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NEWBORNS' PREFERENCE FOR FEMALE VOICES AS A FUNCTION OF SPECTRAL COMPOSITION

The University of North Carolina at Greensboro PH.D. 1984

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NEWBORNS' PREFERENCE FOR FEMALE VOICES AS A FUNCTION OF SPECTRAL COMPOSITION

by

Melanie J. Spence

A Dissertation Submitted to
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Approved by

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Research with human fetuses and neonates has demonstrated that last trimester fetuses can hear *in utero* and that neonates prefer auditory stimuli which are experienced prenatally to novel auditory stimuli. This study was conducted to determine if prenatal experience with the lower frequencies of the maternal voice influence postnatal voice preferences. Tape recordings of maternal voices were low-pass filtered at 1000 Hz in order to simulate intrauterine recordings of maternal voices. Neonates were placed in a discriminated-operant choice task in which they could choose between a recording of the maternal unfiltered voice and the maternal low-pass voice. A second group of neonates was presented the same recordings to assess neonates' preferences for low-pass (nonmaternal) female voices in general. The same unfiltered voice recordings were high-pass filtered at 1000 Hz and the high-pass and unfiltered versions of these voices were presented to a third group of neonates to assess their preferences. The high-pass voices were different from any voices experienced while the unfiltered voices were more similar to maternal prenatal voices. Analyses of preferential responding revealed that neonates did not prefer either the maternal unfiltered or low-pass voice; both were equally attractive. Neonates preferred unfiltered nonmaternal voices to low-pass filtered nonmaternal voices while they did not express a preference for high-pass or unfiltered nonmaternal voices. Pooled preference ratios of the two nonmaternal groups, however, revealed an overall preference for

unfiltered over filtered voices. These results were interpreted within a Gibsonian view of perceptual development, which asserts that perception differentiates and becomes more selective with increasing perceptual experience.

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CHAPTER I

INTRODUCTION

Neonatal perception and behavior of birds and nonhuman mammals, once thought to be solely determined by biological maturation, can be influenced by earlier, prenatal experience. Neonatal auditory perception in particular has been shown to be influenced by prenatal auditory stimulation. Recent data suggest this phenomenon also occurs in human development. Human neonates as young as 36 hours of age prefer their mother's voice, which may have been heard _in utero_, over other female voices. Neonates will work to hear intrauterine heartbeat sounds, which may also have been heard _in utero_. Most significantly, newborns prefer a speech passage which was repeatedly recited by their mothers during pregnancy over a passage she did not recite. These data indicate that not only can a newborn's responsiveness to an auditory stimulus be influenced by prenatal experience with that stimulus but that prenatally experienced sounds are preferred, i.e., are more reinforcing or perceptually salient, to novel sounds.

These data suggest that prenatally experienced stimuli are reinforcing or perceptually salient after birth because they are perceived by neonates as familiar. Perceptual familiarity may occur if a stimulus is identical to one that has been experienced prenatally as well as if it is only similar. The familiarity of a stimulus is hypothesized to be an increasing function of its physical similarity to a previously experienced stimulus.

One implication of the hypothesis is that a stimulus which is highly similar to a prenatally experienced stimulus should be more familiar to neonates and thus preferred to a different stimulus which is less similar to the one experienced prenatally. In this study, a set of maternal voice recordings were altered so that they were similar to maternal voice sounds presumably experienced by the infants before birth. The maternal voice recordings were filtered to eliminate higher frequencies (low-pass filtered) so that they simulated maternal voice recordings that have been made from within the uterus, and the neonates′ preference for their mothers′ low-pass or unfiltered voice recordings were assessed. In a second study, these same voice recordings were also presented to other newborns in order to assess neonatal preference for low-pass or unfiltered female voices in general. It was hypothesized that the low-pass female voices would be more similar to the prenatally experienced maternal voices and thus more familiar to neonates than unfilterd female voices. And in a third study, these same voices were filtered to eliminate lower frequencies (high-pass filtered) and presented to a third group of newborns. The high-pass voices were very different from any voice stimulus which had been experienced by newborns. The unfiltered female voices, because they contain frequencies heard _in utero_, should be more similar to speech heard _in utero_ than high-pass filtered speech, which does not contain frequencies heard _in utero_. The prediction that neonates should prefer unfiltered voices to the high-pass voices was also assessed.

The notion that neonates prefer familiar stimuli is derived from animal research, from literature which indicates that early postnatal experience can influence subsequent infant visual and auditory perception, and from the neonatal preference studies discussed above, which suggest that prenatal experience can influence postnatal perception. Most of the direct evidence for the influence of prenatal auditory stimulation on postnatal auditory perception is provided by animal studies. Thus, the relevant animal data will first be reviewed and will be followed by a review of the human literature.

Influence of Prenatal Auditory Stimulation on Postnatal Perception of Animals

Evidence from birds. Several avian species exhibit postnatal preferences for auditory stimuli experienced prenatally. Chicken embryos exposed to an intermittent 200 Hz tone during the last third of incubation and then exposed to simultaneous 200 Hz and 2000 Hz tones shortly after hatching more closely approached the source of the 200 Hz tone. Control chicks approached both tones equally often (Grier, Counter, & Shearer, 1967). Japanese quail embryos stimulated with 300 or 400 Hz tones from incubation days 12-15 exhibited preferences at 4-8 hours after hatching on day 17 for the prenatally experienced tone over tones one harmonic above or below the prenatal tone (Lien, 1976). Peking ducklings′ perception of the higher frequency components of the maternal mallard call 24 hours after hatching is facilitated by hearing their own and siblings′ vocalizations during the embryonic and posthatching period (Gottlieb, 1976). Ducklings that have been devocalized and isolated as embryos do not respond differentially to the mallard maternal call and the chicken call 24 hours following hatching. The later call is similar to the mallard call but lacks the higher frequency component found in the mallard call. Wood ducklings, following isolation, do not exhibit the normal preference for the descending frequency modulation characteristic of the maternal call. When isolated ducklings are stimulated with a synthetic descending alarm-distress call, however, they exhibit the usual preferences for the synthetic descending call over an ascending call. Wood duckling embryos normally experience their own and siblings′ vocalizations which contain prominent frequency modulations. The preference for the descending frequency modulation characteristic of the maternal call, then, results from the exposure to their own and/or conspecifics′ vocalizations during the embryonic and early postnatal period (Gottlieb, 1981).

Prenatal exposure of laughing gulls to "crooning," a parental call emitted during feeding of the young, results in more pecking in a postnatal test in the presence of "crooning" than during silence or an alarm call (Impekoven & Gold, 1973). Another avian species, the guillemot, responds preferentially to the calls of its parent over other individuals′ calls. Tschanz (1968) has demonstrated that guillemots learn the specific characteristics of their parents′ luring calls during the embryonic period. The luring call is composed of a string of sound pulses. Each individual has a characteristic call in which the duration of the pulses, the length of the intervals between the pulses, and frequency vary (Impekoven & Gold, 1973). Embryos were exposed to luring calls of one adult bird for two and one-half days from the time the embryos began to vocalize. Then when the embryos were presented with the previous adult call and a novel call, embryos vocalized more frequently to the previously presented call. Furthermore, postnatal discrimination tests conducted 3-42 hours after the last prenatal exposure demonstrated the chicks preferred the call presented prenatally. Chicks approached, snuggled against, and pecked at the speaker emitting the previously presented call in a simultaneous choice-discrimination test. Chicks exposed to one adult call during the embryonic period and to a second call postnatally exhibit a preference for the prenatally presented call when tested 42 hours following the last prenatal exposure. Avian data clearly indicate prenatal experience with a stimulus can produce a postnatal preference for that stimulus.

Evidence from mammals. Prenatal exposure to auditory stimuli also influences postnatal perception in several mammalian species. For example, pregnant guinea pigs (and their unborn young) were exposed to game bantam hen clucks each day for the last two to three weeks of the 68-day gestation period (Vince, 1979). Following birth of the litters, the neonates were presented six bantam hen calls on each of the first five postnatal days. Control groups of guinea pigs whose mothers were not exposed to bantam calls when pregnant were also presented these same calls postnatally on each of days 1 to 5 or days 6 to 10. Heart rate response, which typically decelerates when adult guinea pigs are exposed to bantam clucks, was recorded during postnatal testing. The initial heart rate deceleration response of experimental animals was smaller than that of controls and did not change significantly during the five-day testing period. However, the heart rate deceleration of control animals was initially very large but declined during the six trials on the first test day and over the five-day testing period. Heart rate deceleration was similar in both control groups, suggesting that the effect was due to prenatal experience rather than age. Differences between experimental and control animals suggested that heart rate deceleration of experimental animals occurred prenatally.

Neonatal lambs also respond differentially to auditory stimuli presented prenatally (Vince, Armitage, Walser, & Reader, 1982). One group of fetal lambs was exposed to a 6-sec sequence of bleats while a second group was exposed to a 6-sec stimulus consisting of a telephone signal and music during maternal feeding for 4 weeks or for one-fifth of gestation. Neonatal lambs were presented both sounds during a postnatal test within 24 hours of birth. Heart rate acceleration occurred in response to novel sounds while heart rate deceleration occurred in response to previously presented sounds. Augmented breathing, similar to sighs, was also recorded in response to previously presented stimuli on the first test trial.

The avian species discussed above are motorically precocious. Within several days after hatching, the young leave their nests and follow the mother. Prenatal learning of and subsequent preference for the maternal call would seem to be very adaptive for these species. In fact, the maternal wood duck emits her luring calls from outside the nest. The wood ducklings cannot see the mother when they are called as this is a hole-nesting species (Gottlieb, 1981). The guillemot discriminates individual parents' calls from other guillemot calls. The guillemot lives in colonies and must be able to discriminate the parents from other guillemot parents in the colony (Impekoven & Gold, 1973). Prenatal learning would be adaptive for this species also. The neonatal guinea pig and lamb are also precocial mammals. Both are able to locomote soon after birth and the neonatal guinea pig can survive without maternal care (Gottlieb, 1971). Neonatal lambs can discriminate their mothers' voices from those of other ewes when they are not visible to the lambs (Shillito, 1975). Here too postnatal auditory preferences based on prenatal auditory experience may benefit early postnatal adaptation.

Postnatal Experience Influences Neonatal Perception

Developmental continuity from the prenatal to postnatal periods is illustrated by the influence of prenatal auditory stimulation on postnatal perception in avian and mammalian species. Similar phenomena may also occur in human development. Although human neonates are motorically altricial, they may be regarded as sensorily, perceptually, and cognitively precocious. All the sensory systems are functional during the last trimester of gestation (Bradley & Mistretta, 1975) and existing data indicate a high degree of perceptual and cognitive functioning in neonates.

Neonatal perception of events is influenced by previous experience with those events. Neonates differentially attend and respond to events which have been previously experienced. Such events are also preferred. Perceptual development of young infants and the cognitive processes reflected by the effects of experience on subsequent perception can be well conceptualized by the developmental theory of Eleanor Gibson (1969). According to Gibson, perception is an active process by which organisms obtain information about their environments. Perception becomes more selective and differentiated with development as a result of three processes. Organisms abstract relevant features of, properties of, and relations among stimuli in their environments while simultaneously filtering out irrelevant stimulus properties. The third process is exploratory activity, which Gibson describes as selective attention. Thus, perception is an active process involving sensory exploration, extraction of relevant stimulus features and filtering out of irrelevant ones. Perception differentiates as the organism learns about the distinctive features of the environment, those features which distinguish an object or event from others, and invariant features and/or relations. Invariants are higher order relationships and may be common to more than one stimulus modality. Invariance is abstracted from stimulation which is constantly changing. Perception becomes more selective through experience as organisms abstract more embedded and superordinate invariants which have not previously been abstracted. Invariants can also function as distinctive features as they may be used to discriminate between stimuli. Thus, increasingly selective and differentiable perceptions become possible with increasing experience.

Neonatal learning and memory. There is abundant evidence that neonatal memory, i.e., the encoding and retrieval of representations of experiences, influences perceptual and behavioral activity. For example, visual fixation to a checkerboard pattern habituates during repeated presentations of the checkerboard and then increases upon presentation of a novel visual stimulus (Friedman, 1972). There is similar evidence of visual memory in premature infants. Infants of 36 weeks conceptional age were presented checkerboard stimuli contingent on high-amplitude sucking until the response amplitude decreased 20%. Then either the familiar stimulus or a novel stimulus was presented contingent on sucking during a 5-min recovery period. High-amplitude sucking increased during acquisition of the contingency in both conditions and then habituated. However, dishabituation or recovery of high-amplitude sucking only occurred following introduction of the novel stimulus (Werner & Siqueland, 1978). Dishabituation of fixation time or high amplitude sucking to the novel stimulus is interpreted as evidence that the infant perceives the present stimulus as different from (the memory of) the previously presented stimulus.

Although neonates generally prefer familiar stimuli in choice or preference tasks, they will respond to novelty in habituation-dishabituation paradigms. This apparent discrepancy can be resolved by examining the different paradigms. For example, in a standard habituation paradigm, one stimulus is presented until visual fixation time decreases a specified amount, after which either the same or a new stimulus is presented. This procedure, however, does not allow the infant to choose between stimuli, and thus provides no information about the role of previous experience in the formation of preferences. Preferences for visual stimuli are assessed using a paired-comparison paradigm and a modified habituation procedure (Cohen & Gelber, 1975). In the paired-comparison paradigm, two stimuli are repeatedly presented simultaneously for a fixed number of trials. Test trials include one previously presented and one novel stimulus (Fagan, 1974). In the modified habituation paradigm, one stimulus is repeatedly presented for a fixed number of trials or until fixation time decreases a certain amount and then both the previously presented and a novel stimulus are presented (Weizmann, Cohen, & Pratt, 1971). The visual preference research indicates that neonates differentially attend to familiar visual stimuli on the choice trials but that infants two months and older attend to novel visual stimuli (Greenberg, Uzgiris, & Hunt, 1970; Weizmann et al., 1971; Wetherford & Cohen, 1973). That is, neonates and young infants prefer familiar visual stimuli but infants two months and older prefer novel visual stimuli.

Infants 2-4 weeks of age also respond differentially to verbal (auditory) stimuli which have been repeatedly presented by their mothers (Ungerer, Brody, & Zelazo, 1978). Infants were presented one word 60 times daily for 2 weeks. Then, the experimental word, a control word, and the infant's name were presented from one of two speakers placed on each side of the infant. Infants responded to the experimental word with eye movements, raised eyebrows, and head turning toward the speaker but they did not respond to the control word or to their names.

Neonates also remember response patterns and relationships between their behavior and auditory reinforcement contingencies. For example, when neonatal sucking has been reinforced with female singing according to a schedule of reinforcement which produces a characteristic response pattern, that pattern tends to persist at the beginning of a second session 18 hours later (Panneton & DeCasper, 1982; DeCasper, 1980). Newborns also remember the contingent relationship involved in an operant learning task (DeCasper & Carstens, 1981). Newborns who heard a female voice contingent on a particular sucking pattern came to produce the required response. When they experienced noncontingent stimulation in a second session they exhibited negative affect and their sucking patterns were different from before. Other infants who experienced noncontingent stimulation in the initial session and contingent stimulation in the second session exhibited similar patterns of sucking in both sessions (i.e., the contingency did not influence sucking in the second session) and they never exhibited negative affect.

Neonatal perception. The perceptual processes of abstraction of invariant relations, selective attention to specific perceptual events, and activities which direct perceptual exploration (Gibson, 1969) are all observed in young infants. Neonates as well as older infants can abstract invariant properties of stimuli across different sensory modalities. For example, neonates respond differentially to a visual presentation of a stimulus that had previously been presented tactually (Meltzoff & Borton, 1979). Twenty-nine-day-old infants were given oral experience with one of two pacifiers. Infants were orally familiarized with either a pacifier with a smooth sphere attached or one with a sphere with nubs on it. Infants did not see the pacifier. After the pacifiers were removed from their mouths, the visual shapes of the two pacifiers were presented simultaneously. Infants looked significantly longer at the shape which had been tactually experienced. That is, infants demonstrated a visual preference for a stimulus which they had not previously seen but which was similar to one they had previously felt, and therefore familiar. According to Gibson's theory, neonates in this study abstracted the invariant properties of shape from a tactile as well as a visual stimulus and used this distinctive information to discriminate between the two visual stimuli. Similarly, six-month-olds perceive temporal sequences which are invariant across sensory modalities (Allen, Walker, Symonds, & Marcell, 1977). Infants were presented either an auditory or visual sequence of three elements in two temporal patterns until habituation of heart rate and skin potential response occurred. Following habituation, a new pattern or the same pattern was presented in either the same or different modality as the habituation pattern. Dishabituation occurred in response to the new pattern when the new pattern was presented in either the same or different modality. Furthermore, responses did not dishabituate when the same temporal pattern was presented in either the same or different modality as the habituation stimulus.

Temporal invariance of auditory and visual events can also be detected by 4-month-olds (Spelke, 1979). Infants were presented films of two objects in motion and sounds which were synchronous with the visual motion of one of the objects. Infants looked at the object that was synchronous with the sound. Infants also look at objects that occur in the same rhythm as the sound even though the sound is not simultaneous with the motion (Spelke, 1979).

Evidence that perception can be quite selective has been provided by studies demonstrating that infants can attend to one of several simultaneous stimuli. Infants 12 and 25 weeks of age detect their mother′s voice when it is presented within a background of eight other voices (Benson, 1978). Infants as young as 4 months old can also selectively attend one of two simultaneous visual stimuli (Bahrick, Walker, & Neisser, 1981). Films of clapping hands and of two hands operating a slinky toy were superimposed during a familiarity phase in which the sound track of only one of the films was presented. Following familiarization, the films were presented separately and without sound. Four-month-olds looked at the film that had not been accompanied by the appropriate sound, suggesting that they habituated to the film which had been presented with the appropriate sound.

Exploratory activity, according to Gibson, enables the infant to learn about and obtain information about the environment. Exploratory behaviors are present even in newborns although they become more efficient with maturation and experience. Infants obtain information about the environment by looking, mouthing, touching and manipulating objects, listening, and orienting to sights and sounds. Newborns will turn their heads and eyes in the direction of sounds (Wertheimer, 1961) as do 1- and 3-month-olds (Field, Muir, Pilon, Sinclair, & Dodwell, 1980). Auditory stimulation also enhances looking of infants. Visual scanning of an adult face by 3- to 11-week infants increased when a voice was presented (Haith, Bergman, & Moore, 1977). Infants also respond to visually perceived objects with arm and hand movements. Infants 3- to 8 weeks of age oriented arm movements toward visual objects and accuracy increased with age (McDonnell, 1979). Newborns also engage in immature reaching behavior when presented a moving object (von Hofsten, 1982). When infants fixate a moving object, the relative frequency of forward arm extension increases over the frequency of arm movements when the object is not fixated.

Neonates imitate visually presented human movements. Tongue protrusion, mouth opening, and sequential finger movement were modeled to 19-day-old infants by an adult (Meltzoff & Moore, 1977). Afterward the infants' behaviors were recorded for 150 sec. Infants exhibited significantly more tongue protrusions after that gesture than during baseline or after mouth opening and also engaged in more mouth opening after that gesture than during baseline or after tongue protrusion by the model. Finger movement was observed more following modeled finger movement than following the presentation of facial gestures. Discrimination of and imitation of facial expressions by fullterm neonates and 35-week preterm neonates has also recently been reported by Field and her colleagues (Field, Woodson, Greenberg, & Cohen, 1982; Field, Woodson, Cohen, Greenberg, Garcia, & Collins, 1984). An adult model presented happy, sad, and surprised faces to infants in a habituation paradigm. One facial expression was presented until the infant looked at the face for less than 2 sec and then a different expression was modeled. Infants' visual fixation times reliably decreased from middle to late trials of an expression and increased from late trials of one expression to early trials of the subsequent expression. The habituation of fixation to a repeated expression and dishabituaion to a novel expression suggest that neonates discriminate these three facial expressions. Neonates were observed during the modeling for visual fixation patterns and the occurrence of facial movements such as eye and mouth widening. Widened eyes and mouth occurred for a greater proportion of surprise than for other face trials. Lip widening occurred more during happy face trials, and tightened mouth and furrowed brow occurred more for sad face trials. Furthermore, infant fixation patterns revealed that they looked at the features which they expressed. This relationship between fixation patterns and imitated facial features demonstrates the specificity of visual perception of these neonates. Preterm and fullterm neonates selectively attended distinctive features of facial expressions and discriminated the different expressions using these distinctive features.

The influence of prenatal auditory experience on human perception after birth. Perceptual learning during the late prenatal period may occur in humans as it does in various avian and mammalian species because premature and fullterm neonates′ perception of events is influenced by previous postnatal experience with those events and they prefer familiar events to novel events. There is also accumulating evidence that human neonatal responsiveness to certain auditory stimuli is influenced by prenatal auditory experience with those stimuli. Infants 1 and 3 daays old discriminate their mother′s voice from other female voices and prefer her voice over others (DeCasper & Fifer, 1980; Fifer, 1980). This early maternal voice preference is not differentially influenced by breast or bottle feeding (Fifer, 1980).

Infants can also discriminate between male voices (DeCasper & Prescott, in press). However, newborns who had equal amounts of postnatal experience with their fathers′ voices as did infants in the maternal voice studies did not prefer their fathers′ voices to those of other males. Male voices also do not appear to be as potent a reinforcer as female voices (DeCasper & Prescott, in press) or as the intrauterine heartbeat (Panneton & DeCasper, 1984).

Intrauterine heartbeat sounds are effective reinforcers for newborn behavior (DeCasper & Sigafoos, 1983). Infants will change their sucking rates in order to hear intrauterine heartbeat sounds which are contingent on a particular response pattern. Heartbeat sounds also have a calming effect on infants. Newborns exposed to a normal heartbeat sound presented at 72 beats per min at 85 dB SPL cried less than a group of newborns not exposed to the heartbeat (Salk, 1962). Time sampling of crying revealed that experimental infants cried 38.4% of the sampled time while control infants cried 59.8% of the time. Furthermore, children 16-37 months of age fell asleep significantly faster when exposed to this heartbeat sound than when exposed to lullabies, no sound, or to a metronome presented at 72 beats per min. Fussy neonates′ activity levels decrease when recordings of intrauterine heartbeat sounds are presented (Rosner & Doherty, 1979).

The only direct evidence that human prenatal experience influences postnatal auditory perception has recently been reported by DeCasper and Spence (1984; Spence & DeCasper, 1982). Pregnant women read a specific story during the last five weeks of gestation. They read the story twice each day for 8-10 minutes so that by delivery the mothers had read the story an average of 68 times for a total of 5 hours. Within three days after birth, the infants were placed in an operant choice task in which presentation of two stories was contingent on nonnutritive sucking. All infants could produce either a tape recording of the old story, the story read by the mother during pregnancy, or a novel story which the mother had not read, by emitting different sucking patterns. Some of the infants were tested postnatally using a tape-recording of their mother´s voice reading both old and novel stories while the remainder were presented tape-recordings of another infant´s mother reading both stories. The relative frequency of responses which produced the old story increased significantly above baseline levels while the relative frequency of responses which produced the novel story did not change from baseline. This preference for the old story was apparent whether the maternal voice or another female voice was used in the postnatal test. A control group of infants who had never experienced either story did not change their sucking patterns from baseline. These results directly imply that the fetuses heard some aspect of the story read by their mothers during the prenatal period and that some features of the stories were recognized postnatally. In fact, infants demonstrated a preference for the old story even though it was presented by an unfamiliar female voice.

It seems to be biologically advantageous for motorically precocial species to discriminate maternal voices from voices of other individuals shortly after birth because they must stay close to the mother. However, human infants are motorically altricial and certainly cannot locomote in order to maintain proximity to the mother. Thus, one is led to other speculations regarding the functions of their precocial perceptual abilities. Infant responsiveness to tactile, auditory, and visual stimuli and other characteristics such as state, temperament, and sex are known to influence maternal response toward the infant (Osofsky & Connors, 1979). Perhaps differential neonatal responsiveness to the maternal voice also affects the mother's attitude and behaviors toward her infant. For example, infant attention to the maternal voice may elicit greater maternal interest or more nurturant behaviors. Increased maternal nurturance is certainly advantageous for the neonate and may have implications for social and cognitive development as well. Although the perceptual and cognitive precocity of human neonates makes the possibility of prenatal auditory learning seem reasonable, such learning cannot occur unless the appropriate stimulation reaches the fetus and the fetus' auditory system is mature enough to process the stimulation to a useful degree. The literature on the development of the human auditory system, auditory sensitivities of the neonate, and the auditory stimulation available to the fetus will be presented and their implications for prenatal auditory learning discussed.

Early Auditory Development.

Structural development of the auditory system. The neonate's auditory system is well developed structurally and functions quite well. By the seventh month of gestation, the basilar membrane, stapedial footplate area, and ossicular chain have reached adult size (Elliott & Elliott, 1964) and most of the hair cells and nerve endings are present (Nakai, 1970). All hair cells except the outer row of outer hair cells are present in the newborn (Bredberg, 1967). The tympanic membrane does not reach adult size until the second postnatal year (Ballenger, 1969) but the infant's tympanic membrane is more compliant to stimulation than the adult's. This greater compliance may compensate for loss of amplification which may result from the smaller size of the membrane (Aslin, Pisoni, & Jusczyk, 1983). The eighth auditory nerve begins to myelinate during the sixth month (Falkner, 1966) and myelination is completed by birth (Hecox, 1975). During the seventh month the inferior colliculi and medial geniculate nuclei begin to myelinate. Although the auditory cortex undergoes much development after birth, it is well myelinated in the fullterm newborn (Yakovlev & Lecours, 1967).

Neonatal auditory functioning. Newborn infants are sensitive to various characteristics of auditory stimuli, including intensity, duration, and frequency. Several responses of the fullterm infant increase as a direct function of intensity. The amplitude of some components of auditory evoked potentials increases linearly with increases in intensity (Barnet & Goodwin, 1965). As SPL increases, cardiac responsiveness increases and response latency decreases

(Bartoshuk, 1964; Berg, Berg, & Graham, 1971). Respiratory, behavioral, and cardiac responses increase in magnitude as SPL of white noise increases (Steinschneider, 1968). Infant intensity thresholds have been studied using cardiac and EEG responsiveness to sound. The lowest intensities to which 2- to 4-day old infants have responded are 35-40 dB SPL (Eisenberg, 1976; Eisenberg, 1965). Pure tone thresholds for 7-11- month-old infants and adults were obtained with an operant head-turning technique (Sinnott, Pisoni, & Aslin, 1983). Infant thresholds were 17-27 dB higher than adults′ with adult sensitivity ranging between 7-14 dB SPL for .5-8 kHz frequencies while infant sensitivity ranged between 30-36 dB SPL. The newborn′s evoked brainstem response is elicited by click stimuli which are 17 dB more intense than clicks which elicit adult brainstem responses (Hecox, 1975).

Studies of neonatal sensitivity to frequency have generally found a decline in sensitivity to frequencies greater than 4000 Hz (Eisenberg, 1976). Signals below 4000 Hz result in neonatal behavioral responsiveness two to three times more often than do signals greater than 4000 Hz. It has also been demonstrated that frequencies above 2000 Hz do not mask neonatal brainstem evoked potentials to broadband click sounds as they do with adults (Hecox, 1975; Hecox & Galambos, 1974). Little attenuation of auditory brainstem responses occurred unless the broadband masker was extended below 2000 Hz. Attenuation of clicks was present in 10-day and 10-week olds when maskers extended below 10 kHz. These results suggest that neonatal brainstem evoked potentials are generated by low frequencies of the broadband stimuli and that brainstem evoked potentials are not elicited by high-frequency components of auditory stimuli.

Several studies have demonstrated differential responsiveness of neonates to frequencies in the carrier range of speech. Pure tones of 125 and 250 Hz elicited larger EMG responses than 70, 500, 1000, or 2000 Hz tones (Hutt, Hutt, Lenard, Bernuth, & Muntjerwerff, 1968). Cortical evoked potential thresholds were larger and thresholds were lower to 500 Hz tones than to 1000 or 2000 Hz tones. Neonatal evoked potential thresholds were measured within 3 dB of adult thresholds at 250 Hz, but neonatal thresholds were 10-15 dB above adult thresholds for frequencies greater than 1000 Hz (Engel & Young, 1969).

Neonates respond differentially to different noise bandwidths and seem to do so in a manner similar to adults. Adults judge wider noise bandwidths as louder than narrow bandwidths (Scharf, 1978). Stronger responsiveness is elicited in infants by wide bandwidths than narrower ones or pure tones (Berg & Berg, 1979). Larger EMG responses were elicited to square-wave stimuli than to pure tones (Hutt et al., 1968). Reliable cardiac and behavioral responses have been recorded to wideband noise (50-10,000 Hz) but not to pure tones at octave intervals between 250 and 8000 Hz (Turkewitz, Birch, & Cooper, 1972).

Neonates are sensitive to varying durations of sound. Heart rate change is directly related to increases in the duration of tones from 300 msec to 5 secs (Eisenberg, 1965). An inverted-U relationship has been found between newborns' heart rate acceleration to 2-30 sec square-wave stimuli with the 10 sec signal evoking the greatest heart rate acceleration (Clifton, Graham, & Hatton, 1968).

Neonates´ perception of many speech characteristics appear similar to adults´ perception. Like adults, 1- and 4-month-old infants´ perception of voice-onset-time differences of stop consonants is categorical; i.e., infants perceive differences between consonants which vary in mode of voicing such as voiced [b] and voiceless [p] but do not perceive consonants within one voicing mode as different (Eimas, Siqueland, Jusczyk, & Vigorito, 1971). Furthermore, 2-3-day-old infants discriminate the voice onset time difference between voiced [b] and voiceless [p] stop consonants when presentation of speech sounds is contingent on sucking (Butterfield & Cairns, 1974; DeCasper, Butterfield, & Cairns, 1976). However, discrimination was not observed when speech stimuli were presented independent of infant responding (Decasper et al., 1976). Consonants are produced or articulated in different locations. For example, [b] is produced by obstruction of the lips and [d] is produced by placing the tongue tip against the upper gum. Infants can discriminate place of articulation contrasts on the basis of formant transitions, as do adults, but perceive these contrasts differently when formant transition cues are presented in the context of speech and with all other speech information removed (Eimas, 1974). Place of articulation contrasts in medial as well as initial positions of bisyllabic utterances are discriminated by 2-month-olds (Jusczyk & Thompson, 1978). Discrimination of contrasts was not affected by syllable stress as contrasts were detected equally in stressed and unstressed syllables. Vowel contrasts, however, are perceived along a continuum rather than across categories. Two-month-olds discriminated within-category contrasts ([I1]/[I3]) as well as between-category contrasts ([I3]/[i5]) (Swoboda, Morse, & Leavitt, 1976).

Infants are also responsive to suprasegmental information such as pitch and intonation. Two-month-olds discriminate a syllable with falling pitch from one with rising pitch (Morse, 1972). Furthermore, infants detect differences in pitch contours when the contrasts coincide with irrelevant vowel changes (Kuhl & Miller, 1975). Two-month-olds also discriminate bisyllabic utterances which differ in stress pattern ([da´ba] vs [daba´]). Stress of one syllable was produced by increasing pitch, amplitude, and duration of the syllable (Jusczyk & Thompson, 1978). Infants also detect stress pattern changes when duration alone cues syllable stress (Spring & Dale, 1977). Two-month-olds can distinguish between the same female voice speaking in intonations which are characterized as soft or harsh (Culp & Boyd, 1974). One-month-olds discriminated their mother´s intonated from another intonated female voice (Mehler, Bertoncini, Barriere, & Jassik-Gerschenfeld, 1978). However, there was no evidence of discrimination between their mother´s nonintonated and another female nonintonated voice. Research with older infants suggests that frequency modulation is important for eliciting infants´ attention to "motherese" speech. "Motherese" is characterized by exaggerated pitch and intensity ranges, higher overall pitch, and slow tempo (Sachs, 1978). Fernald (1982) found that frequency modulation or pitch contour was relatively more important than amplitude modulation or duration in eliciting 4-month-olds´ attention to motherese. It has also been demonstrated that mothers use different pitch contours when attempting to maintain eye contact with and to regain eye contact with 2- to 6-month-old infants (Stern, Spieker, &

Barnett, 1983). These findings suggest that infants differentiate among subtle intonational variations and that pitch and intonation may be particularly important for the infant's perception of speech sounds and voices.

Several speech researchers assume that the mechanisms involved in such adult-like perceptual abilities are determined by the biological makeup of the organism (Jusczyk, 1981; Eimas et al., 1971). However, it is possible that prenatal experience with speech may influence the development of the mechanisms involved in speech perception. The following section will present data suggesting that speech may be experienced by the fetus during the third trimester of gestation and thus that prenatal auditory experience could influence postnatal perception.

Prenatal auditory functioning. There is evidence that the auditory system functions during the late prenatal period. Heart rate increase of a 26-week fetus in response to a 1-sec 3000 Hz tone of 110 dB SPL has been reported (Wedenberg, 1965). Murphy and Smyth (1962) reported that fetal heart rate increased in a 30-week fetus to 500 and 4000 Hz tones presented at 100 dB SPL. Fetal heart rate increase and movement were recorded from 38-42 week fetuses in response to tones ranging between 500-4000 Hz presented at an intrauterine SPL of 55-90 dB and lasting 20 secs (Grimwade, Walker, Bartlett, Gordon, & Wood, 1971). The number of movements and the fetal heart rate were significantly greater during the experimental sessions than during control intervals, and 78% of the heart rate changes began within 5 secs of the onset of the stimulus.

Increased fetal cardiac rates were measured during the last trimester of gestation in response to 20-5,000 Hz tones presented for 5 secs (Bernard & Sontag, 1947). These investigators prevented contact between the speaker and the maternal skin so that the sound would be conducted through air rather than through contact with the mother's body. The heart rate of fetuses 2-7 weeks before term was recorded before and after presentations of a 1-sec 3000 Hz tone presented at 110 dB SPL (Johansson, Wedenberg, & Westin, 1964). The women wore earphones which presented a broadband masking noise in order to control for maternal responsiveness to the tones which might influence fetal heart rate. Forty-five tests were conducted on 10 fetuses. Only three tests produced nonsignificant increases in fetal heart rate. Fetal heart rate change and movement in response to sound have thus been recorded while vibration of maternal tissues and maternal responsiveness to sounds have been controlled. Fetuses respond to vibroacoustic stimulation with blink-startle responses beginning at about 24 weeks gestational age. Fetal responsiveness was monitored with ultrasound imaging while .5-sec pulses of sound with spectral peaks at 250 and 850 Hz were presented at 110 dB SPL directly to the maternal abdomen. Blink responses were first observed at 24 weeks but were consistently observed after 28 weeks (Birnholz & Benacerraf, 1983).

Recordings from inside the pregnant human uterus after the rupture of the amniotic sac demonstrate that human speech, particularly maternal speech, penetrates the maternal and placental tissues (Querleu & Renard, 1981). Intrauterine and external sounds were recorded by placing a microphone into the amniotic sac adjacent to the fetal head following rupture of the membranes. Vascular, air, and water sounds were recorded. The intrauterine sounds included frequencies from 1 to approximately 1000 Hz. An inverse relationship was measured between frequency and intensity of sounds such that sounds of 1 Hz measured 80 dB SPL, 400 Hz sounds measured 34 dB SPL, and 620 Hz sounds measured 20 dB SPL. Intensities of frequencies above 800-1000 Hz were negligible. The overall intensity of the measured intrauterine noise was 60 dB SPL. White noise presented externally at 110 dB SPL was attenuated by the maternal tissues. Attenuation of low frequencies was weak, 2 dB at 250 Hz, but increased, as frequencies increased, to 20.4 dB at 1000 Hz. Externally presented speech was attenuated but frequencies within the range from 1-1000 Hz were recorded. The authors reported that the highest frequencies of speech were weaker in intensity and were absorbed by the maternal body. The lowest frequency vowels and consonants were audible, however, they were not systematically detected and may have been masked by intrauterine noise.

The maternal voice was transmitted clearly. Single words were spoken by the mother and frequencies between 225 and 500 Hz were measured at approximately 72 dB SPL. Querleu and Renard (1981) suggested that the maternal voice may be clearly detected due to partial transmission of sound through the mother's body and to the frequency characteristics of female speech. The fundamental frequencies of the female voice range from 150-350 Hz (Studdert-Kennedy, 1974). These frequencies are not strongly masked by intrauterine noise as Querleu and Renard (1981) report that 250 Hz tones are attenuated 2 dB. Segments of male speech around 125 Hz were measured inside the amniotic sac at 72 dB

SPL (Querleu & Renard, 1981). However, male speech, which has fundamental frequencies of 90-250 Hz (Studdert-Kennedy, 1974), is probably not experienced as frequently or as completely by the fetus because it is likely to be masked by the higher intensity, low-frequency intrauterine noises. Maternal speech, then, penetrates the intrauterine cavity quite well, presumably providing the fetus extensive experience with the maternal voice as well as speech. These data are consistent with the report that neonates prefer a prose passage read by their mothers during pregnancy to a novel passage (DeCasper & Spence, 1984; Spence & DeCasper, 1982). That is, if maternal speech is transmitted into the uterine cavity, then fetuses′ preference for prose read prenatally is most likely the result of their auditory experience with the passage.

Several other studies provide data consistent with the findings of Querleu et al. (1981). An inverse relationship between the frequency and intensity of intrauterine sounds has been measured in pregnant and nonpregnant humans (Walker, Grimwade, & Wood, 1971) and in sheep (Vince, Armitage, Baldwin, Toner, & Moore, 1982). Attenuation of sounds through the body was also found to vary with frequency in these studies. Attenuation in the sheep is least below 500 Hz and constant between 500 and 2000 Hz. Human voices were also recorded by the intrauterine microphones. Grimwade et al. (1971) also found that human tissue increasingly attenuated external sounds as frequency increased; 500 Hz sounds were attenuated 20 dB, 1000 Hz sounds were attenuated 40 dB, and 5000 Hz sounds were attenuated 85 dB.

Fetuses, then, are capable of hearing. They respond to extrauterine sounds of high intensity during the last trimester. However, it is not presently known whether the fetal cochlea receives acoustic stimulation from the tympanic membrane and ossicles or by bone conduction. As discussed above, the ossicles and tympanic membrane are capable of functioning during the last trimester of gestation. Hearing _in utero_, then, may involve the same mechanisms as postnatal hearing. However, studies of hearing of underwater divers support the hypothesis that divers hear by bone conduction (Hollien & Feinstein, 1975). Divers′ thresholds for 250-8000 Hz sinusoid tones were obtained under three listening conditions. One group of divers wore hoods which completely covered over the external meatus, while a second group wore hoods with tubes which passed into the external meatus. The purpose of the tubes was to allow water to penetrate the meatus so that acoustic stimulation via the external and middle ear could occur. A third group of divers listened without hoods. Thresholds of listeners wearing hoods were significantly higher than thresholds of listeners without hoods. Furthermore, thresholds of listeners wearing hoods without holes did not differ from those of listeners wearing hoods with holes. That is, thresholds were no different when sound waves were allowed to pass through water into the meatus and to stimulate the tympanic membrane than when they were not. This finding in conjunction with the elevated thresholds in both hood conditions over the no hood condition suggest that divers hear by bone conduction. The hoods worn by the divers dampened bone conduction and resulted in elevated thresholds. Hearing _in utero_ may also occur via bone conduction since fetuses are immersed in a fluid environment.

The purpose of this study. The preceding data indicate that neonates prefer stimuli which are similar to those occurring prenatally. A Gibsonian-based familiarity hypothesis is supported by the findings that newborns prefer their mothers' voices to those of other females, and that a prose passage identical to one recited by pregnant mothers is preferred to a novel prose passage, regardless of whether the postnatal renditions are spoken by the mother or by another female. Intrauterine heartbeat sounds, which are part of the fetal auditory environment, are also reinforcing stimuli to neonates and are more reinforcing than a male voice (Panneton & DeCasper, 1984). Further support for the familiarity hypothesis is provided by the findings that while neonates can discriminate between male voices, they do not prefer paternal voices over those of other males and male voices are not very reinforcing.

The precise nature of stimulus properties which were used by the infants for discrimination and which influenced their preferences are unknown. Based on data which show that neonates are especially sensitive to lower frequency sounds and that low frequencies dominate *in utero*, it is likely that either of several components of the stimuli or some combination of them were important. For example, fundamental frequency could provide important information for discriminating the maternal voice from other female voices, and rhythm and frequency contours could be important for perception of intrauterine maternal heartbeats. Since infants are sensitive to subtle differences in speech segments as well as suprasegmental information (e.g., pitch contour), it is not so surprising that they can respond differentially to a speech passage heard repeatedly.

The purpose of this study was to further investigate the role of familiarity with the prenatal maternal voice in the formation of postnatal perceptual preferences. One specific aim was to examine whether prenatal experience with the lower frequencies of the maternal voice exert a significant effect on postnatal perception of voices. According to the familiarity hypothesis, a postnatal stimulus exactly like the intrauterine maternal voice should be preferred to any extrauterine voice, all else equal. However, the postnatal maternal voice experienced by the newborn, although similar, almost certainly is not identical to the maternal voice experienced by the fetus *in utero*. For example, intrauterine recordings indicate that the higher frequencies of the maternal voice are severely attenuated *in utero*, but that the lower frequencies are transmitted quite well (Querleu & Renard, 1981; Vince et al., 1982; Walker et al., 1971). Thus, the familiarity hypothesis predicts that acoustic information contained in the higher frequencies is not important for postnatal perception because this information has not been experienced prenatally. However, the low-frequency information should be important for postnatal perception of voices. Spectral characteristics of the intrauterine voice were approximated by filtering frequencies greater than 1000 Hz out of tape recordings of female′s speech passages. Newborn preferences for unfiltered female (postnatal) voices or low-pass filtered (simulated intrauterine) voices were assessed with a discriminated-operant choice procedure. In the task, newborns could choose between a recording of a female's unfiltered voice and a recording of the same voice which had been filtered.

In the first study, infants heard recordings of their mother's low-pass filtered and unfiltered voices. If the distinctive features of the prenatal maternal voice (absolute, relational, or invariant features) that are abstracted by the fetus are available only from the low-pass filtered voice stimuli (e.g., the presence of lower frequencies and the absence of high frequencies), and newborns respond to these features, then newborns should selectively orient to the filtered voices. The familiarity hypothesis predicts a preference for the low-pass voice. However, if both the filtered and unfiltered voices share properties which have been abstracted from the prenatally experienced voice (e.g., the presence of low frequencies), and infants respond to these shared features rather than to features which distinguish the two voice samples, then postnatal responsiveness to the two stimuli may be the same. In this case the familiarity hypothesis predicts no preference.

This particular manipulation, however, confounds spectral information and cues which may be used for voice recognition such as the time contours of pitch, intensity, and formants (Bricker & Pruzansky, 1976). Nonspectral cues which are invariant across the filtered and unfiltered versions of the maternal voices may be attended and responded to by neonates since neonates are sensitive to duration, intensity, and other nonspectral dimensions of acoustic stimulation. Thus, this study alone cannot determine if neonates are influenced by the spectral information in their mother's voices.

The role of spectral information in voice perception can be assessed, however, if it is also presented within the context of novel prosodic information. Another aim of the project was to determine whether prenatal experience with acoustic information specific to the maternal voice also exerts a significant effect on voice perception. Thus, a second study was conducted in which neonates were presented the same tape-recordings used in the first study but the speaker-specific prosodic information was now novel for these infants. However, the familiarity hypothesis predicts the same outcomes for this group as for the maternal group. Neonates presented nonmaternal low-pass and unfiltered voices may prefer the low-pass voice if the acoustic information contained only in the low-pass spectrum dominates the newborn's perception of voices. However, neonates may not prefer either voice if they respond to spectral features which are invariant across the low-pass and unfiltered voices.

The familiarity hypothesis predicts that low frequencies influence postnatal voice perception because they have been experienced prenatally while the higher frequencies not experienced *in utero* should not be relevant for neonatal perception of voices. In order to test the prediction that high frequencies are not relevant for voice perception, unfiltered voices used in the first two studies and high-pass versions of these voices were presented to other neonates in a third study. Voices were high-passed at 1000 Hz so that they did not contain the lower frequencies experienced *in utero*. If neonatal voice perception is influenced by _in utero_ experience with the lower frequencies, then the familiarity hypothesis predicts a preference for the unfiltered voice over the high-pass voice. The hypothesis does not predict a preference for the high-pass filtered voice or no preference for either of the two. A preference for high-pass voices would contradict the spectral familiarity hypothesis while the absence of a preference would indicate that neonates′ abstraction of invariant features across the two samples was influenced by postnatal rather than prenatal experience with the spectral composition of the maternal and other female voices.

In sum, the role of prenatal experience with the maternal voice on postnatal voice perception was examined by manipulating two variables which are presumed to influence neonates′ voice preferences, the frequency spectrum of a voice and other characteristics which identify it as belonging to a particular person. Thus, the relative importance of prenatal experience with speaker-specific cues and a truncated frequency spectrum on neonates′ preferences for voices could be assessed.

CHAPTER II

METHOD

Subjects and Design

Subjects were 12 male and 12 female newborns selected from infants who met the following criteria: a) birthweight between 2500 and 3940 grams, b) uncomplicated gestation and delivery, c) Apgar scores of at least 8 at 1 and 5 minutes after birth, d) age at test between 24 and 72 hours. Males were tested before or at least 12 hours after circumcision. Informed consent was obtained from the mothers who were also invited to observe the experimental session.

Eight infants were assigned to the maternal voice condition in which low-pass filtered and unfiltered versions of the maternal voice were presented. In the low-pass nonmaternal voice condition eight other infants matched on age, sex, and race were presented with exactly the same low-pass and unfiltered voices. Eight other infants, also matched to the maternal group on age, sex, and race, were presented a high-pass filtered version and the unfiltered version of the same tapes. Thus, each maternal voice served as a nonmaternal voice for a matched infant in both the low-pass and high-pass filtered nonmaternal groups. Each group of infants consisted of four males and four females. The mean age for the maternal group was 48 hrs while the mean ages for the nonmaternal low-pass and high-pass groups were 48.12 and 46.75 hrs, respectively. Individual subject characteristics are shown in Tables

1-3, columns a-c.

Stimuli

The stimuli were a low-pass filtered, a high-pass filtered, and an unfiltered recording of 8 female voices reading the children's story, The Sleeping Princess (Hoxie, 1911). Mothers recorded the story alone in a quiet room using a Marantz PMD 360 stereo cassette tape recorder. They were instructed to read as if they are reading to their infants. Low-pass filtering was accomplished by placing two filters (Krohn-Hite model 3750) in series and adjusting the low-pass filter to 3 dB down at 1000 Hz. Since each filter had a roll-off of 24 dB per octave, the two filters, when placed in series, result in a .5 power point of 6 dB at 1000 Hz and a roll-off of 48 dB/octave. The high-pass procedure used the same logic. The filters, in series, result in 6 dB down set at 1000 Hz and pass frequencies above 1000 Hz. The 3 dB down points, in all cases, were determined using a true RMS voltmeter, frequency counter, and a pure tone oscillator set to 1000 Hz. The oscillator was initially set to 1.0 volt and then passed through each filter (settings wide open to pass all frequencies). The filter was then adjusted until .7 volts were measured at the filter output. The .7 volts, when squared, equals .49 volts. This is the .5 power point (or in dB, -3 dB down from maximum amplitude).

Filtered and unfiltered voices were recorded on separate tracks of cassette tapes using a Technics M222 tape recorder. The filtered and unfiltered recordings were equated for perceived loudness by two adult observers using SE-305 earphones because wideband signals are perceived by adults (Scharf, 1978) and probably also by neonates (Berg & Berg, 1979) as louder than narrow band signals of the same intensity. Stimuli were played back on a Marantz PMD3 recorder through TDH-39 calibrated earphones. The intensity of low-pass speech ranged from 61-64 dB SPL with a mean intensity of 62 dB SPL. The intensity of high-pass speech ranged from 61-66 dB SPL with a mean intensity of 63.5 dB SPL. Unfiltered speech ranged from 61-62 dB SPL with a mean intensity of 61.5 dB SPL, measured at the earphones.

Apparatus and Procedure

Experimental sessions were conducted in a quiet, dimly lit room adjacent to the nursery. All sessions were conducted about 2 1/2 hours after a scheduled feeding. At this time infants are in or can be gently coaxed to a state of quiet alertness. They were required to visually fixate and follow an experimenter's face in order to be tested. Eight out of 88 neonates selected were not tested because they failed to meet the state criteria for testing. Alert infants were then placed supine in their bassinets and fitted with TDH-39 earphones which were suspended from a supporting bar. A nonnutritive nipple was held loosely in the infant's mouth by one experimenter who was blind to the exact experimental manipulation. The nonnutritive nipple was connected by 30-cm surgical tubing to a Statham P23AA pressure transducer. The pressure transducer was connected to a Grass polygraph, which records sucking pressure, and to BRS/LVE solid-state programming equipment. A second experimenter monitored the equipment.

In general, nonnutritive sucking by alert newborns consists of temporally coherent bursts of individual sucks; each burst lasts at least several seconds and the end of one burst is separated from the beginning of the next by several seconds or more. Virtually all sucks consist of negative pressures equivalent to at least 20-mm Hg. A sucking burst is defined as a series of sucks each having an amplitude greater than or equal to 20-mm Hg and which are separated from each other by less than 2 secs. When 2 secs elapse without a suck, the burst is ended. The alert infants were given a 2-min adjustment period during which sucks of at least 20-mm Hg negative pressure had to be emitted in order to begin the testing. Seventeen out of 80 neonates selected were not tested because they either failed to suck, failed to suck with adequate pressure, or sucked without ever pausing.

During preference testing, the end of each burst initiated alternating 4-sec periods of tone (400 Hz at 60 dB SPL) and silence. A random half of the alternating sequences began with the tone period and the other half began with a silent period. Sucking bursts emitted during these two discriminative stimuli were reinforced with the recordings of unfiltered and filtered voices. Half of the infants were reinforced with a filtered female voice when sucking occurred in the presence of the tone, while the unfiltered version of the same voice was presented contingent on sucking in the presence of silence. For the other infants, sucking in the presence of silence was reinforced with filtered voices while sucking in the presence of the tone was reinforced with the unfiltered voices. Matched infants from each group encountered the same testing conditions for filtered and unfiltered voices. The speech reinforcers were presented over the earphones contingent on the onset of sucking and remained on as long as the burst continued.

The mean session length for the Maternal group was 19.5 mins, while the mean session lengths for the Nonmaternal Low-pass and High-pass groups were 16.29 and 17.75 mins, respectively. If an infant twice failed to suck for between one and two minutes or once failed to suck for two consecutive minutes, the session was terminated and the data were not analyzed. Infants were run until completed sessions were obtained from the minimum number of infants required for the study. Out of 63 infants who began the testing phase, 39 did not complete the session. Of these, 15 went to sleep, 21 became fussy and/or cried, and three sessions were interrupted.

CHAPTER III

RESULTS

The primary dependent measure was the preference ratio computed from the relative frequency of sucking in the presence of the stimulus associated with the filtered and unfiltered voices. The preference ratio was computed for each subject with the following formula: (relative frequency of sucking in the presence of the discriminative stimulus associated with the filtered voice) divided by (relative frequency of sucking in the presence of the stimulus associated with the filtered voice) plus (relative frequency of sucking in the presence of the stimulus associated with the unfiltered voice). This ratio measure provides an index of the relative reinforcing value of the filtered voice. A ratio greater than .5 indicates that an infant took advantage of a greater proportion of the opportunities to produce the filtered voice than those which produced the unfiltered voice. A ratio less than .5 indicates that an infant took advantage of a greater proportion of opportunities to produce the unfiltered voice.

A simple matched-groups analysis of variance, in which treatment (three levels) was the within-subject factor, was conducted on preference ratios (see Tables 1-3, col. h). This analysis revealed a significant effect of treatment, $F\ (2,14) = 4.01$, $p < .05$. The treatment means are shown in Figure 1. Differences between treatment means were tested using the Least Significant Difference (LSD) test.

Table 1

Results for the Maternal Low-pass Group

	A	B	C	D	E	F	G	H
S	Age	Sex	Race	Cond	Ses Lth	Rel Freq Fil	Rel Freq Unf	Pref Ra
1	60	M	W	TF	20	.63	.72	.47
2	55	M	W	TF	21	.73	.55	.57
3	55	F	W	TF	19	.67	.43	.61
4	38	F	W	TF	18	.76	.77	.50
5	44	M	W	TU	19	.44	.51	.47
6	46	M	B	TU	20	.51	.63	.45
7	44	F	W	TU	19	.62	.66	.48
8	42	F	W	TU	20	.63	.56	.53
						x=.62	x=.60	x=.51

TF: Tone = Filtered Condition

TU: Tone = Unfiltered Condition

Ses Lth: Session Length

Table 2

Results for the Nonmaternal Low-pass Group

	A	B	C	D	E	F	G	H
S	Age	Sex	Race	Cond	Ses Lth	Rel Freq Fil	Rel Freq Unf	Pref Ra
1	55	M	W	TF	16	.37	.41	.47
2	55	M	W	TF	18	.53	.61	.46
3	50	F	W	TF	15	.65	.63	.51
4	38	F	W	TF	19	.63	.65	.49
5	42	M	W	TU	16	.33	.43	.43
6	48	M	B	TU	19	.49	.59	.45
7	51	F	W	TU	16	.52	.61	.46
8	46	F	W	TU	13	.46	.57	.44
						x=.50	x=.56	x=.46

TF: Tone = Filtered Condition

TU: Tone = Unfiltered Condition

Ses Lth: Session Length

Table 3

Results for the Nonmaternal High-pass Group

S	A Age	B Sex	C Race	D Cond	E Ses Lth	F Rel Freq Fil	G Rel Freq Unf	H Pref Ra
1	62	M	W	TF	17	.50	.62	.44
2	54	M	W	TF	15	.43	.55	.44
3	54	F	W	TF	20	.70	.63	.53
4	35	F	W	TF	19	.57	.52	.52
5	46	M	W	TU	18	.48	.51	.48
6	47	M	B	TU	15	.59	.57	.50
7	39	F	W	TU	19	.57	.64	.47
8	36	F	W	TU	18	.43	.48	.47
						x=.53	x=.56	x=.48

TF: Tone = Filtered Condition

TU: Tone = Unfiltered Condition

Ses Lth: Session Length

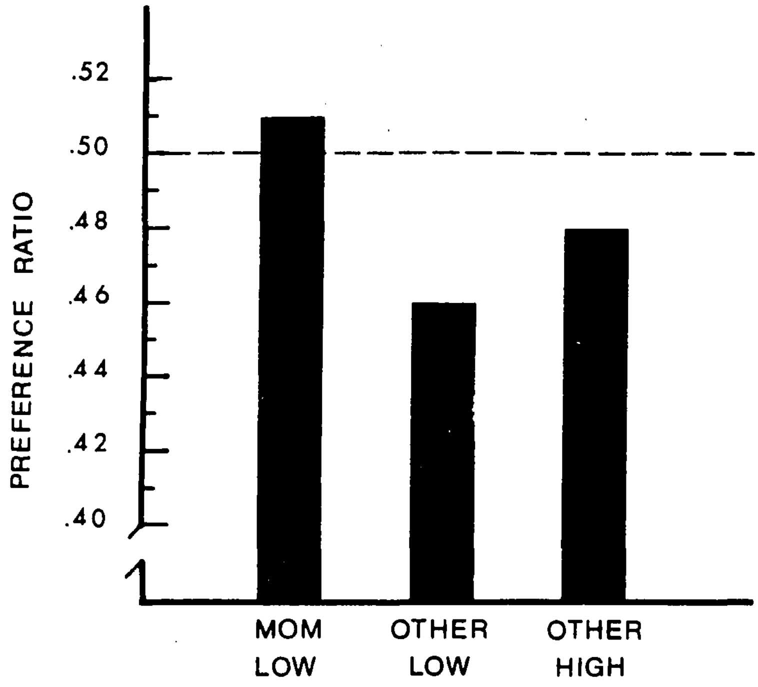

Figure 1. Preference Ratios for Filtered Voices.

Comparison of the mean preference ratios of the maternal and nonmaternal low-pass groups examined whether preference for low-pass or unfiltered voices is influenced by previous experience with the specific voice. The mean preference ratios of the maternal and nonmaternal low-pass groups were significantly different. The difference between groups (.05) exceeded the LSD critical value of .0338, $\underline{p} < .05$. Subsequent tests revealed that this difference resulted because the maternal group took advantage of more opportunities to obtain the low-pass filtered reinforcer than did the nonmaternal group, XD = .12, t (7) = 4.25, $\underline{p} < .01$. The groups took advantage of equal proportions of opportunities to obtain unfiltered voices, XD = .04, t (7) = 0.77, $\underline{p} > .40$.

Comparison of the nonmaternal low-pass and high-pass group means examined whether preferences for filtered or unfiltered versions of nonmaternal voices were influenced by the nature of the filtering. The nonmaternal low-pass and nonmaternal high-pass groups differed only in that the nonmaternal low-pass reinforcer was low-passed at 1000 Hz and the nonmaternal high-pass reinforcer was high-passed at 1000 Hz. The mean preference ratios of the nonmaternal low-pass and high-pass groups did not differ. The mean differrence of .02 did not exceed the critical value of .0338, $\underline{p} > .05$. Preference scores for nonmaternal low-pass and high-pass voices, which did not differ, were combined to form an overall preference ratio for filtered nonmaternal voices independent of the nature of the filtering. The combined preference scores were obtained by entering the relative frequencies of the matched low-pass and high-pass subjects into the equation used to compute preference scores. The overall preference ratio approached significance as the difference between the mean ratio and .50 was .03 while the critical value for significance at the .05 level is .0338.

The first prediction was that infants would prefer the low-pass version of their mother's voice or express no preference. They expressed no preference in that the mean preference ratio for the low-pass versions of the maternal voices, .51, did not differ from .50. The mean difference of -.01 did not exceed the critical value of .0338 computed by the LSD test. Another prediction was that infants would either prefer the low-pass nonmaternal voice or express no preference for either the low-pass or unfiltered versions. Neither predicted outcome occurred. A preference ratio of .46 for the low-pass voice indicated that newborns significantly preferred the unfiltered version of a nonmaternal voice. The mean difference of .04 exceeded the critical value of .0338, $p < .05$.

The third prediction was that newborns would prefer the unfiltered version of a female over a high-pass filtered version. This result did not occur. The mean preference ratio of .48 indicated no preference for either version. The difference of .02 did not exceed the critical value of .03, $p > .05$.

CHAPTER IV

DISCUSSION

The familiarity hypothesis proposed in the Introduction asserted that perceptual familiarity with a stimulus was positively related to the degree of physical similarity between that stimulus and a previously experienced one and that perceptual familiarity determined its reinforcing value. The specific implication of this hypothesis tested in this research was that the frequency spectrum of the prenatal maternal voice would be quite familiar to the newborn and therefore, all else equal, determine the reinforcing value of a voice. The prediction was that low-pass filtered voices would be at least as reinforcing as unfiltered voices, if not more so. This hypothesis, however, was only partially supported.

Infants given a choice between their mother′s low-pass filtered and unfiltered voices did not respond differentially to either voice. The low-pass and unfiltered versions of the maternal voice were equally attractive. This result was consistent with the familiarity hypothesis. It suggests that the perceptually relevant characteristics of the maternal voice are common to both the filtered and unfiltered samples. However, when other infants could choose between the same low-pass or unfiltered voices, they clearly preferred the unfiltered versions. This finding suggests that they were attending to features which distinguished filtered from unfiltered voices and that the perceptual attractiveness of the unfiltered version was greater. This latter finding was not predicted. Together these results indicate that the newborn cannot only distinguish between maternal and nonmaternal voices when given a choice (DeCasper & Fifer, 1980), but that if only one voice is available, perception is affected by the infant's experience with (or lack of) that voice. The mere presence of prenatally experienced frequencies is not sufficient to bias the infant's perception.

When infants were presented with a high-pass filtered nonmaternal voice and its unfiltered version they did not prefer either. Here, the unfiltered voice contains the lower frequency cues which are presumably experienced in utero while the frequencies greater than 1000 Hz which composed the filtered voice sample are not typically experienced prenatally. Under a true prenatal familiarity hypothesis, the unfiltered voice was expected to be perceived as more familiar and thus preferred to a high-pass filtered voice and the absence of a preference was not expected. Together with the Nonmaternal Low-pass group results, these data indicate that neonates are sensitive to the spectral characteristics of a strange female voice and that, in general, they prefer voices having the full spectral range.

A Perceptual Differentiation Interpretation of Neonatal Auditory Preferences.

Perception is an active exploratory process for acquiring knowledge about the environment (Gibson & Spelke, 1983). Features and relations that are present in a perceived event are abstracted into a memorial representation which is used to differentiate the represented event from other events and for comparison of similarities between the represented and other events (Gibson, 1969). The representation is not a literal copy of the physical event, but consists of distinctive features and invariant relations which are abstracted during perception. Recognition occurs when an object or event is judged to be the same as one which has been perceived previously. Accordingly, fetuses experience the physical properties of the maternal voice as they occur *in utero* and abstract and remember some distinctive features or relations which are later used to recognize the postnatal maternal voice (DeCasper & Fifer, 1980). Their finding suggests that some features or relations that are sufficient for the newborns′ recognition of their mothers′ voices are invariant across the intrauterine and postnatal versions. Their result is consistent with the outcome of the maternal voice group in the present study. The absence of a preference for either the low-pass or unfiltered maternal voice suggests that some invariant voice-specific cues were abstracted from both low-pass and unfiltered maternal voices.

The maternal and nonmaternal groups perceived the same voice differently. The present results suggest that different features and relations were salient to infants in the maternal and nonmaternal groups. The absence of a preference for filtered or unfiltered versions of the maternal voice indicates the features which specify the maternal voice were contained in both voice samples and were more salient or reinforcing for infants than other features which differentiated the two voice samples. However, if infants had no experience with the cues specific to the speaker's voice, features which differentiated the two speech samples were more salient or reinforcing for them. Neonates' preferences for these two speech samples then were influenced by their previous experience with specific voices.

A recent study of infant categorization of voices is relevant here (Miller, 1983). Two- and 6-month-old infants were presented a set of six male or female voices until habituation to those voices occurred. Following habituation either novel voices from within the same gender category or voices from the opposite gender category were presented. Six-month-old infants dishabituated only to between-category changes while 2-month-olds dishabituated to both between- and within-category changes. Two-month-olds treated within- and between-category changes as equally salient, suggesting that they did not ignore speaker variations which are irrelevent for categorizing the gender of a voice. Six-month-olds, however, treated between-gender contrasts as more salient than within-gender contrasts. These findings suggest that the salient dimensions for infants' perception of voices change with experience. Features which are salient for less experienced infants may or may not be salient for more experienced infants.

These voice perception data are consistent with Gibson's ideas about perceptual learning. Perception is said to differentiate as perceptual learning progresses; organisms are able to perceive more embedded structure and details and higher superordinate relationships are abstracted. Perceptual differentiation can then result in increased specificity of perception (1969). In the present experiment, the salient features for the maternal group infants were those which indicated the identity of the voice while the salient features for the nonmaternal groups were some features which varied with the frequency spectrum, presumably independent of identity. Thus, perception of a voice varies with experience with that voice. Voice recognition involves perception of more detailed features than does perception of frequency spectrum only, and differential perception of this detail only occurred following extensive experience with those particular features. Analogously, 6-month-olds abstracted superordinate voice category relationships while 2-month-olds did not respond differentially to between- and within-category exemplars of voices. This ability to perceive categories of voice gender presumably results from increased perceptual experience with voices of the two gender classes.

The different response patterns of the two groups are also consistent with data showing that knowledge which is relevant to specific information influences what one perceives and learns about and how well one remembers that specific information. In general, children's memory for specific information is better when that specific information is compatible with the child's existing knowledge (Ceci & Howe, 1978; Spence, 1980; Perlmutter & Ricks, 1979). For example, children who have knowledge of and are good chess players do better at learning and remembering chess positions than do adults who are less advanced players with relatively less knowledge of chess (Chi, 1978). Other studies have shown that preexisting knowledge influences what is learned and remembered from prose passages by children (Brown, Smiley, Day, Townsend, & Lawton, 1977) and adults (Bransford, 1979). Neonates have much more knowledge of the maternal voice than they have about strange female voices. Thus, neonates perceive and respond to different features of the maternal voice samples than they do when presented the nonmaternal voice samples.

The present results imply that experience with a voice results in differential perception of that voice. Available information about voice and speech perception allows some speculation to be made about which acoustic features are relevant for neonatal perception of voices. Nonspectral features of speech sounds to which young infants are sensitive include intensity and duration. Infants are also sensitive to spectral features such as intonation patterns. Unfiltered and low-pass filtered voices both contain the fundamental frequency. The fundamental frequency is the first harmonic of a speech wave which is determined by vibration of the vocal cords (Shoup & Pfeifer, 1976). The fundamental frequency may then be one characteristic which infants use to recognize their mother´s voice. Formant frequencies are the natural frequencies of resonances of the vocal tract. Most vowels are discriminated using the first two formant frequencies. The first formant frequency falls in the frequency range below 1000 Hz, but the other formants fall around or above 1000 Hz. For example, the first three formants of [i] produced by an adult female occur at 310, 2790, and 3310 Hz (Peterson & Barney, 1952). Thus, a low-pass voice contains the first formant frequency but will not contain higher formant frequencies. Infants presented unfiltered and low-pass nonmaternal voices may have used the presence and absence of the higher formant frequencies to discriminate unfiltered from low-pass voices. Infants in the high-pass condition could also have used formant frequency and fundamental frequency to discriminate high-pass from unfiltered voices. Voices which are high-passed at 1000 Hz do not contain the fundamental or the first formant frequency.

The preference expressed by the Low-pass Nonmaternal group implies that these neonates discriminated between low-pass and unfiltered voices. However, the absence of a preference by the Maternal group does not necessarily mean that they could not discriminate maternal low-pass filtered and unfiltered voices. The preference exhibited by the Nonmaternal Low-pass group for unfiltered voices demonstrates that neonates who are unfamiliar with the voice discriminate between its filtered and unfiltered versions. If neonates can discriminate these two variations of a strange voice, it seems reasonable that neonates can also discriminate the same variations of one which they have frequently experienced in both pre- and postnatal versions. Indeed, the evidence indicates that infants and children get better at discriminating stimuli and abstracting distinctive and invariant features of stimuli as they have more experience with those stimuli (Gibson, 1969). Thus, it is most probable that newborns could have discriminated between the maternal filtered and unfiltered voices while not preferring either of the two. It was suggested that these infants were attending and abstracting some features and relations contained in both filtered and unfiltered voices while ignoring the aspects of the samples which could be used to discriminate the two.

Nonmaternal Low-pass voices were not familiar. Infants in the nonmaternal low-pass group preferred unfiltered voices to low-pass filtered voices. Voice-specific cues are not relevant for this choice task as the voices presented are novel to these infants. Thus, any preferences observed reflect the reinforcing value of varying spectral composition. Neonates have experienced maternal and various nonmaternal female voices during the postnatal period and presumably abstracted some features and relations which are invariant across these voices. However, they have never experienced a low-pass nonmaternal voice and have no representation of such an event. If neonates abstract some features or relations from the nonmaternal unfiltered voice used in testing which are shared by the infant′s representation of nonmaternal female voices, then the unfiltered nonmaternal voice would be perceived as the more familiar voice. Although low-pass voices shared certain features with unfiltered voices, the low-pass voices are less similar to unfiltered voices than is the unfiltered female voice presented in the preference task.

The low-pass nonmaternal voice may not have been as familiar as the unfiltered voice even though the frequency spectrums of the maternal prenatal voice and the filtered nonmaternal voice are similar. The low-pass nonmaternal voice was unfamiliar because the neonates had experience with only one low-pass voice, their mothers′, before birth.

Thus, the infants may not have perceived the (low-pass) frequency dimension as one which may have other values. This interpretation is consistent with the argument proposed by Tversky (1977) that object similarity is influenced by the context within which the objects are presented. Tversky has demonstrated that judgments of object similarity change as the grouping of those objects change. Research with older infants indicates that the breadth of a concept is related to the breadth of experience with different instances of that concept. For example, 30-week-old infants who were repeatedly presented one female face in a single orientation in a habituation task dishabituated to both a novel orientation of the face and a completely novel face. Infants presented a variety of poses of the same female dishabituated to a novel female but not to the same female in a novel pose. Thus, the first group of infants formed a concept of a quite specific female face in a specific orientation while infants in the second group formed a concept of a specific female's face (independent of orientation) (Cohen & Strauss, 1979). Fetuses experience the low-pass maternal voice during the prenatal period but never experience any other exemplars of a low-pass voice. Thus, the low-pass frequency spectrum may be represented as a feature of the maternal voice and may not be perceived as a class of events that may have various exemplars. If this occurs, then the nonmaternal low-pass voices may not have been perceived as belonging to the same class of events as the prenatal maternal voice and thus were unfamiliar.

Nonmaternal groups preferred unfiltered voices. Neonates preferred unfiltered nonmaternal voices to low-pass nonmaternal voices but expressed no preference in the high-pass condition. It was predicted that unfiltered voices would be preferred over high-pass voices because infants had no experience with high-pass voices and unfiltered voices were more similar to prenatal voices than were the high-pass voices. However, given the results of the nonmaternal low-pass group, perceptual salience of unfiltered voices probably occurred because of their similarity to postnatal female voices in general. The postnatal test voice shares some distinctive features or invariant relations with the representation of other nonmaternal unfiltered voices.

A preference for unfiltered over high-pass voices may not have been expressed because the spectral composition of the high-pass voice was quite similar to that of the unfiltered voices. The high-pass voice includes all the frequencies between 1000 and approximately 8000 Hz and lacks only the first 1000 Hz. The low-pass voice, however, only contains 0 - 1000 Hz. There is evidence that narrow-band signals are less effective in eliciting neonatal responses than wider bandwidths. For example, pure tones have been found to be less effective than square-wave and synthetic speech stimuli (Clarkson & Berg, 1978), narrow-band noise (Schulman, 1973), and two- or three-tone chords (Turkewitz, Birch, & Cooper, 1972) in eliciting changes in heart rate. Thus, neonatal responsiveness may have been greater to the wider bandwidth unfiltered voice when it was presented with the low-pass voice. However, the difference in bandwidths of high-pass and unfiltered voices was not as large so that preferential responding may not have occurred in this task. This hypothesis could be tested by systematically manipulating spectral range of voices and examining infants' voice preferences.

The general preference for unfiltered voices, suggested by the pooled preference ratios of the two Nonmaternal groups, is consistent with a view of perception as an active, exploratory process. If neonates actively engage in perceptual exploration in order to pick up information about their environments, then when presented with two versions of a strange voice, the most efficient strategy for learning about that voice would be to attend to the version which provides the most information. This interpretation is consistent with a Gibsonian view of perception. Neonates do not express a preference for the unfiltered maternal voice over the low-pass maternal voice because both samples contain sufficient information for recognition of the maternal voice and both samples are familiar to the neonates.

Interpretation of other auditory preference data. This differentiation theory of perceptual development can also account for other neonatal auditory preference data. Neonates prefer their mothers' voices to those of other females in simultaneous choice tasks because they are familiar with its distinctive features. Infants also prefer intrauterine heartbeat sounds over a male voice. Prenatal experience with heartbeats results in a representation of its distinctive features and invariant relations and allows later recognition. Limited experience with male voices does occur postnatally but the specific male voice presented in the preference task has never been experienced.

Thus, the features abstracted from the male voice presented at test are not as similar to features of the representation of male voices as the features abstracted from the heartbeat recording are to the representation of the heartbeat. Preference for a story heard prenatally over a novel story would also result by comparing distinctive features and invariant relations of the story with those abstracted and stored during prenatal experience with the story.

Neonates do not prefer their fathers' voices to other male voices although they have had postnatal experience with the voice. This finding seems puzzling in light of the assertion that they learn something about strange female voices after birth and find strange female voices more perceptually salient than strange male voices (Brazelton, 1978; Wolff, 1963). It may be more difficult for infants to form representations of male voices than female voices. The neonate has had quite a bit of prenatal experience with the maternal voice by birth. Female voices which are encountered postnatally, although different from, are also similar to the maternal voice on several dimensions. Thus, at birth, the neonate has some representation of a specific female voice which may facilitate the acquisition of a representation of other female voices. However, the neonate has not had any experience with male voices at birth and has no representation of a male voice which might facilitate perception of other male voices. Thus, the infant's perception of male voices lags behind that of female voices. This interpretation is consistent with the notion that neonates' existing knowledge influences what they learn about specific events as well as memory for those events.

Further support for the idea that neonatal perception of male voices may be delayed relative to that of females is provided by comparison of spectral characteristics of male and female speech. For example, male and female voices differ in fundamental frequency and formant structure, speech characteristics which reflect structural differences between males and females. Differing acoustic output may be produced by males and females for a single phoneme (Fant, 1973). The first formant of [a] produced by a female is considerably higher than that formant in a male [a]. Also, similar spectral patterns may be produced by males and females for different phonemes (Fant, 1973; Peterson & Barney, 1952). For example, an [e] produced by a male may have the same first three formant frequencies as [o] produced by a female (Fant, 1973). Furthermore, the gender of a speaker influences the category boundaries that adults assign to phonemes along the [bae-dae-gae] continuum (Rand, 1971). Thus, infants may not be able to learn about male voices by generalizing their knowledge of female voices to perception of male voices because many characteristics of male and female speech may differ.

Conclusions

The present study attempted to determine if the spectral characteristics of the prenatally experienced maternal voice would exert a significant influence on postnatal voice perception. Neonates did not exhibit a preference for low-pass filtered or unfiltered maternal voices. However, they preferred unfiltered nonmaternal voices to filtered (low-pass and high-pass combined) nonmaternal voices. It was suggested that both low-pass and unfiltered versions of the maternal voice were equally familiar because neonates attended the common speaker specific cues. Unfiltered nonmaternal voices were more familiar to them than either high-pass or low-pass nonmaternal voices because unfiltered voices were more similar to postnatally experienced nonmaternal voices. However, low-pass voices can be compared to only one specific representation and high-pass voices have no representation. Thus, filtered nonmaternal voices are less familiar than unfiltered nonmaternal voices.

These results provide new information about the nature of neonatal voice perception and about variables which influence perceived familiarity. Neonates recognize their mother′s voice when only a subset (0-1000 Hz) of her voice is available. Although the low-pass maternal voice is more physically similar to the maternal voice experienced *in utero* the unfiltered maternal voice and the low-pass maternal voice were equally attractive to neonates. Neonates can also perceive variations in frequency spectrum of voices as they prefer unfiltered nonmaternal voices to filtered voices. However, because the low-pass voices were never preferred, frequency spectrum is not a dimension which is normally used for perceiving familiarity of voices. Familiarity of a voice was seen to be influenced by both the nature and the extent of experience with different aspects of the voice, i.e., an event may not be perceived as one which may have other exemplars unless various exemplars are experienced. The results then suggest that the nature and amount of perceptual experience with features of voices influence subsequent voice perception.

The present findings, in conjunction with the finding that unfiltered maternal voices are preferred to unfiltered nonmaternal voices (DeCasper & Fifer, 1980), allow certain predictions to be made about relative preferences with voice pairs which have not yet been examined and which are supportive of the perceptual differentiation hypothesis. It can be predicted that low-pass maternal voices would be preferred to unfiltered nonmaternal voices, that unfiltered maternal voices would be preferred to low-pass nonmaternal voices, and that maternal low-pass voices would be preferred to low-pass nonmaternal voices.

Future research might attempt to discover which features and relations of the low-pass and unfiltered versions of the maternal voice can be used for its recognition and which features of nonmaternal voices can be used to discriminate filtered from unfiltered versions. For example, maternal low-pass and unfiltered voices from which the fundamental frequency has been removed might be presented to neonates to assess whether the fundamental frequency is necessary for their equal salience. Such research would provide more specific information about the auditory perceptual abilities of the fetus and neonate as well as information about those features which are abstracted by perinatal humans and which influence familiarity of auditory events.

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