar trials, e.g. the three trials with the mother's voice to the side. In addition, the data for right and left head turns toward the right- vs. the left-side loudspeaker have been combined and designated as either appropriate or inappropriate head turns. For example, an appropriate head turn would be a right turn for an infant with a right-side loudspeaker. An inappropriate one would be a right turn when the signal was presented from the left. The average percentages of time that the infants were turned toward the side loudspeaker are presented in Table 8 for each age, signal, and stimulus period. Only side presentations of the signals are included.

Hypothesis 1: Head turning to the mother's voice vs. the babel signal. It was hypothesized that there would be more head turning to the mother's voice than to the babel signal. This hypothesis is supported by the older infants' data, see Table 8. The 25-week-olds showed more head turning to the mother's voice than to the babel signal for all stimulus periods. However, durational increases in head turning to the onset of the babel signal

TABLE 8

THE AVERAGE DURATION OF APPROPRIATE AND INAPPROPRIATE HEAD TURNING BY AGE AND SIGNAL, EXPRESSED AS A PERCENTAGE OF EACH 5-SECOND STIMULUS PERIOD[a]

Signal Type and Appropriateness	Stimulus Period			
	Prestimulus	Onset	Offset	Poststimulus
	12-Week-Olds			
Appropriate				
Mother	2.4%	2.7%	1.0%	2.0%
Babel	3.8%	5.6%	2.4%	3.0%
Inappropriate				
Mother	.2%	.0%	.6%	.3%
Babel	5.6%	2.1%	2.8%	3.8%
	25-Week-Olds			
Appropriate				
Mother	15.4%	27.4%	25.6%	18.2%
Babel	9.5%	17.7%	19.0%	15.8%
Inappropriate				
Mother	6.2%	6.1%	3.9%	5.8%
Babel	8.8%	2.4%	6.2%	9.8%

Note 1. Right and left head turns to right vs. left loudspeakers have been combined and designated as appropriate vs. inappropriate turns.

Note 2. Only trials with side presentations of the signals are included.

Note 3. Each percentage reflects the average of 3 trials.

[a]N=32, equally divided by age group.

suggest that it may have been detected and localized, although to a lesser extent than the mother's voice was. It is interesting to note that inappropriate head turning to the mother's voice was virtually absent in the 12-week-olds and was of uniformly lower occurrence than head turning to the babel signal. Appropriate head turning increased during the onset period and then tapered off, which would be expected if the signals were being localized.

Hypothesis 2: Age differences in head turning to the signals. It was hypothesized that there would be more head turning by the older infants than the younger ones, and this hypothesis was supported. It can be seen in Table 8 that there was more head turning for the older infants than for the younger ones, especially for appropriate head turns. The overall incidence of head turning was very low for the younger infants. The older infants demonstrated greater amounts of head turning under appropriate than inappropriate conditions.

Smiling. The average percentage of time that the 12- and 25-week-olds smiled to the mother's voice vs. the babel signal during the four stimulus periods are presented in Table 9.

Hypothesis 1: Smiling to the mother's voice vs. the babel signal. The hypothesis was supported that more smiles would occur in response to the mother's voice than to

TABLE 9

THE AVERAGE DURATION OF SMILING TO THE TWO SIGNALS BY AGE AND STIMULUS PERIOD[a]

Type of Signal	Stimulus Period			
	Prestimulus	Onset	Offset	Poststimulus
	12-Week-Olds			
Mother	.2%	.4%	1.5%	2.2%
Babel	.0%	.1%	.1%	.0%
	25-Week-Olds			
Mother	.1%	2.0%	6.0%	5.2%
Babel	.7%	.2%	.4%	1.4%

Note 1. Each percentage reflects the average of 6 trials.

[a]N=32, divided equally by age group.

the babel signal, both because the mother's voice would be more easily detected and because of its social nature. It can be seen in Table 9 that there was more smiling to the mother's voice than the babel signal for both age groups and in all four stimulus periods with the exception of the prestimulus period. (The older infants smiled more on babel trials during the prestimulus period.)

Hypothesis 2: Age differences in smiling. The hypothesis that the older infants would be more likely to smile to the mother's voice than the younger infants would was supported. There was more smiling by the older infants in every stimulus period with the exception of the prestimulus period. The difference between the two was especially great in the condition with the mother's voice.

Other effects of smiling. Smiling was most pronounced for both ages in the offset and poststimulus periods, which immediately followed the period when the signal was presented. The response may have been delayed until after the completion of the mother's greeting, and is thus compatible with the notion of reciprocity in social interactions.

Vocalizing. The average duration of vocalizing by age and stimulus is presented in Table 10 as a percentage of each 5-second stimulus period.

TABLE 10

THE AVERAGE DURATION OF VOCALIZING TO THE TWO SIGNALS BY AGE EXPRESSED AS A PERCENTAGE OF EACH STIMULUS PERIOD[a]

Type of Signal	Stimulus Period			
	Prestimulus	Onset	Offset	Poststimulus
	12-Week-Olds			
Mother	1.1%	.6%	.6%	1.8%
Babel	.4%	.2%	.2%	.3%
	25-Week-Olds			
Mother	1.5%	2.1%	1.4%	4.2%
Babel	1.4%	1.0%	.7%	.8%

Note 1. Each percentage reflects the average of 6 trials.

[a]N=32, divided equally by age group.

Hypothesis 1: Vocalizing to the mother's voice vs. the babel signal. Vocalizations were predicted to occur more often to the mother's voice than to the babel signal, because the mother's voice would be detected more easily and also because of its social nature. The hypothesis was supported. More vocalizing was found to the mother's voice for every stimulus period for each age.

Hypothesis 2: Age differences in the social response of vocalizing. It was hypothesized that the older infants would show more vocalizing in response to the mother's voice than the younger infants would. The hypothesis was supported.

Other effects for vocalizing. In conjunction with the results for smiling, vocalizing tended to be delayed until after the stimulus offset. The delay tended to be even greater, reserved for the poststimulus period.

Fussing. The average amount of fussing is presented in Table 11 for each age, signal, and stimulus period.

Hypothesis 1: Fussing during the mother's voice vs. the babel signal. It was hypothesized that fussing would occur in different amounts to the two different signals, although the direction of the difference was not predicted. For example, if the mother's voice were detected and the babel signal were not detected, more fussing could occur to the mother's voice if the infants were frustrated

TABLE 11

THE AVERAGE DURATION OF FUSSING TO THE TWO SIGNALS BY AGE EXPRESSED AS A PERCENTAGE OF EACH STIMULUS PERIOD[a]

Type of Signal	Stimulus Period			
	Prestimulus	Onset	Offset	Poststimulus
		12-Week-Olds		
Mother	.4%	.3%	.6%	1.1%
Babel	.9%	.1%	.7%	.9%
		25-Week-Olds		
Mother	.7%	.2%	.0%	.3%
Babel	4.3%	2.1%	3.1%	5.1%

Note 1. Each percentage reflects the average of 6 trials.

[a]N=32, divided equally by age group.

at not being able to see her. But on the other hand, infants will often cease fussing at the sound of a voice; therefore, the mother's voice could have terminated fussing. It was found that there was less fussing to the mother's voice for the older infants. Fussing was absent in the 5-second period immediately after cessation of her voice (the offset period). The data for the younger infants are variable and do not lend themselves to easy interpretation.

Age differences in fussing. No particular hypotheses were made. Age differences were found. The older infants showed less fussing to the mother's voice; the younger infants showed no clear result.

Summary of the Results Section

Heart rate deceleration occurred to the mother's voice but not to the babel signal for both 12- and 25-week-olds. Separation of a signal loudspeaker from the background noise produced a stronger offset response in heart rate, but not necessarily facilitation of detection. Increases in the duration of alerting and quieting were found for both age groups. The older infants showed a greater proportion of head turning, smiling and vocalizing to the mother's voice than to the babel signal, as well as cessation of fussing.

CHAPTER VI

DISCUSSION

The initial hypotheses are discussed in relation to the findings of the present study and the related literature.

Hypothesis 1: Detection of the Mother's Voice vs. the Babel Signal

The hypothesis that the 12- and 25-week-olds would detect the addition of their mother's voice, but not the control babel signal, to the background babel was supported by both the heart rate findings and the alerting, quieting, and fussing measures. Discussion of the other behavioral measures will be delayed until the section on age differences.

Heart rate change. The infant's heart rate decelerated an average of 3 beats when the mother's voice was added to the ongoing background babel. The finding confirms the observations of Brazelton (1969) that infants as young as 2 months old will orient to the direction of their mother's voice even when other people are speaking at the same time. It also supports Bundy's (1977) pilot data which suggested that 4-month-olds have the ability to detect a signal within noise.

The fact that heart rate changed in the direction of a deceleration corroborates the previous findings of a deceleration in infants' heart rate to a mild auditory stimulus, e.g. Graham and Jackson, 1970. More detailed discussion of this finding will be reserved for the section on age differences.

Behavioral change.

Visual alerting. There was significantly more visual alerting to the mother's voice than to the babel signal, as was predicted, indicating that the mother's voice was detected. The analysis showed that alerting was not as closely time-locked as the heart rate change because the periods main effect and the voice x periods interaction were not significant. The choice of 5-second stimulus periods was made on the basis of the stimulus length and not on the basis of the characteristics of an alerting episode; it is therefore reasonable that alerting was found to be less time-locked than heart rate change, which was measured every second. (One-second intervals were chosen on the basis of the characteristics of the heart rate response.) Observation of the infants suggested that listening to the mother's voice often initiated prolonged visual fixation of the mobiles.

The choice 5-second stimulus periods was no uninformative, however. For the older infants, visual alerting increased during the stimulus period when the mother's voice was added, and peaked during the offset period. There is some suggestion that the babel signal may have been detected also, as indicated by an increase in the amount of visual alerting to the babel signal during the onset period for both age groups.

The interaction of the type of signal (the mother's voice vs. the babel signal) and the order of presentation of the signals for the visual alerting measure was unexpected. It suggests that the infants who received the babel signal as the first signal may have become fatigued by the end of the first half of the session, showing less visual alerting to their mother's voice during the second half as a result. Whether the fatigue may have occurred because the babel signal was not detected, or because it was detected but not novel, cannot be determined conclusively. Evidently the fatigue was specific in its effect on visual alerting, because no effect of order of presentation was found for heart rate change. This effect of order combined with the lack of a periods effect for visual alerting suggests that the detection of the mother's voice produced a generalized increase in alerting.

Quieting. The hypothesis that there would be more quieting to the mother's voice than to the babel signal was supported. The quieting was not related to stimulus period, however. Both 12- and 25-week-olds showed the effect, which amounted to about twice as much quieting to the mother's voice over the babel signal. Quieting may have been similar to visual alerting in the generalization of the effect.

Fussing. No particular hypotheses were made for the outcome of the fussing measure, other than that a change in the occurrence of fussing might follow the presentation of the mother's voice. More fussing could have occurred to the recording of the mother's voice, as was found by Turnure (1971). However, cessation of fussing to the sound of a voice has also been found in infants (Brazleton, 1969).

A change in the amount of fussing to the addition of the mother's voice to background babel was found for the older infants, in the direction of a decrease. The older infants ceased fussing coincidentally to the mother's voice, and there was less overall fussing during the trials in which the mother's voice occurred. This is in contrast to the finding of Turnure. The data for the 12-week-olds were more variable and do not lend themselves to easy interpretation. There may have been a tendency to increase quieting to the onset of both signals.

Summary for hypothesis 1. The combined evidence of a 3 bpm heart rate deceleration, increased alerting and quieting, and decreased fussing to the mother's voice supports the hypothesis that the mother's voice would be detected within the background babel, as compared to the control babel signal.

Hypothesis 2: Age Differences in the Detection of the Signals for Heart Rate Change and the Behavioral Responses

Heart rate change. Both the 12- and the 25-week-olds showed a significant heart rate change to the onset of the mother's voice. Although changes for both age groups began as decelerations, the overall form for the two age groups differed as indicated by the follow-up trend analyses.

The 12-week-olds. As was mentioned, both the linear and cubic trends over seconds interacted with the type of signal for the 12-week-olds. This means that the forms of the heart rate change to the mother's voice vs. the babel signal differed from each other, but it doesn't specify where the linear and cubic trends occurred. It should be noted that an interaction of trend over seconds with the two types of signals could indicate either that one change showed the trend and the other one didn't, or that both changes showed the trend, but with significantly different slopes to the lines, e.g. a horizontal slope vs. a slope increasing at 45°. Examination of Figure 10, where the 12-week-olds' responses to the mother's voice and the babel signal are depicted, may facilitate the interpretation of the finding.

The interaction of the linear component for the two signals may be due to the small amount of change which occurred to the babel signal as compared to the deceleration and return to baseline which occurred to the mother's voice. Thus the response to the babel signal may have been linear, and with the response to the mother's voice being nonlinear, an interaction would have occurred. Another possible interpretation suggested by Figure 10 is that the return to baseline which occurred to the mother's voice in the 5th second was sufficient to create a linear component in the response to the mother's voice. But it would have had a different slope from the response to the babel signal, and this could have created the linear interaction.

The interaction of the cubic component for the two signals may have been due to the form of the response to the mother's voice: there was an initial deceleration, followed by a return to baseline, and then a leveling off. If the response to the babel were the flat, linear one proposed above, this would have created the interaction. One other possible explanation for the cubic interaction is that the response to the babel signal also showed a cubic trend. The response to the babel signal was initially flat, followed by a small deceleration and return in the latter part of the trial. In other words, the dips in the responses to the two signals occurred at different times, and this could have caused the interaction. It is important to note, however, that if this were in fact what happened, the conclusion that a significant deceleration occurred to the babel signal would not necessarily be justified. The deceleration in the response to the babel signal occurred several seconds after the signal offset. This makes it unlikely that the deceleration on the babel trials was a response to the stimulus.

In summary, although the exact cause of the significant interaction of trend over seconds for the two signals cannot be specified for the 12-week-olds. An examination of Figure 10 suggests that there was a significant deceleration to the mother's voice, but not to the onset of the babel signal, for this age group.

The 25-week olds. The older infants showed linear and quadratic trends which distinguished their responses to the mother's voice and the babel signal. The linear component (again, as seen in Figure 10), may have been due to the fact that there was little change in the response to the babel signal, whereas the response to the mother's voice was a deceleration, followed by a return to baseline. The quadratic trend is most probably due to the deceleration to the mother's voice, and not to the babel signal, which creates the interaction in trend.

The combined age groups. Both the 12- and the 25-week-olds showed a return to baseline in their responses to the mother's voice which moved beyond the prestimulus level somewhat. This may or may not have been an acceleratory response in its own right, because it amounted to less than 1 beat for the 12-week-olds and about 1 1/2 beats for the 25-week-olds. Gray and Crowell (1968) found an initial deceleration followed by an acceleration beyond prestimulus levels 10 seconds after the presentation of an auditory stimulus to 11-week-olds. If this were an acceleration in the present study, it would be difficult to interpret precisely. It could have been due to excitement if the infants expected their mother to appear. Graham and Jackson (1970) and Lewis (1975) have emphasized that many variables affect the specific form of the heart rate response.

The deceleration to the mother's voice was greater for the 25-week-olds than for the 12-week-olds. The age x seconds interaction and the age x voice x seconds interaction both reached significance in the main analysis of variance (Appendix E, Table 18). However, neither effect was supported by a significant difference in trend, which makes the finding difficult to interpret. According to the ground rules discussed earlier, effects of seconds which are not supported by trends are considered to be unreliable differences. For this reason, the age differences in heart rate will be discounted, although it should be mentioned that age differences in this context would not be surprising. Graham, Berg, Berg, Jackson, Hatton, and Kantowitz (1970) found greater decelerations in older infants. Berg's (1974) study with 6- and 16-week-olds suggests that their finding was due to differences in state, because the younger infants have shorter alert periods. (As was mentioned, there was less visual alerting and quieting by the 12-week-olds as compared to the 25-week-olds in the present study, although the difference was not significant.)

Behavioral change.

Visual alerting. Neither the main effect of age nor the interactions of age with other variables were significant in the analysis of variance of visual alerting, with the exception of higher-order interactions. One point of interest was that the 12-week-olds did not show an increase in visual alerting to the mother's voice during the onset period, even though they showed an increase in alerting to the babel signal during the onset period. The older infants showed increased alerting to the onset of both signals. Even though the differences were not significant, the direction of the response of the 12-week-olds to the mother's voice is puzzling. Lewis, Kagan, Campbell, and Kalafat (1966) found a positive relationship between the amount of visual fixation and the amount of deceleration in heart rate. A deceleration in heart rate occurred to the onset of the mother's voice in the present study for the 12-week-olds.

One possible explanation for the discrepancy lies in the theory of Piaget (1952) concerning the development of the coordination of auditory and visual space. As was mentioned in the literature review, Piaget suggested that the coordination of auditory and visual space develops during the first few months. Initially the infant tries to see *while* he hears, but when the two sensory spaces are coordinated the infant tries to see *what* he hears. The 12-week-olds in the present study were probably in the initial phase of coordinating auditory and visual space. The continual background babel may have interfered with the timing of the response of visual alerting to the signal. Although an increase did occur to the onset of the babel signal for the 12-week-olds, the overall pattern of increases and decreases in alerting for them was erratic and seems random, with the exception of greater values for the mother's voice.

Quieting. Although the 25-week-olds showed more quieting than the 12-week-olds, the differences were not significant. The amount of quieting to the babel signal was virtually identical for the two age groups.

Head turns. Head turning in the appropriate direction was found for the 25-week-olds but not for the 12-week-olds, as was predicted. The amount of head turning on side trials is presented in Table 8. The 12-week-olds showed very small amounts of head turning, and no clear pattern for head turning to either signal emerged. The only interesting finding was that inappropriate head turns were virtually absent during the entire trial when the mother's voice was presented, especially during the onset period when they were absent.

The older infants showed appropriate head turning. There was more head turning to the mother's voice than to the babel signal, as was predicted. Appropriate head turning to the mother's voice occurred the greatest amount of time during the onset period. Although the amount of head turning to the babel was less than to the mother's voice, there was an increase in appropriate head turning to the onset of the babel signal, which peaked in the offset period. This suggests that the babel may have been detected and localized, at least by the older infants.

The fact that the two age groups differed in their head turning responses to the signals supported the hypothesis that head turning would be more likely in the older infants. The absence of inappropriate head turning to the mother's voice and the generally low levels of head turning in the younger infants suggests that the typical response of the 12-week-olds was one of quieting rather than a more active response. The 12-week-olds may not have been coordinating auditory and visual space in this task yet.

The absence of head turning to the signals by the 12-week-olds in the present study was not surprising. As was mentioned in the literature review, the presence of head turning to sound in this age group is less reliable than in older infants (Bayley, 1969; Cattell, 1940; Field & Muir, 1978; Gesell, 1925). Moore, Wilson, and Thompson (1977) found that even reinforcement procedures were ineffective in increasing the likelihood of a head turn to sound in infants younger than 5 months of age.

Smiling. The hypothesis that the 25-week-olds would be more likely than the 12-week-olds to smile to the signals was supported. There was little difference between the two age groups in their smiling during the prestimulus period. Both age groups showed increased smiling to the mother's voice during the onset period, although the older infants smiled more than the younger infants. The offset period showed even more smiling for both age groups, again with more for the older than the younger. The poststimulus period also showed high levels of smiling to the mother's voice. For the 12-week-olds, this was the period with the greatest amount of smiling. Both age groups showed more smiling to the mother's voice than to the babel signal. Additionally, both groups showed smiling in the latter part of the trial. This finding will be discussed later in conjunction with some of the other behavioral evidence.

Vocalizing. The hypothesis that the infants would show more vocalizing to the mother's voice was supported. More vocalizing was shown to the mother's voice than to the babel signal for each age. Vocalizing tended to be delayed until after the completion of the mother's greeting, just as smiling was. For both age groups, the period of most vocalizing was the poststimulus period. More vocalizing was found for the 25-week-olds, supporting the hypothesis of age differences in their behavior. The fact that, in general, the amount of vocalizing in the present study was very low, is not surprising given the finding of Kagan and Lewis (1965). They found that vocalization was low when the infants showed long visual fixations. Visual alerting was the most frequently occurring behavioral response in the present study. Barrett-Goldfarb and Whitehurst (1973) found that spontaneous infant vocalizations were suppressed during stimulation with their parents' taped voices, which also helps to explain the low incidence of vocalizations in the present study.

Summary for hypothesis 2. In general there were no significant age differences for the measures of heart rate change, alerting, and quieting. The heart rate change for the two age groups differed in form: the 12-week-olds showed a cubic trend and the 25-week-olds showed a quadratic trend to the mother's voice. This suggests that the older infants showed a deceleration and return to baseline in heart rate change whereas in the younger infants the deceleration and return were followed by a second change in the form of the response. Figure 10 suggested it was a linear response of no change.

Head turning, smiling, and vocalizing all occurred more often in the older infants than in the younger ones, as was predicted. The younger infants did show a tendency to respond socially in a manner similar to the older infants. There were more social responses to the mother's voice than to the babel signal, and social responses were delayed until after the mother's greeting was over. There were no inappropriate head turns to the onset of the mother's voice for the younger infants.

One important consideration which has only been alluded to up to this point is the relative timing of the behavioral responses. Wilson and Lewis (1972) identified two successive components in infants' behavioral responses to pictures of faces. The first component was orientation, consisting of intense looking, cardiac deceleration, and cessation of activity. The second component was affective, and included smiling and vocalizing. The results for the present study were similar to those of Wilson and Lewis. The initial response to the onset of the mother's voice was one of cardiac deceleration, alerting, and quieting for both age groups. The social responses of smiling and vocalizing occurred later in the trial. Thus the finding of Wilson and Lewis for visual stimuli was replicated for auditory stimuli in the present study.

Another facet of importance for the delay in social responses is the notion of reciprocity (e.g. Brazelton, Kozlowski, and Main, 1974). Infants develop the capacity to be a partner in social interactions, and reciprocity is found early in mother-infant interactions. The delay in responding to the mother's voice suggests that infants "waited for their turn" until the mother's greeting was over.

Hypothesis 3: Separation of the Signal and Background Loudspeakers

Heart rate change. Separation of the signal and background loudspeakers facilitates detection of a signal for adults, and it was predicted that it would facilitate detection of the mother's voice for the infants. A voice x location x seconds interaction suggested that the hypothesis was supported, but with a qualification. The interaction of voice x location x seconds was supported by a linear trend which was due to an acceleration in heart rate to the offset of the mother's voice from the side. This may have been due to the fact that the signal from the side was detected more easily, supporting the hypothesis. Clifton and Meyers (1969) found cardiac acceleration to signal offset in infants. An interaction supported by a quadratic change with a deeper deceleration to the side presentation would be stronger evidence. Although that particular interaction was not significant, the difference in the responses to the two locations was in the predicted direction.

Behavioral change.

Visual alerting. Increased visual alerting to the side loudspeaker (indicating improved detection) was not found. On the contrary, the 25-week-olds showed increased visual alerting to the mother's voice from the front, rather than from the side. There were slightly more alerting responses to the side than to the front for the babel signal, however. The 12-week-olds showed more visual alerting to the side than to the front for both signals.

One possible explanation for the discrepancy to the mother's voice for the 25-week-olds is that the interesting visual stimuli were to the front. Visual alerting to the front may have been maintained by the interesting visual stimuli in the experimental environment and perhaps by the background babel , as well. Field (1978) suggested that visual stimuli were essential to maintain an alerting episode.

Quieting. Location did not have an effect on quieting for the two age groups.

Other behavioral measures. The other measures, e.g. head turning, occurred too infrequently to allow analyses of variance to be conducted. As a result of this, and because their chief importance was in distinguishing the two age groups, the other behavioral measures will not be discussed with respect to Hypothesis 3.

Summary for Hypothesis 3. It cannot be stated conclusively that separation of the signal loudspeaker from the background babel facilitated detection of the signal. The weight of the evidence was in this direction, however.

Summary of the Discussion

The mother's voice vs. the babel signal. The combined evidence from the heart rate and behavioral data in the present study suggests that the 12- and 25-week-olds segregated their mother's voice from the background babel. An important distinction which should be made is that the evidence can only speak for the detection of the mother's voice and not the recognition of it. The responses to the mother's voice are in contrast to those made to the control babel signal. There were no significant effects suggesting detection of the babel signal.

One question which may arise concerning the babel signal has to do with the likelihood that the infants would show a cardiac deceleration to the babel signal. The pilot subjects showed less deceleration to the babel signal than to the mother's voice when there was no background noise. It is possible that although the babel signal was detected as easily as the mother's voice was, the tendency to respond to it with smaller decelerations caused the average deceleration to fail to reach significance. In conjunction with this, there may have been fewer decelerations to the babel signal because it was not novel, but more noise-like. The infants had been listening to the ongoing background babel since their arrival, and both the babel signal and the background babel were obtained from the same tape. Several writers have stressed the fact that the heart rate response is not an automatic consequence of the detection of a signal, but rather relates to the meaning and importance of what is detected (e.g. Brown, Morse, Leavitt, & Graham, 1976; Sameroff, 1972).

However, even if these factors caused insignificant levels of heart rate change to the babel signal when it was in fact detected, this does not negate its use as a control. It shows that the addition of a speech signal of similar SPL, duration, and location as the mother's greeting was insufficient in and of itself to create a heart rate deceleration. Therefore, the response to the mother's voice was more likely to have been due to the fact that the voice was segregated from the background. Detection of the babel signal would also show ability to detect a signal within noise.

Age differences. Both the 12- and the 25-week-olds responded to the mother's voice as indicated by heart rate change, alerting, and quieting. The age differences in these measures were not significant, although the differences were in the direction of greater changes for the older infants. Localizing head turns, fussing, and social responses (smiling and vocalizing) did show greater levels of occurrence in the older infants, although analyses of variance could not be performed due to the very low levels of occurrence of the behaviors.

Separation of the signal and background babel loudspeakers. Whether or not detection of the signal was made easier by separation of the signal and noise is not completely clear. The cardiac results were in this direction and were supported by a significant difference in the offset response. But the deceleration to the side stimulus was not significantly deeper than the deceleration to the front.

An important consideration with respect to this issue is that the front signal was discriminable in the present study. A replication which would clarify the issue might involve testing for a signal-to-noise ratio which did not allow the front signal to be heard, but which allowed discrimination of the same signal when it was separated from the noise. An initial study with adults could determine what these levels might be, and although infants might need a slightly louder signal, it would provide a place to start. An additional control which could be displayed which might affect the finding would be to start the trials only when the infant was at midline. In general, the infants faced front and this was not a problem; but occasionally infants would be turned to the side prior to signal onset.

The interesting visual stimuli were to the front in order to keep the infants in the midline position as much as possible, because trials were not delayed until the infant was at midline. The visual stimuli which were to the front probably caused the 25-week-olds' greater visual alerting to the front, and may have enhanced any cardiac decelerations which occurred, as well. This could have lessened the average difference in heart rate change between front and side trials. There may have been fewer detections of the front signals and, consequently, fewer decelerations in heart rate to the front presentations. But these differences may have been masked because the decelerations were deeper due to the interesting visual stimulation. An important control which could be added in future studies would be to equate the level of visual interest in all locations where auditory stimuli are presented.

Suggestions for Further Research

The major questions which remains concerns how the infants were able to segregate the signal. Because of the acoustically complex stimuli used in the study, it is not possible to specify the exact means by which the mother's voice was detected. It differed from the babel in many respects, e.g. frequency, message, rhythm, familiarity, etc. Studies of specific acoustical parameters would help clarify the issue. One important replication would be the use of a stranger's voice. It may be the familiarity of the mother's voice which is of importance.

More specific analyses of the behavioral data should be made. Frequency information would be especially valuable for the head turning, smiling, and vocalizing measures. Another behavior which was not analyzed, but which gained the author's attention during coding of the videotapes, was mouthing to the mother's voice in the 12-week-olds. Turnure (1971) found that the amount of mouthing was significantly greater to the mother's voice than to a stranger's voice in 3-month-olds. That result may have been replicated in the present study.

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APPENDIX A

FORMS USED TO CONTACT, TO OBTAIN PERMISSION FROM, AND TO REPORT TO PARENTS

Letter to Parents Inviting their Participation in the Project

Final Report which was Sent to Parents

Written Explanation of Experimental Procedures and Permission Form

The Commonwealth of Massachusetts
University of Massachusetts
Amherst 01003

DEPARTMENT OF PSYCHOLOGY

Dear Parents,

I am a graduate student in developmental psychology at the University of Massachusetts, Amherst, and I am conducting a research project with 2- and 5-month-old infants. I understand from newspaper birth announcements that you are parents of a child of this age. My project, which is a requirement for the Ph.D. degree, is concerned with the development of the infant's ability to hear his or her mother's voice over a background of other voices. I will observe whether the baby turns toward the sound and responds with a heart rate change. Very little is known about the developmental changes in this ability, although it has been suggested by Piaget and others that the ability may develop sometime between the ages chosen for study. I hope that you and your child will help me by participating.

Participation in the project would involve one visit to the Infant Research Laboratory in Tobin Hall at the University. In addition, I would arrange to visit your home prior to your appointment to tape record your greeting to your baby. Although I'm looking at responses to mothers' voices, fathers are welcome to attend. The project has received approval from the departmental committee on ethics in research with humans.

I will be calling you soon to see if you are interested and to answer any questions you might have. If you are particularly interested in learning more or wish to arrange a time more quickly, I can be reached at 545-3882. Thank you.

Sincerely,

Katherine A. Benson

Report to Parents

July 10, 1978

Study of the Development of Auditory

Figure/Ground Segregation in Young Infants

I want to thank you for participating in my study of hearing in young infants. I enjoyed meeting you and I appreciate your help in my research.

If you remember, I was interested in seeing if young infants respond to the addition of their mother's voice to a background babel of voices. The results of the study are very interesting. Both the younger (about 12 weeks) and the older (about 25 weeks) infants were able to hear their mother's voice added to the background babel of voices, as indicated by heart rate deceleration. It was easier for the babies when the voice was played from the side, spatially separated from the babel in front of them.(This is true for adults, too.) The babies didn't detect the control signal of extra babel. Typical behavioral responses were alerting and quieting to the addition of the voice, for both ages. There was a significant amount of head turning to the correct side in the older infants, but not in the younger ones. These are typical patterns of response to sound at these two ages, and they add further support to the heart rate data. Smiles were significantly related to the mother's voice, occurring in response to her greeting.

Thank you again for your participation. If you have questions, I can be reached at the Psychology Department, 545-2383.

Sincerely,

Kathy Benson

Infants' Heart Rate and Behavioral Responses to their Mother's Voice

This project is concerned with the study of infants' responses to a recording of their mother's voice. I am testing 2- and 5-month-olds to see if they will change their ongoing behavior when they hear their mother speak. You have been asked to record a greeting to get the baby's attention. The recording will be played over a loudspeaker to the front or the side of the infant. The baby will be observed to see if he or she responds with a heart rate change or a head turn in the direction from which your voice is coming. For example, if your voice comes from a loudspeaker to the side, will the baby look in that direction? In addition, some infants will hear their mother's voice when other background voices are played as well. Will the infant be able to detect the mother's voice in this case? The mother's voice is being used because I want to maximize the likelihood that the infant will respond to the sound. The procedures which are experimental are varying the location of the mother's greeting, varying the presence of the background voices, and testing infants at two age periods.

There is no discomfort to the baby in the procedures, as the voice will be presented at normal conversational levels (60 decibels). The doll mobile is provided to keep the baby interested between presentations of the recording. You will be seated directly behind your infant. If he or she starts to cry for any reason, the session will be stopped. The recording of heart rate is a completely safe procedure, and we have special safeguards that prevent any hazard to the baby.

I hope this project will tell us something about the normal infant's development of the ability to respond to and localize his or her mother's voice, even when it is heard with a background of other voices. I hope that all infants will show a response to the sound. I expect that the older infants will be more likely to look in the direction of the sound, but I want to see if the younger infants will also respond overtly, perhaps with quieting because they are listening. The results will increase scientific knowledge about normal hearing, and what kinds of infant responses can be expected. This will make further research into infant hearing possible. Although there is no personal benefit to your own baby, I am very grateful for your cooperation. If at any time you wish to discontinue the procedure, please tell me and the session will be stopped immediately. Please feel free to ask any questions you might have.

I understand the procedure, and my signature below indicates that I will allow my infant, ______________ ________________, to participate in this project.

Signed: __________________ Date: ____

APPENDIX B

THE COMPUTATION AND EDITING OF HEART RATE DATA

Figure 12: The Formula For Computing a Weighted Average of Heart Rate in bpm for 1 Second

Table 12: The Edits of Artificial Data by Trial and Second Number for each Individual Subject who Required Them, and the Criteria for Editing

$$60 \sum_{i=a}^{n} \left[\left(\frac{1}{p_i} \right) \left(\frac{1}{R\text{-}R_i} \right) \right]$$

Figure 12: The formula for computing a weighted average of heart rate in bpm for 1 second:

$R\text{-}R_i$ is the time in seconds between R-waves for the i^{th} R-R interval;

a is the first R-R interval or fraction of an interval within the second;

n is the total number of R-R intervals within the second;

p_i is the proportion of the second which the i^{th} R-R interval occupies (the weight).

TABLE 12

THE EDITS OF ARTIFACTUAL DATA BY TRIAL AND SECOND NUMBER FOR EACH INDIVIDUAL SUBJECT WHO REQUIRED THEM

# Subject	Trial Number (T)	Second Number (S)
14	T 12	S 12
16	T 5	S 4
	T 6	S 8
17	T 2	S -3
	T 3	S -3
	T 9	S 8
18	T 4	S -3
21	T 10	S 2
	T 12	S 2
23	T 10	S 4
29	T 4	S 6
	T 9	S 11
	T 12	S -1, S 3
30	T 2	S 7
	T 6	S 6
31	T 2	S -3
32	T 8	S 15
33	T 2	S 11
	T 9	S 15
34	T 3	S 14
36	T 4	S 6, S 7
37	T 4	S 3
	T 12	S -3
40	T 5	S 3, S 8
	T 10	S 11, S 12
41	T 7	S 13
42	T 4	S 13, S 14
44	T 4	S 12
	T 9	S 14
46	T 9	S 5
	T 11	S 6
	T 12	S 3
47	T 4	S 5
48	T 7	S 13

TABLE 12--*Continued*

# Subject	Trial Number (T)	Second Number (S)
49	T 1	S -2
	T 2	S 15
	T 5	S -3, S 15
	T 7	S -3
	T 10	S 8
53	T 3	S 12
57	T 7	S 8
	T 10	S 6, S 15
	T 12	S 7

The criteria for edits of artifactual data were:

(1) No more than 2 consecutive seconds were edited, with averages inserted.

(2) Two consecutive seconds missing immediately before and after the stimulus onset were not acceptable.

(3) No more than 3 seconds in any one trial were edited for a trial to be acceptable.

(4) If a subject had many edits, even though all were acceptable, that subject was replaced. (This happened in one instance.)

APPENDIX C

ANALYSIS OF PILOT DATA

Table 13: Analysis of Variance of Heart Rate Change For the Pilot Subjects

TABLE 13

ANALYSIS OF VARIANCE OF HEART RATE CHANGE

FOR THE PILOT SUBJECTS[a]

Source	df	Mean Square	F	p
Mean	(1,2)	16637312.57748	2255.473	.001
Seconds	(15,30)	226.48076	4.19598	.001
Linear Trend	(1,2)	484.65131	86.09649	.011
Voice x Seconds	(15,30)	84.87208	3.07052	.004
Cubic Trend	(1,2)	351.24417	44.43098	.022
Voice x Location x Trials x Seconds	(30,60)	26.76398	2.82163	.001
Cubic Trend	(2,4)	94.03864	18.104965	.010

<u>Note 1</u>. The design of the analysis was an age (2) x subjects (2) x voice (2) x location (2) x trials (3) x seconds (16) repeated-measures design.

<u>Note 2</u>. Only the main effects and interactions which reached the significance level of $p < .05$ have been listed.

[a]N=4

APPENDIX D

PRELIMINARY ANALYSIS OF HEART RATE CHANGE

Table 14: Analysis of Variance of the One-Second Prestimulus Periods

Table 15: Analysis of Variance of Heart Rate Change by Sex of Subject

Table 16: Analysis of Variance of Heart Rate Change by Order of Signal Presentation

Table 17: Analysis of Variance of Heart Rate Change by Right- vs. Left-Side Loudspeaker

TABLE 14

ANALYSIS OF VARIANCE OF THE ONE-SECOND PRESTIMULUS PERIODS[a]

Source	df	Mean Square	*F*	*p*
Mean	(1,30)	8271651.92042	6491.03813	.001

Note 1. The design of the analysis was an age (2) x subjects (16) x trials (12) repeated-measures design.

Note 2. Only the main effects and interactions which reached the significance level of $p < .05$ have been listed.

[a]N=32.

TABLE 15

ANALYSIS OF VARIANCE OF HEART RATE CHANGE BY SEX OF SUBJECT[a]

Source	df	Mean Square	*F*	*p*
Mean	(1,28)	131891065.33208	6700.32016	.001
Age x Sex x Seconds	(15,420)	82.40616	2.38001	.003
Linear Trend	(1, 28)	712.44976	6.30932	.018
Sex x Trials x Seconds	(30,840)	35.04787	1.79020	.006
Cubic Trend	(2,56)	207.48052	3.289108	.049
Sex x Voice x Location x Trials	(2,56)	1093.94891	3.49516	.037
Sex x Voice x Location x Trials x Seconds No supporting trends	(30,840)	31.66022	1.65362	.016
Age x Sex x Voice x Location x Trial x Seconds No supporting trends	(30,840)	47.02390	2.45606	.001

Note 1. The design was an age (2) x sex (2) x subjects (8) x voice (2) x location (2) x trials (3) x seconds (16) repeated-measures design.

Note 2. Only the main effects and interactions which reached the significance level of $p < .05$ and which included the variable of the sex of the subject have been listed.

[a] N=32.

TABLE 16

ANALYSIS OF VARIANCE OF HEART RATE CHANGE BY ORDER OF SIGNAL PRESENTATION[a]

Source	df	Mean Square	*F*	*p*
Mean	(1,28)	131891065.33208	6072.53284	.001
Order x Voice x Trials	(2,56)	1657.31110	3.34764	.042
Age x Order x Voice x Location x Trials	(2,56)	1049.07060	3.30278	.044
Age x Order x Voice x Location x Trials x				
Seconds	(30,840)	52.99583	2.68740	.001
Linear Trend	(2,56)	691.09176	4.6272226	.049
Quadratic Trend	(2,56)	463.67964	3.2270946	.049

Note 1. The design was an age (2) x order (2) x subjects (8) x voice (2) x location (2) x trials (3) x seconds (16) repeated-measures design.

Note 2. Only the main effects and interactions which reached the significance level of $p < .05$ and which included the variable of order of signal presentation have been listed.

[a]N=32.

TABLE 17

ANALYSIS OF VARIANCE OF HEART RATE CHANGE BY RIGHT- VS. LEFT-SIDE LOUDSPEAKER[a]

Source	df	Mean Square	*F*	*p*
Mean	(1,28)	131891065.33208	6072.53284	.001
Age x Side x Trials	(2,56)	2478.75849	5.04755	.010
Age x Side x Trials x Seconds No supporting trend	(30,840)	30.26377	1.53158	.035
Side x Voice x Trials x Seconds No supporting trend	(30,840)	41.57837	1.71245	.011

Note 1. The design was an age (2) x side (2) x subjects (8) x voice (2) x location (2) x trials (3) x seconds (16) repeated-measures design.

Note 2. Only the main effects and interactions which reached the significance level of $p < .05$ and which included the variable of the location of the side loudspeaker have been listed.

[a]N=32.

APPENDIX E

PRIMARY ANALYSES OF HEART RATE CHANGE

Table 18: Analysis of Variance of Heart Rate Change By Age and Type of Stimulus

Table 19: Analysis of Variance of Heart Rate Change to the Mother's Voice

Table 20: Analysis of Variance of Heart Rate Change to the Babel Signal

Table 21: Analysis of Variance of Heart Rate Change for the Younger Infants

Table 22: Analysis of Variance of Heart Rate Change for the Older Infants

TABLE 18

ANALYSIS OF VARIANCE OF HEART RATE CHANGE BY AGE AND TYPE OF STIMULUS[a]

Source	df	Mean Square	*F*	*p*
Mean	(1,30)	131891065.33208	6306.77278	.001
Voice	(1,30)	22840.37595	12.34815	.001
Seconds	(15,450)	206.50795	5.80278	.001
Linear Trend	(1,30)	1487.64559	11.32250	.002
Quadratic Trend	(1,30)	988.49955	6.26370	.018
Cubic Trend	(1,30)	477.21106	4.51146	.042
Age x Seconds	(15,450)	85.89293	2.41355	.002
No supporting trend				
Voice x Seconds	(15,450)	164.31880	4.98971	.001
Quadratic Trend	(1,30)	1428.66901	9.91818	.004
Age x Voice x Seconds	(15,450)	56.56326	1.71760	.045
No supporting trends				
Voice x Location x Seconds	(15,450)	32.21648	2.18840	.006
Linear Trend	(1,30)	366.30062	5.76868	.023
Age x Location x Trials x Seconds	(30,900)	35.26559	1.49542	.043
No supporting trend				
Voice x Location x Trials x Seconds	(30,900)	33.62813	1.64100	.017
Quadratic Trend	(2,60)	680.28149	4.5186169	.025

Note 1. The design was an age (2) x subjects (16) x voice (2) x location (2) x trials (3) x seconds (16) repeated-measures design.

Note 2. Only the main effects and interactions which reached the significance level of $p < .05$ have been listed.

[a]N=32.

TABLE 19

ANALYSIS OF VARIANCE OF HEART RATE CHANGE

TO THE MOTHER'S VOICE[a]

Source	df	Mean Square	*F*	*p*
Mean	(1,30)	43740037.06082	4255.49375	.001
Seconds	(10,300)	207.60111	4.09818	.001
Quadratic Trend	(1,30)	1849.77694	7.85831	.009

Note 1. The design was an age (2) x subjects (16) x location (2) x trials (3) x seconds (11) repeated-measures design.

Note 2. Only the main effects and interactions which reached the significance level of $p < .05$ have been listed.

[a]N=32.

TABLE 20

ANALYSIS OF VARIANCE OF HEART RATE CHANGE TO THE BABEL SIGNAL

Source	df	Mean Square	*F*	*p*
Mean	(1,30)	46493383.44116	7958.32539	.001
Trials	(2,60)	1326.75949	3.50553	.036
Age x Seconds	(10,300)	33.91395	2.27614	.014
No supporting trend				
Age x Location x Trials	(2,60)	665.39187	3.85508	.027
Age x Location x Trials x Seconds	(20,600)	42.74273	2.66497	.001
Cubic Trend	(2,60)	369.47157	6.5066243	.005

Note 1. The design was an age (2) x subjects (16) x location (2) x trials (3) x seconds (11) repeated-measures design.

Note 2. Only the main effects and interactions which reached the significance level of $p < .05$ have been listed.

[a]N=32.

TABLE 21

ANALYSIS OF VARIANCE OF HEART RATE CHANGE FOR THE YOUNGER INFANTS[a]

Source	df	Mean Square	*F*	*p*
Mean	(1,15)	67675278.20799	3020.49650	.001
Voice	(1,15)	9652.21966	4.77367	.045
Voice x Seconds	(15,225)	81.85980	3.85609	.001
Linear Voice x Seconds Trend	(1,15)	597.61916	11.84345	.004
Cubic Voice x Seconds Trend	(1,15)	363.01312	6.45933	.023
Location x Trials x Seconds	(30,450)	40.93980	1.61778	.022
Quadratic Location x Trials x Seconds	(2,30)	508.5508	4.02961	.05
Voice x Location x Trial x Seconds	(30,450)	37.55206	1.61045	.023
No supporting trend				

Note 1. The design of the experiment was a subjects (16) x voice (2) x location (2) x trials (3) x seconds (16) repeated-measures design.

Note 2. Only the main effects and interactions which reached the significance level of $p < .05$ have been listed.

[a]N=16.

TABLE 22

ANALYSIS OF VARIANCE OF HEART RATE CHANGE FOR THE OLDER INFANTS[a]

Source	df	Mean Square	*F*	*p*
Mean	(1,15)	64238179.93087	3307.85898	.001
Voice	(1,15)	13336.75022	7.95070	.013
Seconds	(15,225)	265.84795	5.51819	.001
Linear Trend	(1,15)	1783.85743	11.06540	.005
Quadratic Trend	(1,15)	1531.24068	6.07827	.026
Voice x Seconds	(15,225)	139.02226	3.11471	.001
Quadratic Voice x Seconds Trend	(1,15)	1621.80608	8.91941	.009

Note 1. The design was a subjects (16) x voice (2) x location (2) x trials (3) x seconds (16) repeated-measures design.

Note 2. Only the main effects and interactions which reached the significance level of $p < .05$ have been listed.

[a]N=16.

APPENDIX E

Table 23: Analysis of Variance of Heart Rate Change to the Mother's Voice in the Front Location

Table 24: Analysis of Variance of Heart Rate Change to the Mother's Voice in the Side Location

TABLE 23

ANALYSIS OF VARIANCE OF HEART RATE CHANGE

TO THE MOTHER'S VOICE IN THE FRONT LOCATION

Source	df	Mean Square	*F*	*p*
Mean	(1,30)	32106076.75294	4482.17098	.001
Seconds	(15,450)	92.78489	2.45671	.002
Quadratic Trend	(1,30)	755.47269	4.19572	.049

Note 1. The design of the analysis was an age (2) x subjects (16) x trials (3) x seconds (16) repeated-measures design.

Note 2. Only the main effects and interactions which reached the significance level of $p < .05$ have been listed.

[a]N=32, divided equally by age group.

TABLE 24

ANALYSIS OF VARIANCE OF HEART RATE CHANGE TO THE MOTHER'S VOICE IN THE SIDE LOCATION[a]

Source	df	Mean Square	*F*	*p*
Mean	(1,30)	32115237.77981	4356.50638	.001
Seconds	(15,450)	299.80745	8.51711	.001
Linear Trend	(1,30)	1909.49186	16.16168	.001
Quadratic Trend	(1,30)	1743.25349	12.35168	.001
Cubic Trend	(1,30)	686.05967	5.87530	.022
Trials x Seconds	(30,900)	29.97093	1.50286	.041
Quadratic Trend	(2,30)	565.04533	3.9720305	.049

Note 1. The design of the analysis was an age (2) x subjects (16) x trials (3) x seconds (16) repeated-measures design.

Note 2. Only the main effects and interactions which reached the significance level of $p<.05$ have been listed.

[a] N=32, divided equally by age group.

APPENDIX F

ANALYSIS OF BEHAVIORAL DATA

Table 25: Analysis of Variance of Visual Alerting

Table 26: Analysis of Variance of Quieting

TABLE 25

ANALYSIS OF VARIANCE OF VISUAL ALERTING[a]

Source	df	Mean Square	*F*	*p*
Mean	(1,16)	92.45790	103.01868	.001
V[b]	(1,16)	1.38590	11.96242	.003
AL	(1,16)	.18712	6.68735	.020
OV	(1,16)	2.02458	17.47511	.001
VL	(1,16)	.18658	5.27795	.035
SXV	(1,16)	1.91884	16.56246	.001
XVL	(1,16)	.27770	7.85533	.013
SOL	(1,16)	.25992	9.28917	.008
ASXV	(1,16)	.97110	8.38200	.011
AOXL	(1,16)	.22095	7.89629	.013
SOXL	(1,16)	.19853	7.09512	.017
OXVP	(3,48)	.05691	3.01873	.039
SOLP	(3,48)	.10159	4.18348	.010
AVLP	(3,48)	.05433	3.48269	.023
ASOVL	(1,16)	.21345	6.03789	.026
AXVLP	(3,48)	.06332	4.05905	.012
ASOXVP	(3,48)	.08906	4.72401	.006
ASOVLP	(3,48)	.06924	4.43834	.008
AOXVLP	(3,48)	.05217	3.34398	.027
ASOXVLP	(3,48)	.06035	3.86856	.015

Note 1. The design was an age (2) x side (2) x order (2) x sex (2) x subjects (2) x voice (2) x location (2) x periods (4) repeated-measures design.

Note 2. Only the main effects and interactions which reached the significance level of $p < .05$ have been listed.

[a] N=32.

[b] The initials stand for the following:

A = age
S = side-loudspeaker location
O = order of signal presentation
X = sex
V = voice
L = location
P = periods

TABLE 26

ANALYSIS OF VARIANCE OF QUIETING[a]

Source	df	Mean Square	*F*	*p*
Mean	(1,16)	11.59211	65.04895	.001
V[b]	(1,16)	1.71843	15.80080	.001
ASOL	(1,16)	.15687	6.10919	.025
AOXL	(1,16)	.16124	6.27941	.023
ASVP	(3,48)	.04943	3.04293	.038
AOXVP	(3,48)	.05313	3.27100	.029
SXVLP	(3,48)	.06051	3.79021	.016

Note 1. The design was an age (2) x side (2) x order (2) x sex (2) x subjects (2) x voice (2) x location (2) x periods (4) repeated-measures design.

Note 2. Only the main effects and interactions which reached the significance level of $p < .05$ have been listed.

[a] N=32

[b] The initials stand for the following:

A = age
S = side-loudspeaker location
O = order of signal presentation
X = sex
V = voice
L = location
P = periods