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PRENATAL AUDITORY EXPERIENCE WITH MELODIES: EFFECTS ON
POSTNATAL AUDITORY PREFERENCES IN HUMAN NEWBORNS

The University of North Carolina at Greensboro

Ph.D. 1985

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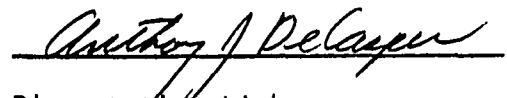
by

Robin Kay Panneton

A Dissertation Submitted to
the Faculty of the Graduate School at
The University of North Carolina at Greensboro
in Partial Fulfillment
of the Requirements for the Degree
Doctor of Philosophy

Greensboro
1985

Approved by



Dissertation Adviser

APPROVAL PAGE

This dissertation has been approved by the following committee of the Faculty of the Graduate School at the University of North Carolina at Greensboro.

Dissertation Adviser

Anthony J. DeClasper

Committee Members

Timothy D. Austin

David J. Brownstein

Samuel A. Doherty

Robert Gottlieb

November 15, 1985

Date of Acceptance by Committee

November 15, 1985

Date of Final Oral Examination

ABSTRACT

Panneton, R. K., Ph.D. Prenatal Auditory Experience with Melodies: Effects on Postnatal Auditory Preferences in Human Newborns. (1985)
Directed by Dr. Anthony J. DeCasper. Pp. 72

It has recently been demonstrated that human newborns prefer a story their mothers had read aloud while pregnant over an unfamiliar story. It is unclear from these results, however, whether the newborns were using word information, non-word information (e.g., rhythmic structure) or both in their postnatal recognition of the story. The present study was conducted to determine if prenatal experience with non-word information was sufficient to produce a postnatal preference. Pregnant women who were close to term sang a melody everyday for the rest of their pregnancies. Their infants were tested postnatally with a choice procedure in which they could listen to the familiar melody or an unfamiliar melody. The melodies differed only in their prosodic characteristics (e.g., frequency contours). A previous experiment had demonstrated that non-experienced newborns could discriminate between these two melodies. Analyses of preferential responding showed that the prenatally experienced newborns preferred the familiar melody over the unfamiliar melody whereas a control group of non-experienced newborns showed no systematic preference. These results are consonant with our understanding of the fetal auditory system and the intrauterine sound environment.

To my parents

ACKNOWLEDGEMENTS

I would like to thank the following for their help in seeing this project to its completion: the mothers and their infants who participated in this study; the maternity staff of Nursery B at Moses Cone Hospital; Dr. Phyllis Prescott and Dr. Anthony DeCasper for their help with data collection; Drs. Gottsegen, Fore , Dickstein, Kaplan, Neal, and McPhail for allowing my solicitation of subjects from their private practices; the instructors of the childbirth classes at Moses Cone Hospital; Dr. Sandra Forman for her recording of the melodies; Dr. Giles Warrack for his statistical consultation; and Lee D. Cooper for his help in the preparation of this manuscript.

I am grateful to the members of my committee, Drs. Gilbert Gottlieb, Aaron Brownstein, Timothy Johnston, and David Ludwig, for their continued advice and encouragement. I am especially indebted to my dissertation adviser, Dr. Anthony DeCasper, for his unending confidence in me. His guidance and instruction have enabled me to not only achieve my professional goals, but to lead a more effective personal life.

Lastly, my deepest thanks to my family and friends for believing in me even when I did not. Their support was invaluable to me.

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INTRODUCTION

Until the early 1970's, little information existed on the auditory competencies of young infants, particularly those abilities related to language development. The paucity of research in this area resulted from the interaction of several factors including the lack of methodologies appropriate for studying auditory perception in young infants (Aslin, Pisoni, and Jusczyk, 1983) and also a prevalent view of the young infant as being behaviorally and perceptually incompetent. Within the last 10 years, methodological and theoretical advancements have allowed us to obtain new and interesting information about early auditory perception. For example, human newborns evidence a variety of auditory preferences. They prefer their mother's voice over that of a strange female (DeCasper and Fifer, 1980), intrauterine heartbeat sounds over silence (DeCasper and Sigafos, 1983), and intrauterine heartbeat sounds over a male voice (Panneton and DeCasper, 1984). They do not, however, show a preference for their father's voice over that of a strange male, even though they can discriminate between them (DeCasper and Prescott, 1984). Because such specific preferences would seem to require some previous experience, the suggestion has been made that they may be influenced by the infant's prenatal auditory experience. Although there has been few direct tests of this hypothesis, it receives some support from studies that demonstrate the availability of sound

(e.g. maternal speech) in utero; the functional maturity of the auditory system in the late-term fetus; the ability of the human fetus to respond to sound; by experiments showing that prenatal experience affects postnatal perception in several infrahuman species; and by one experiment demonstrating the same effect in humans. These data emphasize the importance of further investigating the possible influences of prenatal auditory experiences on the development of early auditory perception in humans, especially the early perception of speech. If it is true that prenatal auditory experience (especially with speech) affects the newborn's auditory preferences, young infants should be able to respond differentially to specific properties of acoustic stimuli, in general, and to specific properties of speech, in particular, because stimulus preference necessitates stimulus discrimination.

Auditory psychophysics of young infants

Young infants are competent processors of both artificial acoustic stimuli, such as pure tones, and naturally occurring ones, such as human speech. Electromyographic responses of 3- to 8-day-old neonates to sine and square waves presented over a loudspeaker were greater to low frequencies (i.e., 125 and 250 Hz) than to higher frequencies (Hutt, Hutt, Lenard, Bernuth, and Muntjewerff, 1968). Also, the newborns were more reactive to the low-frequency square waves than to the low-frequency sine waves. Hutt et al. concluded that maximal responsiveness to the low-frequency square-wave stimuli suggested that newborns should be differentially sensitive to human speech because,

like speech, those stimuli were patterned and fell within the range of fundamental frequencies of voices (see also Weir, 1976).

Turkewitz, Birch, and Cooper (1972) studied the responsiveness of 45 female neonates, ranging from 24 to 72 hours old, to complex (white noise) and simple (pure tone) auditory stimuli presented over a loudspeaker. According to three separate response measures (heart rate acceleration, directional eye-turning, and finger movement) these newborns showed greater responsiveness to the white noise than to any of the pure tones (from 250 to 8000 Hz). The behavior during presentation of the pure tones was not different from that found during control trials. These data corroborate those presented by Hutt et al. (1968) in showing that neonates are more responsive to complex stimuli than to simple auditory stimuli.

Bartoshuk's (1964) data from human neonates indicate a linear relationship between the logarithm of a momentary heart rate increase triggered by the onset of a 1000-Hz tone and the intensity of the tone. Infants between 6 and 12 months have pure-tone thresholds and broad-band thresholds approximately 17 to 30 dB greater than adults, with the lowest thresholds for frequencies below 500 Hz (Sinnott, Pisoni, and Aslin, 1983; Trehub, Schneider, and Endman, 1980). Thus, young infants' threshold functions for simple and complex auditory stimuli look like elevated adult functions, their responsivity to suprathreshold intensities resemble the adults' magnitude-estimation function, and they seem to be particularly responsive to broad-spectrum sounds within the range of fundamental frequencies of human speech.

Young infants' perception of speech segments. In their often-cited study, Eimas, Siqueland, Jusczyk, and Vigorito (1971) demonstrated categorical perception of voiced and unvoiced consonants, similar to that shown by English-speaking adults, in 1- and 4-month-old infants. The distinction between the two consonant types depends on the interval, the voice-onset time or VOT, between the release of air and the onset of vocal-cord vibration. For example, in the voiced syllable /ba/ the release of air and vocal-cord vibration are simultaneous ($VOT=0$), whereas in the unvoiced syllable /pa/, vocal cord vibration is delayed by approximately 20 msec ($VOT= -20$ msec). The infants in the Eimas, et al. study did not discriminate between two versions of /ba/ that differed by 20 msec in VOT, nor did they discriminate between two versions of /pa/ that differed by the same amount. They did, however, discriminate between a version of /ba/ and a version of /pa/ that also differed by 20 msec in VOT. Thus, even though the members of the three different pairs of phonemes were separated by the same physical difference in VOT, the members of two pairs are perceived as belonging to the same categories whereas the members of the third pair were perceived as belonging to separate categories.

Discrimination of /ba/ and /pa/ phonemes whose VOT differed by more than 20 msec has been demonstrated in human newborns ranging in age from 24 to 72 hours (DeCasper, Butterfield, and Cairns, 1976). Infants less than 6 weeks old can discriminate between syllables that differ in the order of their consonant-vowel-consonant patterns; for example, between "pat" and "tap" (Bertoncini and Mehler, 1981). In these two studies, infants could have discriminated the speech contrasts on the basis of

the change in initial consonant. In order to determine whether infants can also discriminate changes in combinations of individual sounds, Miller and Eimas (1979) first familiarized young infants with the phonemes /ba/ and /dae/. After familiarization, the stimuli were changed to /bae/ and /da/. Thus, the particular sounds remained the same, but their combinations were changed. The infants discriminated the recombination of the individual segments. A later study showed that 2- to 4-month olds also discriminate recombinations of phonemes with different pitch contours (Eimas and Miller, 1981). In addition to making consonant-vowel discriminations, young infants have been shown to discriminate vowels from one another in spite of irrelevant changes in pitch contours (Kuhl, 1979) or changes from one voice to another (Kuhl, 1983). As these examples suggest, young infants are capable of a variety of auditory discriminations relevant to the perception of language. These discriminations include not only individual segments, but also the ways in which segmental information is arranged.

Eimas et al. (1971) proposed that, because young infants have (presumably) little experience with speech (either self-generated or other-generated), their perception of speech sounds is mediated by innate detectors of speech features (Eimas, 1978; Trehub, 1979). An alternative view states that because young infants from many cultures perceive certain speech sounds categorically, as do the adults of their cultures, and since they also discriminate certain speech contrasts that the adults do not discriminate (cf. Werker and Tees, 1984), the role of early experience is thought to be a selective one: at birth, a newborn can discriminate various speech-related contrasts, but the only

discriminations that persist into adulthood are those of functional significance in the child's native language. This notion of speech-specific perceptual mechanisms has, however, met with some difficulty. For example, infants can perceive both speech and nonspeech sounds categorically (e.g., Cutting and Rosner, 1974; Jusczyk, Rosner, Cutting, Foard, and Smith, 1977; Pisoni, 1977) and nonhuman animals can perceive speech sounds categorically as well (Kuhl and Miller, 1975; 1978). These findings imply that early speech perception may not be governed by linguistically based mechanisms, but rather by the psychophysical properties of speech sounds per se (Aslin and Pisoni, 1980; Walley, Pisoni, and Aslin, 1981). The question remains, however, whether these early perceptual abilities are independent of previous auditory experience. An alternative explanation for the origins of speech perception is that early (postnatal and/or prenatal) experience with speech is necessary for the subsequent development of the discrimination of various speech contrasts, even though the experience of the newborn is obviously limited compared with that of older infants (Aslin and Pisoni, 1980; Eilers, Gavin, and Wilson, 1979). Since newborns have been shown to discriminate between phonemes (DeCasper et al., 1976), it may be that early (postnatal and/or prenatal) experience with maternal speech is a factor in the development of young infants' perception of the segmental (i.e. phonetically based; see Miller, 1978) aspects of speech.

Young infants' perception of suprasegmental aspects of speech. The literature on infants' perception of suprasegmental speech characteristics such as intonation, pitch, stress and duration (i.e., those aspects of speech that transcend the phonetic level) is growing. For example, several studies have examined the young infant's perception of higher-order relations between the stimulus elements of patterned sounds. Three-month-old infants, after habituating to a melody sung by a female, discriminated a change in the notes of the melody even though the voice remained constant (Hennessy, Palmer, Jones, Richardson, Unze, and Pick, 1983). They also discriminated a change in key even though both the melody and voice remain the same. Washburn and Cohen (1984) showed that 3-1/2- to 4-month-old infants dishabituated to a tonal sequence when it was different in overall rhythmic form from the habituated sequence: the inter-note intervals were the same in the two sequences but their order of occurrence was changed.

Using an operant procedure with a head-turning response, Trehub, Thorpe, and Morrongiello (1985) showed that 6- to 8-month olds could discriminate single note changes (where a note change = 10 semitones) in melodies composed of six sequential pure tones. These infants discriminated the note change regardless of its position in the melody and regardless of whether the changed note increased or decreased in frequency. Young infants have also been shown to detect changes in the direction of successive frequency changes or contour of a melody when the frequencies of individual notes remain constant (Trehub, Bull, and Thorpe, 1984). In a situation where two tonal patterns with contrasting harmonic structures are being discriminated, 7- to 8-month-olds can

ignore variations in their fundamental frequencies, durations and intensities. They can also ignore variations in harmonic structure while discriminating differences in fundamental frequency, duration and intensity (Endman, 1984).

Analogous discriminations have been demonstrated with speech sounds. For example, Eimas and Miller (1981) showed that 3- to 4-month-olds discriminated between two presentations of the same phoneme when the pitch had been altered. Bull, Eilers, and Oller (1984) showed that 5-month-old infants can discriminate 5- to 30-Hz increments in the fundamental frequency of multi-syllabic words. Because such frequency changes often occur when certain syllables are being emphasized, these results suggest that young infants are sensitive to differences in stress placed on various syllables in continuous speech.

Miller, Younger, and Morse (1982) examined the ability of 7-month-olds to classify male and female voices. Using an operant head-turning task, they showed that these infants discriminated a class of male voices from a background of female voices (and vice versa). In their second experiment, the authors combined both male and female voices and divided them into a low-pitched group and a high-pitched group. The mean fundamental frequency of the low-pitched group was similar to that of male voices and the mean fundamental frequency of the high-pitched group was similar to that of female voices. In this second experiment, 7-month-olds failed to discriminate between the low- and high-pitched groups. It appears, then, that infants can discriminate between male and female voices on the basis of complex acoustic

information that does not necessarily include fundamental frequency.

Perhaps one of the most salient suprasegmental features of the speech directed at young infants is its intonational pattern or frequency contour (Fernald, 1984). Studies analyzing the acoustic properties of speech to young infants, including newborns, show that mothers tend to use expanded frequency contours, wider pitch excursions, and greater degrees of pitch continuity in their speech to infants (Fernald and Simon, 1984; Stern, Spieker, and MacKain, 1982). Since segmental aspects of speech vary more within a speaker than do suprasegmental aspects, Fernald (1984) has suggested that highly exaggerated, recurring intonational contours may be a more salient acoustic determinant for individual voice recognition in young, prelinguistic infants. One-month-old infants responded differently to their mothers' voices and a strange female's voice when both were intonated but did not respond differently when both were monotone (Mehler, Bertoncini, Barriere, and Jassik-Gerschenfeld, 1978). When given a choice between infant-directed speech ("motherese") and adult-directed speech, 4-month-old infants prefer "motherese" (Fernald, 1982; 1985). When all of the segmental information was filtered out of the speech samples so that they retained only their intonational contours, 4-month-olds still preferred the intonational contours of the "motherese". Thus, the presence of segmental or phonetic aspects of a speech utterance are not necessary to maintain young infants' preference for highly intonated female speech. Fernald (1984; 1985) suggests that the high degree of pitch continuity found in "motherese" may facilitate the young infant's ability to locate and follow the mother's voice,

while the expanded pitch ranges may serve to maximize perceptual contrast, thus better eliciting and maintaining the infant's attention.

Taken together, the preceding studies establish that young infants are capable of perceiving both suprasegmental and segmental aspects of speech. It seems likely that their ability to do so is influenced by earlier auditory experiences with speech and speakers (cf., Eilers, Gavin, and Wilson, 1979; Werker and Tees, 1984). Since there is a possibility that human fetuses are exposed to various kinds of acoustic information (including speech) in utero, it may be that important experiences begin with prenatal exposure to speech. In order for this hypothesis to be credible, it is important to establish that: (1) The human auditory system is functional prior to birth, and that sound (particularly speech) is available to the fetus; and (2) Prenatally experienced sounds can influence postnatal perception.

Fetal responsiveness to sound

Cochlear function is demonstrable by the 5th fetal month, by which time both middle- and inner-ear structures have reached their adult size. Auditory nerve fibers begin to myelinate during the 6th fetal month and by birth the auditory cortex has become medulated. The entire auditory system is functional by the third trimester of gestation (Eisenberg, 1976; Rubel, 1978).

The possibility that this system is stimulated by sound before birth is supported by data indicating the availability of sound in utero, as well as by the fetus's responsiveness to such sound. Walker, Grimwade, and Wood (1971) recorded intrauterine sound in 16 pregnant women, before and after the rupture of the fetal membranes. The average noise level was 85 dB SPL both before rupture of the membranes (with the microphone in the cervical canal) and after their rupture (with the microphone lateral to the fetal head). They also recorded the intrauterine attenuation of externally presented tones ranging from 50 to 3000 Hz. Frequencies above 1000 Hz were attenuated by 40 dB or more while lower frequencies were attenuated by 20 dB. Walker et al. concluded that higher-frequency environmentally generated sounds should rarely exceed intrauterine noise levels because attenuation increases with frequency while the lower frequency extrauterine sounds, although not as severely attenuated, are most likely masked by other low-frequency intrauterine sounds. Human intrauterine recordings, taken after rupture of the amniotic sac, indicated that the most audible speech stimulus in utero was the mother's voice, presumably because her vocal tract is located closer to the uterus than are any other speech generators (Querleu and Renard, 1981). Thus, the intrauterine environment is a potentially rich source of speech and non-speech sounds.

Studies of other placental mammals corroborate this view of the fetus's auditory environment. By suturing a hydrophone to the external uterine wall of a pregnant goat (directly over the fetal head), Bench, Anderson, and Hoare (1970) were able to record the amount of frequency

distortion of externally presented pure tones in utero. They recorded the sound pressure level of 500, 1000, and 2000 Hz tones from the 75th day (approximately 2 1/2 months) of gestation on. They found little distortion in the signals, whose average sound pressure level remained well above the intrauterine ambient background. However, Bench et al. did note that the signals became increasingly attenuated with gestational age, presumably because of structural changes in the dam's geometry which increased the distance between the sound generator and the hydrophone.

Armitage, Baldwin, and Vince (1980) were able to obtain even more precise information about the prenatal auditory environment of sheep by suturing hydrophones to the necks of two sheep fetuses within their amniotic sacs and recording sounds originating outside and within the dam. They found that externally presented sounds were attenuated by an average of 20 dB (with a maximum attenuation of 37 dB at 1000 Hz), that conversation outside the dam was occasionally discernible, and that raised voices were almost always distinct. Audible sounds produced by the mother included drinking, eating and rumination and were characteristically of low frequencies (up to 500 Hz). The dam's heartbeat was not audible in their recordings.

As the following sample of studies shows, human fetuses are capable of hearing externally presented sounds. Bernard and Sontag (1949) stimulated three fetuses within the last 2 1/2 months of gestation with a wide range of pure tones, presented via a loudspeaker positioned over the head region of the fetus. Cardiac acceleration (indicative of a

startle response) was seen in all fetuses shortly after the onset of tonal stimulation. Fetuses within the last 7 weeks of gestation showed an increase in pulse rate in response to the presentation of a 3000-Hz pure tone at 110 dB (Johansson, Wedenberg, and Westin, 1964) and fetal eye-blink responses have been observed, via ultrasound imaging, to vibroacoustic stimulation from the 25th week of gestation on (Birnholtz and Benacceraf, 1983). Auditory evoked responses have been obtained from fetuses in response to a pulsed sound stimulus after rupture of the amniotic sac during labor (Scibetta, Rosen, Hochberg, and Chik, 1971). By the use of ultrasound imaging, third trimester fetuses have been shown to increase their activity levels when a 2000-Hz tone at 110 dB was presented to the lower maternal abdomen (Gelman, Wood, Spellacy, and Abrams, 1982). Fetuses between 37- and 40-weeks gestational age showed significant increases in heart-rate and limb movements to an 800-Hz tone presented through the maternal abdomen at both 106 dB and 113 dB (approximately 86 dB and 93 dB in utero, respectively; Granier-Deferre, Lecaunet, Cohen, Busnel, and Sureau, 1984).

Thus, the intrauterine environments of both human and some infrahuman fetuses provide a variety of sounds that fetuses can hear. The human auditory system is capable of processing sound by the third trimester and human fetuses, near term, appear to be responsive to the presentation of certain sounds. Whether and how fetal experience with sound actually affects postnatal auditory perception was the central concern of this project.

Effects of prenatal auditory experience on postnatal perception

Infrahuman research. Evidence for prenatal auditory learning in humans is recent but evidence for such learning in infrahumans has a substantial history. Vince (1979) exposed one group of fetal guinea pigs to a recording of the feeding call of the bantam game hen once each day during their last 2-3 weeks of gestation. This broad-band call typically elicits startle, freezing and heart rate deceleration in young guinea pigs. Nine out of 12 experimental animals showed no heart rate deceleration to the call after birth while 8 out of 9 control animals showed a significant heart rate deceleration. Thus, a defensive reaction to a particular sound typically seen in neonatal guinea pigs can be diminished if the sound is experienced prenatally. Vince, Armitage, Walser, and Reader (1982) stimulated fetal sheep twice daily for 2-4 weeks prior to birth with a series of pure tones ranging from 200-400 Hz or a series of bleats recorded from pregnant ewes. As newborns, the lambs showed a marked acceleration of heart rate when presented with an unfamiliar sound (one not experienced prenatally) and marked heart rate deceleration (or lack of acceleration) when presented with the familiar non-natural sounds (i.e. the tones). There was no discernible effect of the species-specific familiar sound (i.e. the bleats) on heart-rate activity. Thus, at least two species of mammal show habituation to sounds prenatally and this experience influences postnatal perception of similar sounds.

Numerous studies have shown similar effects of prenatal experience on postnatal auditory perception in birds. Vince (1980) stimulated bantam game chick embryos for varying amounts of time with the adult alarm call of their species. Prenatally, heart-rate responses habituated to the onset of the calls. Postnatally, experienced chicks opened their eyes and vocalized less often when the call was presented than did control chicks. Although the most experienced chicks showed the least amount of postnatal vocalization to the call, chicks with only 55 seconds of prenatal experience showed significantly less eye-opening to the call than did the control chicks. Thus, even small absolute amounts of prenatal auditory stimulation can alter postnatal responsiveness to the sound.

Impekoven (1970; 1975) demonstrated a variety of ways in which laughing gull chicks' prenatal exposure to the adult "crooning" call influences their responses to these sounds after birth. For example, chicks that had been exposed to the call prenatally tended to move in response to the call and to approach the speaker emitting it; chicks without that prenatal exposure ceased moving and crouched during the sound period. The results of these studies are consistent with those of Vince (1979; 1980) and Vince et al. (1982) in that they demonstrate the effect of prenatal auditory experience on the habituation of responses (e.g., the suppression of movement) to those sounds postnatally. Lien (1976) stimulated Japanese quail embryos with either a 300 or 400 Hz pure tone on the 12th through 15th days of incubation. No stimulation was delivered during the 48 hours prior to hatching on Day 17. Four to eight hours after hatching the chicks spent significantly more contact

time with a speaker emitting the target tone than with a speaker emitting a tone 1 harmonic either above or below the target tone, even though the chicks had not experienced the target tone within the last 52 hours. Chicks tested 16 hours or more after hatching showed no significant preference for the tone experienced prenatally. This study confirms that prenatal effects can be stimulus specific and that they may be temporally constrained as well.

In a comprehensive series of studies, Gottlieb investigated the role of prenatal auditory experience on the postnatal preference for the species-typical maternal call in birds. For example, newly-hatched mallard ducklings typically prefer their own species' maternal call over that of a different species, even if they have not previously experienced the call. However, if mallard embryos are devocalized in ovo and incubated in isolation (thus preventing experience with self- and sibling-vocalizations), the chicks no longer always prefer the maternal call of their species (Gottlieb, 1978). Gottlieb went on to show that prenatal auditory experience is necessary for the development of the normal perceptual selectivity seen in mallard embryos in their response to various acoustic features of the maternal call (Gottlieb, 1979; 1980). Wood duck embryos, like mallards, also show differential responsiveness to their species-typical maternal call when communally incubated but in isolation from any contact with adults of their species (Heaton, 1972). After being aurally isolated from siblings during incubation, however, wood ducklings do not prefer the specific acoustic characteristics of their maternal call (Gottlieb, 1980). Thus, the normal preferences of mallard and wood ducklings for their respective

species-typical maternal calls depends upon prenatal (in the mallard) or early postnatal (in the wood duck) experience with specific acoustic features that occur in their own and sibling vocalizations (Gottlieb, 1985).

Human studies. Studies investigating the effects of prenatal auditory experience on postnatal perception in human infants are few. In a pioneering study, Salk (1960) presented a normal heartbeat sound (72 beats per minute at 85 dB) to a group of 102 newborns for several days, 24 hours per day. A control group of 112 newborns were not exposed to the heartbeat sound postnatally. Salk found that the exposed newborns gained more weight and cried significantly less than the control infants. Highly aroused newborns have also been shown to be significantly quieted by a recording of maternal intrauterine sounds (Rosner and Doherty, 1979) and newborns' sucking can be reinforced with intrauterine heartbeat sounds (DeCasper and Sigafos, 1983). Salk interprets such results as indicating that the infants had prenatal experience with their mother's heartbeat. Although this interpretation is plausible, the effect may not rely solely on prenatal experience with the heartbeat but rather on the more general effect of rhythmic stimuli on newborns' behavior.

Since the time of Salk's (1960) study, few studies have pursued the possible effects of prenatal auditory experience on postnatal perception in human infants. DeCasper and Fifer (1980) used an operant choice procedure to show that newborns less than 4 days old prefer their mothers' voices to those of unfamiliar females. In a subsequent study,

Fifer (1980) showed that this maternal-voice preference in newborns was unrelated to their age (1-day-old vs 4-day-old) and their method of feeding (breast vs bottle). Fifer's data are important in that they failed to support the notion that the newborns' maternal-voice preferences are strongly influenced by earlier postnatal experience with the maternal voice: If the preference was generated postnatally, an infant's age and feeding method should affect its preference for its mother's voice. This was not the case, however, suggesting that other factors determine this early voice preference. A similar conclusion is suggested by data showing that 3-day-old infants do not show a preference for their fathers' voices over those of other males despite their postnatal auditory experience (DeCasper and Prescott, 1984). They can, however, discriminate between two male voices. Newborns also prefer the intrauterine heartbeat over a male voice (Panneton and DeCasper, 1984). Thus, newborns show a variety of auditory preferences which seem to be fairly independent of postnatal auditory experience. Given the evidence that the fetus can hear and that the intrauterine environment contains auditory information, it is reasonable to suggest that some of these postnatal preferences may result from specific prenatal auditory experiences.

In a direct test of this prenatal hypothesis, Spence and DeCasper (1982) had pregnant women read a specific children's story aloud twice daily during the last five weeks of gestation. Shortly after birth, their infants were placed in an operant choice task in which listening to one of two stories was contingent on the temporal pattern of their sucking. For example, some infants heard a recording of the story their

mother had read while pregnant (the 'old' story) if they sucked at relatively high rates, but heard a different story (the 'new' story) if they sucked at relatively low rates. Thus, infants had a choice between listening to the 'old' or 'new' stories. Thirteen out of 16 newborns preferred the 'old' story over the 'new' story. In addition, infants who had not experienced either story prior to being tested showed no systematic preference between the stories. Spence and DeCasper concluded that the experimental infants preferred the 'old' story because they had heard it prenatally. These are the first human data directly showing that prenatal experience with maternal speech can affect postnatal auditory perception. Spence and DeCasper's study should sharpen our appreciation of the effects of prenatal auditory experience on postnatal perception and learning in humans and it generates new and important research questions. For example, because the data indicate a highly specific relation between prenatal auditory experience and postnatal auditory preferences, it should be possible to specify the acoustic features of the prenatal sounds on which the later perceptual preference is based. Spence and DeCasper (1982) did not determine which of the many possible acoustic features of human speech, including both segmental and suprasegmental features, form the basis for the infant's postnatal preferences and discriminations. However, some inferences can be drawn from existing data.

DeCasper and Fifer (1980) and Fifer (1980) showed that when the words in a spoken passage are held constant but the voices speaking the words are changed, newborns prefer the voice of their mother over that of another female. These data suggest that voice-dependent

suprasegmental, rather than segmental, acoustic characteristics can influence voice recognition in human newborns (cf. Mehler et al., 1978). On the other hand, Spence and DeCasper (1982) showed that when the voice reading two spoken passages is held constant, but the words in each passage are changed, newborns prefer the passage that contains the words that were heard prenatally. That is, newborns may also utilize voice-independent suprasegmental and/or segmental information (cf. DeCasper et al., 1976). Spence (1984) also examined newborns' preferences between filtered and unfiltered samples of their mother's voice, the filtered samples having had all frequencies above 1000 Hz removed. If frequencies above 1000 Hz are necessary for voice recognition, newborns should prefer the unfiltered version but Spence's subjects showed an equal preference for both the filtered and unfiltered versions of the maternal voice. However, a group of different infants, tested under identical conditions using the same voices (so that the voices were not their own mothers') did prefer the unfiltered over the filtered version. One explanation for the difference between the two groups is that both the filtered and unfiltered voices were familiar to the newborns listening to their mother's voice, because both were similar to the voice that the infants had heard prenatally (i.e., both contain voice-specific cues carried by frequencies between 0 and 1000 Hz), and the presence of the lower frequencies in the unfiltered version was not sufficient to produce a preference. However, when the voice is entirely novel, newborns prefer the version with more spectral information present. Apparently, sufficient cues for voice recognition are available in the lower 1000 Hz of speech, although newborns can

discriminate between speech stimuli that differ in the presence or absence of higher frequencies.

These results (DeCasper and Fifer, 1980; Fifer, 1980; Spence and DeCasper, 1982; Spence, 1984) suggest that newborns can utilize both voice-dependent (suprasegmental) and voice-independent (suprasegmental and/or segmental) acoustic characteristics in the postnatal recognition of familiar speakers and familiar speech, respectively, and that relevant experience with these cues occurs prenatally. The main focus of the present study was to make a direct test of the hypothesis that prenatal experience with suprasegmental acoustic aspects of maternal speech is sufficient to produce a postnatal preference for those aspects of speech in human newborns.

Purpose of the study

The primary interest of this study was whether fetuses could learn about suprasegmental information (e.g., frequency contours) in utero and whether this specific experience could influence postnatal perception. In order to test this prenatal hypothesis, pregnant women sang a melody to their fetuses every day during the last weeks of their pregnancies. The melody was that of the nursery rhyme "Mary Had A Little Lamb" but instead of singing the normally occurring words, each woman sang this melody with the syllable "la". Their infants were tested postnatally to see whether they had a preference for this familiar melody over another, unfamiliar melody. The unfamiliar melody was also sung with "la" and was composed of the same individual notes, but had a very dissimilar

note arrangement. If suprasegmental information can be perceived prenatally and can influence postnatal auditory preferences, then these infants should prefer the familiar melody over the unfamiliar melody.

To provide the strongest possible test of this prenatal hypothesis, it was first ascertained that the two melodies to be used in the preference test were discriminable from each other. Thus, in Experiment 1, newborn infants with no prior experience with either melody were tested for their ability to discriminate between them using an habituation procedure.

A subsidiary goal of this study was to replicate Spence and DeCasper's (1982) finding that prenatal auditory experience of the prosodic aspects of speech can influence postnatal auditory perception. A methodologically different replication of that basic finding is useful for establishing its generality.

GENERAL METHOD

Subject selection. All subjects were randomly selected from those infants in the regular-care nursery that met the following selection criteria: uncomplicated delivery, no abnormalities noted at birth, birth weight between 2500 and 4000 grams, no indication of pre- or post-maturity, and APGAR scores of at least 8 at both one and five minutes after birth. Males were not tested until 12 hours after circumcision. Testing took place approximately 2 1/2 hours after a feeding and the subject's parents were invited to observe the testing session.

Apparatus. Each infant had well-padded TDH-39 earphones cupped over both ears for binaural listening and a non-nutritive nipple placed in his/her mouth. The nipple was attached via rubber tubing to a pressure transducer (Stathan P23AA), which was attached to a polygraph recorder (GRASS Instruments Model 7) and solid state programming equipment (BRS/LVE). A two-channel stereo cassette tape recorder (Marantz Model PMD 360) was gated to the programming equipment so that each channel of the recorder could be activated independently. The tape recordings used as stimuli in this study were prepared by a professional singer. The singer sang the melodies of "Mary Had A Little Lamb" (MARY) and "Love Somebody" (LOVE) with the syllable "la" substituted for the normally occurring words. The musical notation of these two melodies is shown in

Appendix A. Each melody was recorded from a master tape on to one of two channels of a stereo cassette tape to provide 30 minutes of uninterrupted singing on each channel; Mary on one channel, LOVE on the other. Both melodies contained the same segmental information (i.e. repetitions of the syllable "la") and the same individual notes, but the temporal order, duration, and relative number of the notes were different in each melody.

Procedure. Each infant was brought to the dimly lit experimental room, and was gently and slowly aroused to a state of quiet alertness (Wolff, 1966). Testing proceeded only if the infant visually tracked movements of the experimenter's face when the infant was held upright and spoken to. Otherwise, the infant was returned to the nursery and, if possible, a second attempt was made to test him/her after a later feeding.

The quiet, alert infant was placed supine in his/her bassinet, with the earphones on his/her head and the nipple in his/her mouth. Two minutes of non-rewarded sucking were observed to ensure that the infant could produce enough negative pressure (a 20 mm Hg: high-amplitude suck or HAS) to trigger the response counter. Healthy newborns can easily produce a negative pressure of 20 mm Hg and setting the pressure counter at this threshold prevented non-sucks (e.g., mouthing movements) from triggering the counter. Infants who could not produce enough negative pressure were not tested.

After this initial adjustment period, testing began. Any infant who did not suck on the nipple for two 1-minute periods during the session was returned to the nursery and the data were discarded. Two experimenters were present during the session, one to hold the nipple and monitor the infant's state and the other to monitor the recording equipment. The experimenter monitoring the infant was blind to the exact experimental condition in effect.

EXPERIMENT 1: Discriminability of Test Melodies

The purpose of Experiment 1 was to determine whether newborns who had no pre-experimental exposure could discriminate between the two melodies to be used in Experiment 2. An habituation procedure was used to determine whether newborns who had never heard MARY or LOVE could discriminate between them. This procedure has been used previously in our laboratory to demonstrate that newborns discriminate among male voices (DeCasper and Prescott, 1984) and is similar to other high-amplitude sucking procedures used to study infant speech perception (c.f. Jusczyk, 1985).

Method

Sixty three infants were tested in order to obtain complete experimental sessions from 16. Of the 47 subjects who did not complete testing, 18 were eliminated for crying, 15 were eliminated for sleeping, 7 were eliminated for failing to meet the habituation criterion after 15 consecutive minutes of sucking, 6 were eliminated for inadequate HASs, and 1 was eliminated because of equipment failure. The sixteen infants who did complete testing were assigned to one of two groups. Infants in the Change Group (CG, $n=8$) heard a 2-second presentation of the melody LOVE after each high-amplitude suck (HAS). If the infant sucked more frequently than once every 2 seconds, the melody was heard continuously. Sucking continued to produce LOVE until the infant's sucking rate

declined sufficiently to meet the habituation criterion (defined below), after which sucking produced the other melody, MARY, for a 2-minute period. Infants in the No Change Group (NCG, $n=8$) underwent the same procedure, except that their sucking continued to produce the same melody (LOVE) for 2 minutes after they met the habituation criterion. The habituation criterion went into effect after the infant had been sucking on the nipple for 3 minutes. The habituation criterion required that the infant's sucking rate decline to at least 75% of the rate in the preceding minute and remain at this rate for 3 consecutive minutes. An illustration of this procedure for a subject in the Change Group is provided in Figure 1. The average age of the infants in the Change Group was 47 hours, with a range from 32 hours to 85 hours. The mean age of infants in the No Change Group was 52 hours, with a range from 38.5 hours to 92 hours.

Data Analysis

If infants in the CG discriminated between the two melodies, their sucking should dishabituate when the new melody was presented. That is, their sucking rate in the post-change period should be significantly higher than that before the change. Infants in the NCG should show no change in sucking rate between the pre- and post-change periods, because the melody they heard remained the same. In order to determine whether dishabituation occurred, an analysis of variance (ANOVA) was performed on the sucking rates of the last two pre-change minutes (Pre 2 and Pre 3; see Figure 1) and the first two post-change minutes (Post 1 and Post 2; see Figure 1) for infants in the CG and NCG. Because this analysis

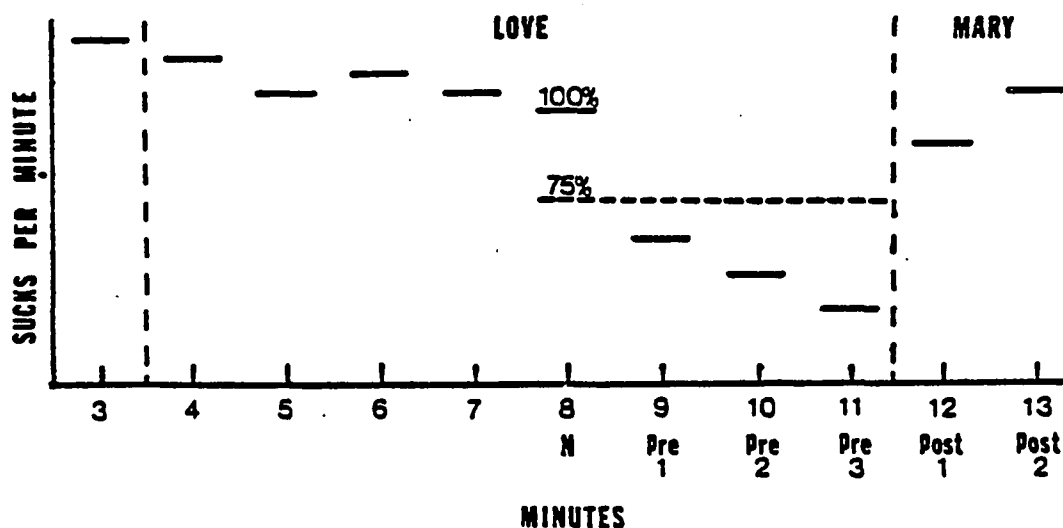


Figure 1. Illustration of the habituation procedure used in Experiment 1. The habituation criteria required that (1) Infants suck for 3 minutes and (2) Sucking rate decline by 75% of the preceding minute (N), for 3 consecutive minutes (Pre 1, Pre 2, Pre 3). After habituation, the melody was changed (Change Group) so that the next suck produced a novel melody. This melody change lasted for 2 minutes (Post 1, Post 2).

involved repeated-measures, conservative F-tests were conducted on the within subject factor (i.e. minutes) and its interaction with the between-subject factor (i.e. group; Ludwig, 1979). Dishabituation was also measured by the ratio $(R2-R1)/R1$, where $R1$ =sucking rate in the pre-change period (Pre2 and Pre3), and $R2$ =sucking rate in the post-change period (Post1 and Post2). A ratio greater than zero indicates an increase in sucking rate after the change of melody. This ratio permitted the analysis of both individual and group differences: There should be significantly more infants with dishabituation ratios greater than zero in the Change Group than in the No Change Group. The frequency of positive and negative dishabituation ratios as a function of group was compared by the Fisher's exact test.

Results and Discussion

As described in detail below, both methods of analysis showed that after the infants in the Change Group had habituated to one melody (LOVE), their sucking rates increased significantly when sucking produced a novel melody (MARY), thus showing that they were able to discriminate the two melodies. In contrast, the infants in the No Change Group showed no increase in response rate after habituation when their sucking responses continued to turn on the same melody (LOVE).

The results of a 2 x 4 mixed ANOVA with Group (Change vs. No Change) as the between-subjects factor and Minutes (Pre2 vs. Pre3 vs. Post1 vs. Post2) as the within-subject factor showed a statistically significant main effect of Minutes [$F=3.49 (3,42)$ $p = .03$, according to

the Huynh-Feldt test] and, more importantly, a significant Group x Minutes interaction [$F=3.10$ (3,42), $p = .04$, according to the Huynh-Feldt test]. A summary of the ANOVA is presented in Table 1.

In order to interpret the Group x Minutes interaction, orthogonal contrasts were conducted. The results of these tests indicated that a significant amount of the variation in the interaction was due to the difference between the Change and No Change Groups in their pre-change and post-change means. The mean sucking rate in the pre-change minutes for the Change Group was 23.88 whereas the mean sucking rate for the No Change Group during the pre-change minutes was 29.50. The mean sucking rates for the Change and No Change Groups during the post-change minutes were 39.62 and 32.56, respectively. Thus, infants in the Change Group showed a significantly greater increase in mean sucking rate from the pre- to post-change minutes than did infants in the No Change Group. Group means for the three pre-change minutes (Pre 1, Pre 2, Pre 3) and the two post-change minutes (Post 1, Post 2) are presented in Figure 2.

In addition to these analyses, dishabituation ratios were calculated for individual subjects, as described in the Method section. These ratios are presented in Table 2. Eight out of 8 infants in the CG had dishabituation ratios greater than zero while only 4 out of the 8 infants in the NCG had dishabituation ratios greater than zero. According to the Fisher's exact test, this pattern of results is significantly different from chance ($p = .04$, one-tail).

TABLE 1

Analysis of Variance Summary Comparing Mean Sucking Rates
For Pre-Change and Post-Change Minutes By Group

Source	df	Mean Square	F-value	p	G-G*	H-F**
Group	1	8.27	0.05	.82		
Between Error	14	265.23				
Minutes	3	543.39	3.49	.02	.04	.03
Pre3 vs Post1	1	1415.12	9.08	.01		
Pre2 vs Pre3	1	161.78	1.04	.31		
Post1 vs Post2	1	52.99	0.34	.56		
Group x Minutes	3	482.56	3.10	.04	.06	.04
Pre3 vs Post1	1	643.66	4.13	.05		
Pre2 vs Pre3	1	578.20	3.71	.06		
Post1 vs Post2	1	225.98	1.45	.24		
Within Error	42	155.85				

* Geisser-Greenhouse probability

** Huynh-Feldt probability

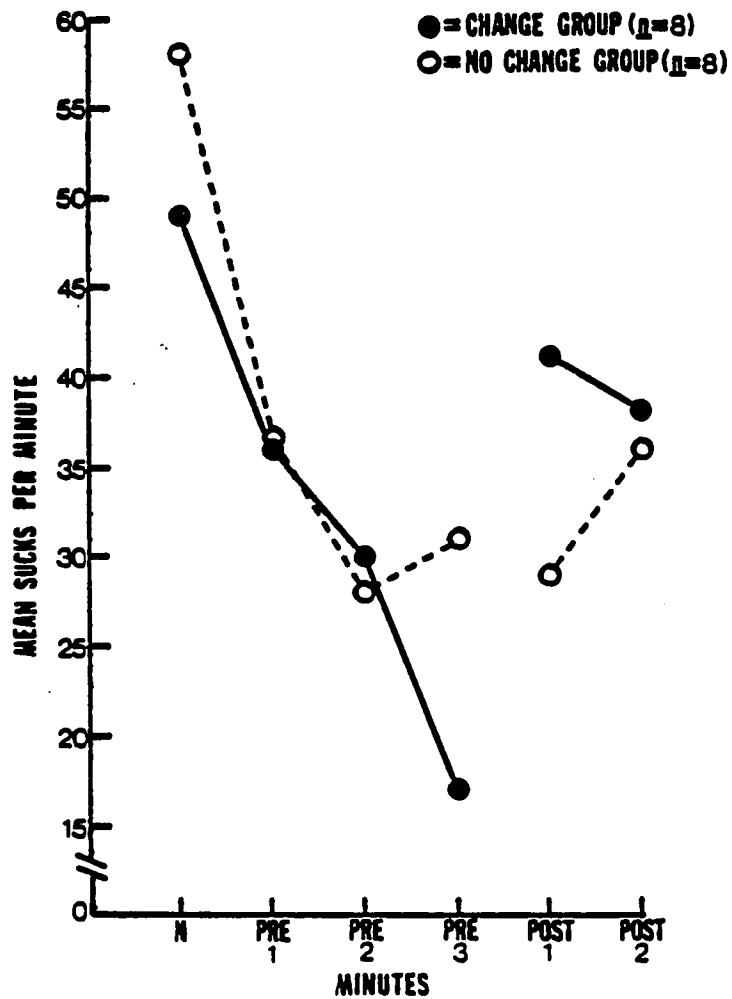


Figure 2. Mean sucking rates during the criterion minute (N), the three pre-change minutes (Pre 1, Pre 2, Pre 3), and the two post-change minutes (Post 1, Post 2) for the Change and No Change Groups.

TABLE 2

Dishabituation Ratios for Infants in the
Change and No Change Groups

GROUP	SUBJECT	SEX	DISHABITUATION RATIO ¹
CHANGE	1	F	0.02
	2	F	1.03
	3	F	0.08
	4	F	1.27
	5	M	0.18
	6	M	3.15
	7	M	0.31
	8	M	0.97
NO CHANGE	9	F	-0.01
	10	F	0.27
	11	F	-0.63
	12	F	0.56
	13	M	-0.03
	14	M	-0.43
	15	M	0.51
	16	M	3.94

¹

Dishabituation ratios were calculated by subtracting the mean sucking rate during the 2 pre-change minutes (Pre 2, Pre 3) from the mean sucking rate during the 2 change minutes Post 1 and Post 2 and dividing by the mean rate of the 2 pre-change minutes. Ratios greater than zero indicate an increase in sucking rate in the change period (i.e. dishabituation).

Note: According to the Fisher's exact test, the number of positive and negative dishabituation ratios differed significantly as a function of group ($X = 5.33$, $p = .02$).

The results of Experiment 1 showed that the sucking rates of infants in the Change Group increased significantly when a novel melody was introduced following habituation. Although this result could have been produced by some aspect of the procedure unrelated to the change in melodies, the behavior of infants in the NCG showed that this was not the case. Those infants were tested under the same conditions but showed no recovery of response rate when sucking continued to produce the same melody. Thus, the dishabituation of sucking shown by infants in the CG demonstrates that they were able to discriminate between the 2 melodies, on some acoustic dimension, after several minutes exposure to one of them. Because the individual notes in each melody were the same, infants could not have used this dimension to discriminate them. However, temporal order, relative occurrence, and duration of the notes did vary between melodies, and the infants could have used any of these dimensions individually or in combination to discriminate between them.

One potential limitation of this study was the high subject attrition rate (i.e. 47 out of 63 infants did not complete testing). Informal observations suggested that almost all of the infants were engaged by the task; that is, their sucking rates increased when sucking initially produced the melody as did other signs of attention (e.g., eye movement; leg and arm movement). After several minutes of responding, one of two response patterns emerged for many of these infants: (1) No indication of any habituation was present within a reasonable amount of time (15 minutes) and, in some cases, the infant went from a high rate of sucking to a very low rate, accompanied by signs of sleepiness (e.g., eyelids fluttering; very little muscle tone); or (2) No indication of

habituation was present and then the infant became very agitated (e.g., crying; pushing the nipple out of its mouth). One possible explanation for these procedural difficulties is that "habituation" may often be accompanied by agitation in young infants; infants may be initially attracted by the task but after a few minutes the task loses its appeal and remaining in the situation becomes aversive. Crying has been largely responsible for high attrition rates in other studies using an habituation procedure (e.g., Eimas, 1985), although it is difficult to know whether to ascribe crying under these conditions to agitation, hunger, or to some combination of the two. Subjects were also discarded because they fell asleep during the task, so agitation alone cannot account for all of the attrition. A more general explanation may be that extended periods of habituation increase the probability of a state change in the infant, with some infants becoming fussy and others going to sleep.

Since the infants in Experiment 1 had no previous exposure with either melody, prior auditory experience with the melodies is not necessary for newborns to discriminate between them. Although some other type of experience may be required for infants to be able to make this discrimination, it must be of a more general nature. Since the results of this experiment showed that the two melodies were discriminable, their use in Experiment 2 provided a strong test of the prenatal hypothesis. It was predicted that infants who had experience with one of the melodies prenatally would prefer that melody over an unfamiliar melody. In the event that these infants showed no such preference, it could not be argued that the task was made too difficult

by choosing melodies which were not discriminable since even non-experienced infants could discriminate between them.

EXPERIMENT 2: Preference for Test Melodies

The purpose of Experiment 2 was to test the hypothesis that prenatal experience with one of the melodies used in Experiment 1 would produce a postnatal preference for that melody in human newborns. In order to assess this preference, prenatally experienced (Prenatal Group) and non-experienced (Control Group) infants were tested under the same postnatal conditions. Using an operant choice procedure, infants could hear one melody by sucking fast and the other by sucking more slowly. A preference would be shown if infants adjusted their pattern of sucking so as to hear one of the melodies more than the other.

Method

Prenatal Phase. Healthy pregnant women were solicited by letter from the childbirth classes at Moses Cone Hospital, Greensboro, North Carolina, and from local obstetric clinics. The study was thoroughly explained to each volunteer and each woman was told that she could terminate her involvement in the study at any time (see Appendix B for a sample letter).

Each pregnant volunteer was asked to begin singing "Mary Had A Little Lamb" on the 14th day prior to her expected delivery date. Instead of singing this song with its normally occurring words, however, the mother was instructed to sing the syllable 'la' to the melody. The

volunteer was instructed to sing the melody ten times through, once each day, totalling approximately 5 minutes of singing daily. Each woman was instructed to sing in a quiet place at a time when she thought that her baby was awake. The experimenter played a tape recording of the melody to each mother over the telephone to demonstrate how it was to be sung.

Each participant was given a log book which contained the sheet music of the melody, a place to record the date and time of her singing, and instructions for rating her estimate of the fetus's activity level immediately before, during, and after each day's singing. In addition, the mother could record any other observation she liked. An example of a log sheet is provided in Appendix C. Each participant was contacted periodically by phone to ensure that she was singing daily and that she was not experiencing any difficulty.

Of the 29 initial volunteers, five were rejected before their infants could be tested due to some perinatal complication (e.g., mother not feeling well at the end of her pregnancy; prematurity; neonatal jaundice). One other infant was eliminated from the study because the mother stopped recording her daily singing 15 days before the infant's birth so that no record of her singing during these last days was available.

Postnatal Phase. The 23 infants from the Prenatal Phase all met the selection criteria as described earlier (see General Method) except that 3 of them had APGAR scores of 7 at the first minute after birth. Since all of their APGAR scores went up to at least 8 at five minutes after birth, these infants were not eliminated from the study. Of the

23 infants in the Prenatal Group (PG) meeting these criteria, 13 successfully completed experimental sessions. Ten infants failed to complete a session because of excessive crying, inability to stay awake, or a lack of the appropriate sucking pattern required by the task (e.g. not enough HASs). The mean age of the 13 infants in the Prenatal Group was 52 hours (ranging from 33.5 to 72 hours). The mean age of the 8 infants in the Control Group was 47 hours (ranging from 39.5 to 59.5 hours).

An operant choice procedure was used to test for preferences. The subject could hear one melody by sucking fast and could hear the other melody by sucking more slowly. A predominance of one sucking pattern over the other indicated a preference for the melody associated with that pattern. This procedure has been previously used to show newborns' preferences for maternal voices over other women's voices (DeCasper and Fifer, 1980) and also to show newborns' preference for a familiar prose passage (one read aloud by the mother during her pregnancy) over an unfamiliar passage (Spence and DeCasper, 1982).

When newborns suck on a non-nutritive nipple, they typically produce a short series of individual sucks and then pause for several seconds before the onset of the next series of sucks (see Figure 3 for an example of non-nutritive sucking). In this study, a sucking burst was defined as a series of individual sucks separated by less than 2 seconds. The time between sucking bursts will be called the interburst interval (IBI). For each subject in Experiment 2, non-rewarded sucking was recorded during a baseline period in order to determine each

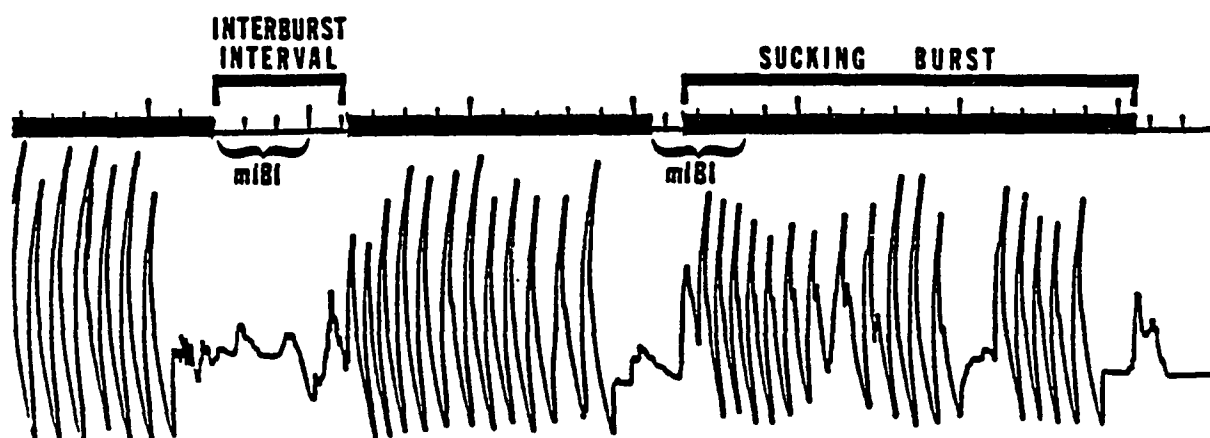


Figure 3. Polygraph record of a newborn's non-nutritive sucking. The vertical hash marks on the event line indicate time in seconds. The median interburst interval (mibi) for this infant was 3 seconds. Note that during the first interburst interval 3 seconds elapsed before a suck occurred. Sucking in this case produced one melody. During the second interburst interval, sucking occurred before 3 seconds had elapsed. In this case, sucking produced the other melody. Each melody was heard for the length of the sucking burst which produced it.

infant's median interburst interval (mIBI). The median interburst interval was calculated from the first 21 IBIs to occur during the baseline period. After the median had been established, the infant was randomly assigned to either the Short IBI or Long IBI condition; In the Short IBI condition, sucking bursts that ended IBIs less than the baseline median turned on the familiar melody "Mary Had A Little Lamb" whereas sucking bursts that ended IBIs greater than or equal to the baseline median turned on the unfamiliar melody "Love Somebody". Likewise, in the Long IBI condition, sucking bursts that ended IBIs greater than or equal to the baseline median turned on MARY whereas sucking bursts that ended IBIs less than the baseline median turned on LOVE. Each melody was heard continuously throughout the sucking burst that produced it. Each experimental session lasted for approximately 20 minutes (i.e. approximately 5 minutes of baseline and 15 minutes during which sucking produced the melodies).

Data Analysis

In order to test for preferences, the relative frequencies of both short IBIs (less than the baseline mIBI) and long IBIs (greater than or equal to the baseline mIBI) were calculated. It was expected that infants in the Prenatal Group would prefer the familiar melody (the one they had been exposed to prenatally) over the unfamiliar melody, and that the infants in the Control Group would show no systematic preference. A preference for the familiar melody would be shown by a significant increase in the relative frequencies of those IBIs that were associated with its production (i.e. Short IBIs for some infants and

Long IBIs for other infants). Since this task required that the infant learn a particular contingency (e.g., suck faster in order to hear MARY), it was expected that the beginning minutes of each session would reflect acquisition of this contingency while later minutes in the session would reflect more stable responding. Thus, separate analyses were done comparing the frequency of the two melodies during the last 25 responses of the session and also comparing the last 25 responses to the baseline responding of each infant.

Results and Discussion

According to three different response measures, infants in the Prenatal Group showed a preference for the familiar melody MARY, whereas infants in the Control Group showed no systematic preference for either MARY or LOVE. Analyses for infants in the Prenatal Group are presented first. Analyses for the control infants are presented in a later section.

Prenatal Group. In order to determine whether the infants who had heard MARY prenatally preferred that melody postnatally over the novel melody LOVE, the number of times each infant turned on MARY during the last 25 responses of the session was divided by 25. Thus, preference scores greater than .5 indicated that MARY was turned on more often than LOVE during the last 25 responses of the session. Ten out of 13 infants in the Prenatal Group had preference scores greater than .5, that is, they turned on MARY more than LOVE during the last 25 responses ($p=.03$, binominal test).

In order to examine more specifically the magnitude of this preference for MARY and to examine differences in the occurrence of short and long IBIs as a function of melody, the relative frequencies of the IBIs which produced both melodies were calculated. Because the reinforcement contingency for each infant was determined by its mIBI, which differed among infants, the data were standardized to allow for comparisons across infants as follows. Each infant's IBI frequency distribution was divided into 10 bins, each bin's width being one-fifth of that infant's mIBI. For example, a mIBI of 5 seconds produces 10 bins each with a width of 1 second (i.e. 0-1, 1-2, 2-3, 3-4, 4-5, etc.), whereas a mIBI of 3 seconds produces 10 bins each with a width of .6 seconds (i.e. 0-0.6, 0.6-1.2, 1.2-1.8, 1.8-2.4, 2.4-3.0, etc.). Thus, each infant's IBI distribution was divided into 10 bins of equal width, 5 bins being less than mIBI (responses that produced one melody) and 5 bins being greater than or equal to mIBI (they produced the other melody). The relative frequencies of IBIs producing each melody were then adjusted for differences in opportunities (cf. Anger, 1956). If infants in the Prenatal Group preferred the melody their mothers sang while pregnant then the relative frequency of those IBIs producing the familiar melody MARY should be greater than those producing the unfamiliar melody LOVE during the last 25 responses of the session. This prediction was tested by comparing the relative frequencies of IBIs between 0.0(mIBI) and 0.4(mIBI) seconds (the first two bins of the IBI distribution that were reinforced by one melody) and those between 1.0(mIBI) and 1.4(mIBI) seconds (the first two bins of the IBI distribution that were reinforced by the other melody). Using the

Wilcoxon matched-pairs signed-ranks test, this comparison showed that the mean rank of the relative frequencies of those IBIs producing MARY was significantly higher than the rank of those producing LOVE ($N=13$, $z=-1.99$, $p=.05$, one-tail). Thus, the infants gave more responses (IBIs) of the length required to produce MARY than they did responses of the length required to produce LOVE, indicating a preference for the familiar melody. The relative frequencies of these IBIs for individual infants are presented in Table 3.

In order to look at the extent to which the infants' response patterns changed from baseline, reinforcement ratios were calculated ($RL/RL + RB$) where RL = the relative frequency of IBIs producing one melody during the last 25 responses and RB = the relative frequency of those same IBIs during baseline. The resulting reinforcement ratio could range from 0.00 to 1.00, with ratios greater than .5 representing higher relative frequencies for that melody during the last 25 responses of the session. Reinforcement ratios were calculated for both MARY and LOVE. If the Prenatal Group produced more responses that turned on MARY at the end of the session than they did during baseline, then their reinforcement ratios should exceed .5. Likewise, if they turned on LOVE more at the end of the session than during baseline, reinforcement ratios for that melody should also exceed .5. The results of the Wilcoxon signed-ranks test indicated that these reinforcement ratios were significantly greater than .5 for MARY [$n=13$, $z=-2.49$, $p=.01$, one-tail], but were not significantly greater than .5 for LOVE [$N=12$, $z=-.36$, $p=.36$, one-tail]. When the reinforcement ratios for MARY were compared to those for LOVE by the Wilcoxon matched-pairs signed-ranks

TABLE 3

Relative Frequencies of the Shorter IBIs Producing Each Melody
During Last 25 Responses for the Prenatal Group

SUBJECT	SEX	CONDITION ¹	RELATIVE FREQUENCY ²	RELATIVE FREQUENCY
			MARY	LOVE
1	M	<3	.18	.15
2	F	<3	.25	.17
3	M	<4	.42	.24
4	M	<4	.28	.30
5	F	<5	.50	.49
6	F	<6	.38	.33
7	F	<6	.44	.35
8	F	>3	.60	.17
9	F	>3	.13	.36
10	M	>4	.29	.31
11	F	>4	.57	.44
12	F	>4	.27	.18
13	M	>5	.40	.21

¹ Signs and numbers under CONDITION specify the IBI requirement and median baseline IBI for individual infants.

² Relative frequencies for each melody were calculated by dividing the number of IBIs occurring in the shorter response bins under each condition by the total number of responses. Relative frequencies were adjusted for differences in opportunities.

Note: According to the Wilcoxon matched-pairs signed-ranks test, the relative frequencies of the shorter IBIs producing the familiar melody (MARY) were significantly higher than those producing the unfamiliar melody (LOVE) during the last 25 responses ($p = .02$).

test the results showed that the ratios for MARY were significantly greater than those for LOVE ($N=13$, $z=-1.61$, $p=.05$ one-tail). The reinforcement ratios for both melodies for individual infants are presented in Table 4.

In sum, three related measures (preference scores, relative frequencies, and reinforcement ratios) showed that infants in the Prenatal Group preferred the familiar MARY over the unfamiliar LOVE in the last minutes of the session. In addition, evidence of this preference emerged after the infants had learned the appropriate response for turning on the prenatal melody; that is, the probability of turning on the familiar melody was greater in the last 25 responses of the session compared to the pattern of responding occurring during baseline.

Control Group. In the absence of any prenatal experience with the target melody, it was hypothesized that infants in the Control Group would not show a systematic preference for either melody when tested under the same conditions as those infants in the Prenatal Group. Preference scores were also calculated for these infants. Again, the preference score was calculated by dividing the number of times each infant turned on MARY by 25. Thus, preference scores greater than .5 indicated a preference for MARY. Four out of the 8 control infants had preference scores greater than .5 ($p>.05$, binomial test), suggesting no systematic preference for either MARY or LOVE.

TABLE 4

Reinforcement Ratios for Prenatal Group

SUBJECT	SEX	CONDITION ¹	REINFORCEMENT RATIO MARY ²	REINFORCEMENT RATIO LOVE
1	M	<3	.58	.34
2	F	<3	.53	.39
3	M	<4	.65	.34
4	M	<4	.66	.50
5	F	<5	.79	.46
6	F	<6	.50	.65
7	F	<6	.64	.47
8	F	>3	.50	.27
9	F	>3	.53	.66
10	M	>4	.64	.58
11	F	>4	.51	1.00
12	F	>4	.38	.50
13	M	>5	.63	.43

¹ Signs and numbers under CONDITION specify the IBI requirement and median baseline IBI for individual infants.

² Reinforcement ratios were calculated by dividing the adjusted relative frequency of one melody during the last 25 responses by that number plus the relative frequency of those same responses during baseline. Reinforcement ratios greater than .5 indicate higher relative frequencies during the last 25 responses.

Note: According to the Wilcoxon signed-ranks test, the reinforcement ratios for familiar MARY were significantly greater than .5 ($p=.025$, one-tail), and significantly greater than those for LOVE ($p=.05$, one-tail), but the reinforcement ratios for LOVE were not significantly greater than .5 ($p > .05$, two-tail).

As with the experimental infants, a Wilcoxon matched-pairs signed-ranks test was performed comparing the relative frequency of the shorter interburst intervals producing MARY with the shorter IBIs producing LOVE, during the last 25 responses of the session. Again, IBIs producing each of the melodies were adjusted for differences in opportunity. The results showed no significant difference between the relative frequencies for MARY and those for LOVE ($N=8$, $z=-.14$, $p = .44$, one-tail). Individual infant relative frequencies for the two melodies are presented in Table 5. Also, the Wilcoxon signed-ranks test comparing the reinforcement ratios for MARY to .5 and comparing LOVE to .5 showed no significant differences [for MARY ($N=8$, $z=-.84$, $p = .20$, one-tail); for LOVE ($N=8$, $z=-.14$, $p = .44$, one-tail). A Wilcoxon signed-ranks test performed on the reinforcement ratios for MARY and those for LOVE showed no significant difference between the mean ranks of the two melodies ($N=8$, $z=-.14$, $p = .44$, one-tail). The reinforcement ratios for each melody by individual infants are presented in Table 6.

In sum, the measures of preference scores, relative frequency and reinforcement ratio showed no systematic preference for either melody in the infants in the Prenatal Control Group. Taken together with the results from the Prenatal Group, Experiment 2 showed that infants who had received prenatal experience with a particular melody preferred that melody over a novel melody when tested within the first 3 days of postnatal life. Thus, the infants in the Prenatal Group discriminated a familiar melody from an unfamiliar one and showed a preference for the one they had experienced prenatally. Since the infants in the Control Group who had received no prenatal experience with either melody showed

TABLE 5

Relative Frequencies of the Shorter IBIs Producing Each Melody
During Last 25 Responses for the Control Group

SUBJECT	SEX	CONDITION ¹	RELATIVE FREQUENCY ² MARY	RELATIVE FREQUENCY LOVE
1	M	<3	.24	.15
2	M	<4	.17	.10
3	F	<5	.26	.13
4	F	<6	.14	.58
5	F	>3	.13	.44
6	F	>3	.40	.25
7	M	>3	.26	.23
8	M	>3	.25	.14

¹

Signs and numbers under CONDITION specify the IBI requirement and median baseline IBI for individual infants.

²

Relative frequencies for each melody were calculated by dividing the number of IBIs occurring in the shorter IBI bins under each condition by the total number of responses. Relative frequencies were adjusted for differences in opportunity.

Note: According to the Wilcoxon matched-pairs signed-ranks test, the relative frequencies of the shorter IBIs producing MARY were not significantly different from those producing LOVE during the last 3 minutes ($p > .05$, two-tail).

TABLE 6
Reinforcement Ratios for Control Group

SUBJECT	SEX	CONDITION ¹	REINFORCEMENT RATIO ²	
			MARY	LOVE
1	M	<3	.72	.40
2	M	<4	.44	.35
3	F	<5	.61	.26
4	F	<6	.46	.71
5	F	>3	.60	.43
6	F	>3	.65	.86
7	M	>3	.42	.69
8	M	>3	.37	.48

¹ Signs and numbers under CONDITION specify the IBI requirement and median baseline IBI for individual infants.

² Reinforcement ratios were calculated by dividing the adjusted relative frequency of one melody during the last 25 responses by that number plus the relative frequency of those same responses during baseline. Reinforcement ratios greater than .5 indicate higher relative frequencies during the last 25 responses.

Note: According to the Wilcoxon signed-ranks test, neither the reinforcement ratios for MARY nor LOVE were significantly different from .5 ($p > .05$, two-tail for both tests), and they were not significantly different from each other ($p > .05$, two-tail).

no systematic preference between them, it is clear that the specific prenatal experience with the melody produced the postnatal preference.

Although infants in the Prenatal Group showed a preference for the familiar melody and infants in the Control Group showed no systematic preference, these results were obtained by using within-group tests. Analyses that compared these two groups failed to show a significant difference between them. One reason for this lack of a group effect may be due to the fact that some subjects in the Control Group showed individual preferences, although not systematically in favor of one melody over the other. It was not the case that the individual infants in the Control Group showed no preference. The tendency of some Control subjects to show similar preferences as infants in the Prenatal Group obscured the between-group effects. One explanation for these melody preferences in the Control Group could be that, for non-experienced infants, some aspect of the operant choice procedure promoted the development of a preference. In reviewing the data, however, there appeared to be no systematic connection between the preferences shown in the Control Group and any aspect of the procedure. Another possibility is that the infants in the Control Group were not equal in their non-experience. In order to be included in the study, the mothers of these infants had to indicate that they had not sung either of the melodies (MARY or LOVE) during their pregnancies. Several of the mothers did indicate, however, that they had sung other nursery rhymes during the last weeks of their pregnancies to their older children. It is possible that these other melodies bore some resemblance to the ones used in this experiment, although such information was not recorded.

Ideally, the mothers of the control infants should have been required to have not sung any songs during their last weeks of pregnancy, although such a restriction places further constraints on an already difficult selection process.

Since a lack of a group effect was also seen in Spence and DeCasper's (1982) study, future research should attempt to reduce any factors that may bias the control infants in the direction of the experimental infants and should increase their sample size in an attempt to reduce the between-groups variability.

GENERAL DISCUSSION

When given the choice of listening to either of two discriminable melodies, newborn infants preferred to listen to the one their mothers had sung prenatally. That finding replicates and extends the work of by Spence and DeCasper (1982), who found that newborns preferred a story that their pregnant mothers had read aloud over a novel story. The newborns in their study could have used segmental information, suprasegmental information, or both to recognize the familiar story. Since the familiar and unfamiliar melodies used to test for preferences in the present study had the same segmental information (i.e. they were both sung with the syllable "la" in place of their normally occurring words), the infant subjects must have used some aspect(s) of the melodies' suprasegmental information to recognize the familiar melody. Thus, the results of the present study suggest that suprasegmental information produced the postnatal preference in this study and can explain other postnatal preferences in young infants (e.g., Spence and DeCasper, 1982).

The Role of Suprasegmental Information in Early Auditory Perception

Young infants' responsiveness to the suprasegmental aspects of speech has been demonstrated in studies investigating the ability of older infants to recognize melodies. Trehub, Bull, and Thorpe (1984)

familiarized 8 to 11-month-olds with a specific melody and then tested their ability to discriminate that melody from similar melodies that had undergone several acoustic transformations. When the transformation preserved the melodic contour of the original melody but altered some other acoustic characteristic (e.g., absolute frequency), the infants failed to perceive the change; that is, they treated the melodies as though they were the same. When the transformation resulted in a change in melodic contour (e.g., a rearrangement of individual notes), the infants did perceive the change. Thus, young infants treat melodies as familiar if they have the same melodic contour but treat them as novel if the contours differ. This has been referred to as a global processing strategy that is similar to one seen in adults when they are first learning a melody; the more global characteristics are perceived and remembered initially, with more specific properties (e.g., internote intervals, absolute frequency) being learned with additional exposure (Trehub et al., 1984; Trehub, Thorpe, and Morrongiello, 1985).

In addition to studies examining melody perception in infants, other studies have shown that melodic contour is a potent acoustic determinant of infant auditory preference. Several studies have shown that exaggerated frequency contours are a common component of adult speech directed at infants (Fernald and Simon, 1984; Stern, Spieker, Barnett, and MacKain, 1983), and that such exaggerated contours may serve to facilitate certain interactions between the infant and the speaker. For example, rising intonation patterns in speech are often observed when a mother is attempting to initiate eye contact with her infant whereas a rising-falling contour is observed when the mother is

attempting to maintain eye contact (Fernald, 1984; Stern, Spieker, and MacKain, 1982). Four-month-old infants who were given a choice between listening to a female speaking "motherese" and listening to a female speaking to another adult preferred the motherese (Fernald, 1985). By filtering out all frequency information above the fundamental frequency in the motherese and adult speech samples, Fernald (1982) was able to construct two frequency contours which contained no segmental (word) information. In a preference test, four-month-olds again preferred the "motherese" contour to the "adult" contour. Normal intonation has also been shown to be necessary for the maintenance of young infants' recognition of the maternal voice. One-month-olds will respond differentially to their mothers' voices only if the voices are normally intonated; if they are presented in monotones, no recognition is shown (Mehler, et al., 1978). In sum, research has shown that young infants can discriminate one frequency contour from another, that they prefer more exaggerated frequency contours to less variable ones, and that certain frequency contours can be used to initiate and maintain infant attention.

Thus, suprasegmental aspects of speech play an important role in early auditory perception. Although the relative importance of various cues for auditory perception has not been established for young infants, frequency contour would most likely be of great importance because of its general effect of eliciting infant attention (as in "motherese") and for its more specific importance in individual voice recognition (Gottlieb, 1985). The results of the present study confirm the importance of frequency contour in early auditory perception. The

infants in this study could not have used segmental information to discriminate the familiar from unfamiliar melodies, since it did not differ between melodies. Also, since the individual notes making up each melody were the same, subjects could not use differences in individual notes to recognize the familiar melody (a cue that older infants have been shown to use in melody recognition; see Trehub et al., 1985). Rather, it seems likely that the newborns discriminated the two melodies on the basis of their different arrangements of individual notes (i.e. their melodic contour). It is possible, however, that other cues were used in addition to melodic contour (e.g. differences in internote durations).

Prenatal Experience with Suprasegmental Information

Within the past 15 years, developmental research has shown that young infants are competent perceivers of auditory information in general and of the acoustic features of speech in particular (see Aslin, Pisoni, and Jusczyk, 1983 for a general review). We seem to have acquired a good deal of information on the auditory competence of young infants, but little information on how these competencies come about. One account of the young infant's responsiveness to the acoustic properties of speech holds that the infant's ability to make certain segmental discriminations exists independently of specific auditory experience (Eimas et al., 1971; Eimas, 1978). Similarly, young infants' preferences for certain suprasegmental speech properties (e.g., wide pitch excursions) are thought to exist independently of any specific experience (Fernald, 1984; 1985). The results of the present study

suggest, however, that prenatal experience with maternal speech may account for the early perceptual salience of suprasegmental information. In order to support this account, it is important to bear in mind that early perception can be constrained by both the state of the organism and the nature of environmental input (Aslin, 1981; Johnston, 1985). Such constraints can be identified by examining the sound conduction properties of the uterine environment as well as the competence of the fetal auditory system.

The fetal auditory system. As noted earlier, the human fetal auditory system is structurally mature by the 6th month of gestation (Eisenberg, 1976; Rubel, 1978). Its functional maturity is evidenced not only by the results of this study and those of Spence and DeCasper (1982), but also by studies showing fetal responsiveness to the presentations of various sounds through the maternal abdomen (e.g., Bernard and Sontag, 1949; Birnholz and Benacceraf, 1983; Gelman et al., 1982; Johansson et al., 1964). Although we know that late-term human fetuses can respond to sound, we still know very little about the more specific characteristics of fetal hearing (e.g., frequency thresholds). If we extrapolate from studies with older infants, we can assume that fetal auditory thresholds are elevated in comparison to adult thresholds at least for those frequencies spanning the range found in human speech (Olsho, 1984; Sinnot, Pisoni, and Aslin, 1983). Importantly, it has also been shown that auditory frequencies most likely to elicit physiological and behavioral responses from the late-term fetus are in the low- to middle-frequency range (i.e. 500 to 1500 Hz) and that responses to higher frequencies are the last to develop (Gottlieb, 1971;

Rubel, 1978). Young infants have also been shown to be more responsive to patterned sounds than to simple auditory stimuli such as pure tones (Berg and Berg, 1979; Fernald, 1985; Hutt et al., 1968; Turkewitz et al., 1972). Since at least one of these studies involved neonates (i.e. Turkewitz, et al., 1972), it is possible that the late-term fetus would also show increased responsiveness to patterned sound. In sum, the late-term fetus can hear although its thresholds are higher than those of adults and it discriminates higher frequencies more easily than lower frequencies. Infants also seem to be more responsive to patterned auditory stimuli (e.g., speech) than to pure tones.

The uterine sound environment. Given that the human fetus is an active perceiver of sound, what is it likely to be listening to? Querleu and Renard (1981) recorded sounds from within the human uterus by placing a small hydrophone next to the fetal ear after rupture of the amniotic sac. They found that in general, external voices and other sounds were considerably attenuated by maternal fluid and tissue, with higher frequencies being more attenuated than lower frequencies. For example, a 250 Hz tone was attenuated by 2 dB whereas a 1000 Hz tone was attenuated by at least 20 dB. The overall intensity of sound within the uterus was approximately 60 dB. Thus, normally occurring extrauterine speech (usually occurring at 70-75 dB) may penetrate the uterus but be too attenuated to be audible once it reaches the fetus's ear. The mother's voice, however, is thought to be less attenuated because of its possibly different mode of conduction (i.e. through her body). Querleu and Renard's recordings show that the mother's voice was the most

audible of the voices recorded (recordings of her voice were around 75 dB). Also, frequencies above 1000 Hz were rarely recorded in utero whereas frequencies ranging from 150 to 1000 Hz were more common. This frequency selectivity does not prevent voices from penetrating the uterus since the fundamental frequency of female voices ranges from approximately 200 to 350 Hz, whereas it ranges from 80 to 250 Hz for male voices. However, the presence of maternally generated non-speech sounds (e.g., digestive sounds, blood flow, heart beat) which are of high intensities but low frequencies may mask the lower-frequency extrauterine sounds. The mother's voice, however, is of sufficient intensity and frequency to be audible to the fetus.

What aspect of maternal speech is the fetus most likely to learn about? Since the frequencies that carry much of the vowel information are above 1000 Hz (Aslin et al., 1983) it is unlikely that word information per se is available to the fetus on a regular basis because frequencies above 1000 Hz are typically not recorded in utero and fetal responsiveness to these frequencies is less than their responsiveness to lower frequencies. Suprasegmental information (e.g., the patterning of the mother's voice) is more likely to be available for fetal perception because the mother's voice is audible in utero and it is composed of those frequencies that the developing fetus is most responsive to. The results of the present study suggest that not only is such information available, but that experiencing it prenatally can affect postnatal auditory preferences. The postnatal saliency of suprasegmental information may benefit the young infant in at least two ways. First, it may initially establish the mother's voice as a reinforcer, thus

increasing the positive valence between infant and mother (c.f. DeCasper and Fifer, 1980). For example, the ability of a mother to engage her newborn's attention during a feeding bout may be enhanced by the presence of her voice. Secondly, since understanding speech depends on the perception of its features distributed in time, the infant may come into the world with this processing ability already in its repertoire. That is, it has learned to recognize auditory events that are time-dependent (e.g., frequency contours). Since the analysis of segmental information depends on suprasegmental information (Miller, 1978), an infant who pays attention to auditory features such as frequency contours, is ensured exposure to the speech of its culture.

Direction of Future Research

In sum, the results of this study showed that human fetuses can learn about the suprasegmental aspects of speech in utero and that this learning affects their postnatal preferences. It seems that suprasegmental information is more likely to be learned in utero than segmental information given the structure of the uterine sound environment and the functional characteristics of the fetal auditory system.

Whether segmental information in speech can be learned prenatally and affect postnatal preferences has not been tested directly. One way to test this possibility would be to have each pregnant woman sing a song to her fetus that was composed of a distinct melody and distinct words. Postnatally, these infants could be tested with a preference

procedure under the following conditions: (1) a choice between the familiar song and another song with a very different melody but the same words; (2) a choice between the familiar song and another song with the same melody but different words; and (3) a choice between a song that was composed of the same melody but different words and a song with both a different melody and different words. Based on our current knowledge we could make the following predictions: Infants should prefer the familiar song under condition (1) since only the melody is different and we know from the results of the present study that this is sufficient for their discrimination; infants should prefer the familiar song under condition (2) only if they learned about the words prenatally since the melody remains the same. If infants under condition (2) did not prefer the familiar song, then it could be concluded that word information in the absence of suprasegmental information is not sufficient for maintaining a postnatal preference. It would still not be known, however, whether the melody preference is dependent on the presence of familiar word information; that is, whether infants can discriminate suprasegmental information when the segmental information that accompanied it prenatally is removed. If discrimination of suprasegmental information exists independently of segmental information, then infants under condition (3) should prefer the familiar melody even though the words are unfamiliar.

If suprasegmental information continues to be sufficient to account for newborns' auditory preferences, it will also be possible to refine our knowledge of the role that specific suprasegmental characteristics play in postnatal preferences by controlling the presence of these

characteristics in the auditory signal. For example, it is possible to generate artificial stimuli in which the contour varies while duration, amplitude, internote intervals, etc. are held constant (cf. Fernald, 1982). The presentation of such stimuli to fetuses, however, will mostly likely have to take place by some means other than the mother. One alternative is to present the sounds to the fetus through the maternal abdomen by the use of a speaker. This represents a trade-off of sorts because it sacrifices one effective mode of sound conduction (i.e. the mother's voice) for more precision in the auditory stimuli. Regardless of the specific form that such a research strategy takes, the results of the present study are encouraging for a general research program on prenatal learning since they provide a methodology that is non-intrusive prenatally and a postnatal procedure that is capable of demonstrating preferences in very young infants.

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APPENDIX A
TEST MELODIES

LOVE SOMEBODY

moderately

The musical score for 'Love Somebody' is written for guitar and voice. It consists of two systems of music. The first system has four measures with lyrics: 'Love some-bod-y, yes I do; Love some-bod-y, yes I do;'. The second system has four measures with lyrics: 'Love some-bod-y, yes I do; Love some-bod-y, but I can't tell who.' Above the first system, guitar chords G, D7, G, and D7 are indicated. Above the second system, guitar chords G, Am, G, D7, and G are indicated. The music is in 4/4 time and G major.

MARY HAD A LITTLE LAMB

Moderato

The musical score for 'Mary Had a Little Lamb' is written for piano and voice. It consists of two systems of music. The first system has four measures with lyrics: 'Ma - ry had a lit - tle lamb, lit - tle lamb, lit - tle lamb.' The second system has four measures with lyrics: 'Ma - ry had a lit - tle - lamb, its fleece was white as snow. And'. Below the first system, piano chords F, Bb, F, C7, and F are indicated. Below the second system, piano chords Bb, F, C7, and F are indicated. The music is in 2/4 time and Bb major.

APPENDIX B

SAMPLE LETTER

THE UNIVERSITY OF NORTH CAROLINA
AT GREENSBORO



Department of Psychology

Dear Mother to Be:

We would like to have you and your baby participate in a study to help us learn more about the kinds of sounds babies hear in utero and whether they can recognize these sounds after birth. Attached is a reprint from Redbook Magazine that will give you a brief history of our work at Moses Cone Hospital. Right now, we are asking pregnant women who are close to term and who plan to deliver at Moses Cone to sing a particular nursery rhyme for a short time each day until their baby is born. You can sing this song in the privacy of your home and no one except you and your baby will need to listen to your singing. After the baby's birth and providing that both you and your baby are doing fine, we will observe the baby to see if he/she recognizes a tape recording of a woman singing the same song that you sang while pregnant.

Your participation in this study is completely voluntary and you are free to terminate your participation at any time and for any reason. All of our procedures have been approved by the Human Subject Ethics Committee at UNC-Greensboro, and by Dr. Richard Weaver, Director of Neonatal Medicine at Moses Cone Hospital. Your doctor is aware of our work and has given us his/her permission to invite your participation in this study. Your decision to participate or not, however, will in no way affect your relationship with your doctor.

If you are interested in participating in our study, please return the postcard accompanying this letter with your name and telephone number, or feel free to call me at one of the phone numbers listed below. I will be happy to answer any further questions you may have regarding this study. Thank you so much for your time and interest.

Sincerely,

Robin K. Panneton, M.A.
Department of Psychology
UNC-Greensboro
Greensboro, NC 27412
(919) 379-5013
(919) 275-7199

Anthony J. DeCasper, Ph.D.
Department of Psychology
UNC-Greensboro

GREENSBORO, NORTH CAROLINA / 27412-5001

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APPENDIX C

SAMPLE LOG

Dear

Thank you so much for your interest in prenatal learning. Enclosed you will find: (1) the words to the song we would like you to sing, and (2) log sheets on which you can record your perceptions of your baby's activity during your daily singing.

Regarding your baby's activity, we would like you to record the amount of movement you perceive immediately before, during, and after each time you sing. We would like you to assign a score to the amount of movement your baby makes during these times. The scale we would like you to use ranges from 0 to 10, with 5 being the average amount of movement you perceive in your baby on any given day. For example, if your baby is moving less than average before you begin singing, give him/her a score between 0 and 5. If the baby moves more than average before you begin singing, give him/her a score between 5 and 10. Please judge the baby's activity before, during, and after each time you sing. The log sheet is designed so that you may do this easily and any further comments you'd like to share with us are very welcome.

Once again, we would like you to:

- (1) start singing on the 14th day prior to your expected delivery date.
- (2) sing the song 10 times each day at a time that is convenient for you, when you think your baby is awake, but not within one hour after eating a full meal.
- (3) record the date and time of your singing and your perception of your baby's movement immediately before, during and after you sing.
- (4) please not sing the song to your baby after he/she is born until we have completed our testing.

Your participation is deeply appreciated. If I can answer any further questions for you, please feel free to call me at the numbers listed below. I am looking forward to meeting you at Moses Cone Hospital sometime in the near future.

Best wishes,

Robin K. Panneton
(919) 379-5013 (office)
(919) 275-7199 (home)

<u>DATE</u>	<u>TIME</u>	<u>ACTIVITY SCORE</u>	<u>BEFORE</u>	<u>DURING</u>	<u>AFTER</u>
	A.M.				
	P.M.				

COMMENTS: _____
