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Exposure to Maternal Voice in Preterm Infants: A Review

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Abstract

The mother's voice, along with other developmentally appropriate sensory events (i.e., touch, light, smells) stimulates maturation of the sensory systems and helps shape normal fetal development. While vast changes in the neonatal intensive care unit (NICU) have occurred over the last two decades, little research has addressed the loss of exposure to maternal voice for the preterm infant. To address this gap, we compared studies that directly investigated effects of exposure to maternal voice on preterm infants. Studies reviewed were conducted between 1972–2007. All presented recordings of maternal voice at sound levels above current recommendations, and few of the findings reached statistical significance. Some potentially positive developmental effects were indicated. Future study of the effects of exposure to maternal voice on preterm infants using recommended sound levels is needed.

Keywords

Premature Infant; Maternal Voice; Sound; NICU; Development; Environment

The maternal voice is a predominant source of multimodal stimulation for the developing fetus that is largely lost for the preterm infant amidst the unfiltered levels of auditory stimuli in the neonatal intensive care unit (NICU). In the normal womb environment, the fetus not only hears her voice, but feels her vertebral column and diaphragm gently vibrate and move in sync with her voice. The fetus thus receives multiple forms of sensory stimulation. that occur at developmentally appropriate times across gestation and are theorized to function as a key aspect of normal fetal growth and development.^{1, 2} For the preterm infant, however, care provided in the NICU disrupts this normal sequence of exposure to sensory events. The purpose of this review was to compare studies investigating one aspect of this experience--exposure to maternal voice.

Safe Sound Levels

Studies investigating impact of exposure to any form of auditory stimulation in humans have been complicated by a large range of decibel levels. A likely explanation for this is that many studies were conducted before or close to the time the American Academy of Pediatrics Committee on Environmental Health was making recommendations for what is now considered safe sound levels within the NICU (hourly Leq of 50 dB; hourly L₁₀ of 55 dB; and 1-second duration L_{max} < 70 dB).^{3, 4}

These elevated levels of auditory stimulation can interfere with an infant's sleep and have a negative effect on vital signs and oxygen saturation.^{5, 6} Common sources of sound for the preterm infant are derived from routine incubator noise, monitoring alarms, and the speech sounds of health care team; all of which they would not typically encounter if life in the uterus had continued to term. In the midst of these additional sounds, preterm infants lose significant contact with an auditory stimulus they would typically be exposed to until full term birth (their mother's voice).

Maternal Voice As A Source of Sound

The specific focus of this review was exposure to maternal voice because, in the normal uterine environment, maternal speech provides a predominant, unique source of sensory stimulation (auditory, vibratory, and vestibular) for the developing fetus.² Disruption of this normal exposure to the maternal voice has been hypothesized to negatively impact normal language development in humans⁷ and recognition of the maternal call in nonhumans.^{1, 8}

The preterm, due to an unusual early birth, is deprived of normal in utero, developmentally appropriate stimuli, including a possibly critical aspect—*the mother's voice*. Using a nonhuman model of prematurity in Bobwhite quails, Lickliter and colleagues have worked towards investigating the impact of loosing exposure to the maternal voice within an environment with significantly elevated light and sound levels.^{9, 10, 11} Sleigh and Lickliter did not allow quail chicks to hear their mother's call during late prenatal development.⁹ Once hatched, they did not walk towards their mother's voice. Further, moving toward their mother's call was also interrupted by elevated levels of light and sound prior to hatching.^{10, 11} Like the Bobwhite quails, the preterm infant similarly loses significant contact with his/her mother's voice late in prenatal development and is cared for in a hospital environment that necessitates elevated light and sound levels. All this happens due to the need for prolonged hospitalization and the daily care provided within the NICU. This, taken together with the fact that the preterm infant is at increased risk for developmental delay,^{12–16} suggests there may be a relationship between the preterm's early altered sensory experiences while cared for within the NICU and developmental outcomes.

While there is general theoretical support for the view that interactions with one's mother may play a significant role in a child's normal growth and development,^{7, 17, 18} very little is known about how the loss of exposure to maternal voice impacts preterm infant development. The purpose of this review was to compare studies investigating the effect of exposure to maternal voice on preterm infants. For this, consistent search terms (*maternal voice*, *preterm infant*, and *sound*) were fed into three highly used databases: PUBMED, CINAHL, and PSYELIT. Bibliographies of studies originally identified were then reviewed to find potential articles that were missed during database searches. Ten studies were identified. Two nonhuman studies were discussed in the introduction;^{9, 11} one study was a dissertation and not reviewed.¹⁹ Of the final 7 human studies, 5 addressed additional exposures to maternal voice while cared for within the NICU and 2 addressed preterm infants' ability to differentiate between the maternal voice and that of a stranger (See Table 1).

RESULTS

Effects of Additional Exposure to Maternal Voice

Using a 3-group design, Chapman²⁰ and Malloy²¹ studied the effects of exposure to a taped recording of the maternal voice, an orchestra playing Brahms' *Lullaby*, and standard NICU care (control group). The infants were all born preterm or between 26–33 weeks' gestational age and exposed to a recording of their mother speaking or a lullaby (stimuli presented at 70–75 decibels) for 5 minutes, every 2 hours, 6 times daily until their weight reached 1,844 grams (approximately 36 weeks' post-menstrual age). The control group received standard NICU care with no additional auditory stimulation.

Chapman²⁰ reported findings related to limb movement following the approximate 34-day history of auditory stimulation exposure and compared between groups. No statistically significant finding related to limb movement were noted. A clinically relevant finding related to exposure to maternal voice, however, was that more infants exposed to mothers' voice (34/50) demonstrated the gross motor pattern of laterality (preference for use of one side) than

the lullaby (29/50) and control group (26/52). The achievement of laterality was interpreted as a positive indication of preterm infant development.

In the same infants, Malloy²¹ evaluated weight gain and selected developmental scales from Rosenblith's Behavioral Examination of the Neonate tool and the Bayley Scales of Infant Development tool 1-day after discharge and at 9-months of age.^{21–23} No statistical differences in the developmental scales were noted between groups. The authors did conclude however that the experimental group gained weight faster because they reached the weight selected for testing (1,844 g) faster. Infants exposed to the lullaby reached the selected weight significantly earlier (9.9 days; $F=4.33$, $p<.05$) compared to those in the control group. Infants exposed to maternal voice also reached the selected weight earlier (6.2 days) than control group infants but, this finding was not statistically significant.

In another historical study, Segall²⁴ described the cardiac response following exposure to maternal voice in preterm infants born between 28–32 weeks' post-menstrual age (PMA). Using an experimental design, infants received 30-minutes exposure to a daily recording of their mother's voice for 4–8 weeks. All recordings were presented at 85 decibels. Once the infants reached 36 weeks PMA they were all tested. The experimental group responded with a significantly ($p<.01$) greater decrease in heart rate to a recording of the mothers' voice and a recording of an unfamiliar female (–24.5 beats per minute; –19.50 beats per minute) than the control group (–7.95 beats per minute; –8.33 beats per minute), respectively. The author interpreted the larger decrease in heart rate as a more adaptive response (compared to the control group) and indicative of greater attention and awareness of the NICU environment for the experimental group given a history of hearing their mothers' voices.

Segall²⁴ also reported that the experimental infants displayed a more adaptive heart rate pattern to a new or novel source of auditory stimulation (operationalized using white noise) than the control group. During repeated trials or presentations of a white noise, infants' responses progressed more quickly from a heart rate acceleration to a more adaptive or non-acceleratory response. A two-way analysis of variance revealed a significant ($p<.01$) interaction between group assignment and trial.

More recently, Standley and Moore²⁵ compared the effects of exposure to maternal voice and music on preterm infants. The PMA of these infants was not indicated, but they were referred to as preterm and 14–16 days post-birth. Using an experimental, repeated measures design, they exposed infants to 20-minute recordings of either maternal voice or music (overall decibel level=65–70) for 3 consecutive days. They found that both maternal voice and music positively affected mean percent oxygen saturation rates compared to baseline rates; the music group displayed significantly higher oxygen saturation rates on days 2 and 3 (Day 2: $t=3.40$, $df=8$, $p<.05$; Day 3: $t=2.81$, $df=8$, $p<.05$). This finding suggests that exposure to music stabilizes infants' oxygen regulation better than exposure to maternal voice.

Johnston, Filion & Nuyt²⁶ (2007) examined infants delivered between 32 to 36 weeks of age during a routine painful procedure in the NICU (heel stick). Using a within-subject experimental design, infants were tested 10 days after birth following a 48-hour exposure to hearing their mothers' voices 3 times a day. Recordings were presented for 10 minutes at 70 decibels and filtered, in order to mimic how the mother's voice sounds from within the amniotic fluid of the uterus. Outcomes measured were components of a pain tool (oxygen saturation, facial expressions, and sleep-wake state). No significant findings were reported related to the components of the pain tool; however, a significantly greater decrease in oxygen saturation rates ($p<.01$) was noted following exposure to maternal voice (94.1) compared to no exposure prior to the heel stick (96.2). The authors noted the sound level for the maternal recording (70

dB) was greater than recommended levels³ and questioned whether using such high decibel levels was aversive to the infant.

Preterm and Term Infant Comparison of Response to Maternal Voice

Two of the studies reviewed compared the preterm and newborn response to maternal voice and that of a stranger.^{27, 28} The primary outcome measure for both researchers was event-related potentials or a neurophysiologic technique derived from the more traditional electroencephalogram²⁹ and hypothesized to measure the infants' ability to remember or recognize the maternal voice.

In the first study, deRengier et al.²⁷ evaluated the effects of maturation on the development of the infants' response to maternal voice. Using a repeated measure experimental design, preterm infants between 35–38 weeks of age were compared to infants delivered at term (38–41 weeks). Testing occurred approximately 1 week following birth during which the infants received random presentations of maternal and stranger voice recordings. The stimuli were presented 100 times with the mother or stranger speaking the word “baby” while event-related potentials were measured. All recordings (maternal and stranger) were presented at 80 decibels. Age was found to be significantly correlated with event-related potentials ($F=7.55$, $p=.009$), in that, the maternal voice elicited larger and more frequent peaks in full term, as compared to preterm infants. It was concluded that, compared to the term infant, early birth significantly decreased recognition memory in the preterm infant.

A similar study comparing the response to maternal voice between preterm and newborn infants was conducted by Therien et al.²⁸ In this study, the response to maternal voice was compared between preterm at 40 weeks PMA between infants delivered at approximately 28 weeks of age and term infants.²⁸ Using a repeated measures, experimental study, 120 presentations of the stimuli (mother's or stranger's voice) were provided at 78 decibels. It was noted that preterm infants at the same PMA displayed significantly lower peak amplitudes ($p<.009$) compared to term infants and displayed no significant changes in event-related potentials between syllables (Bi, Gi) or voices (maternal or stranger) audio presentations. It was concluded that the preterm infants, once they had progressed to 40 weeks PMA, were unable to tell the difference between the syllables or the voices as compared to term newborn infants. Findings demonstrated, like that noted by deRengier et al.,²⁷ suggest that the human preterm infant's ability to remember and thereby differentiate between a stranger's and the mother's voice is negatively affected by an early birth.

Summary

The findings highlight the potential importance of providing developmentally appropriate (within recommended sound levels) longitudinal exposure to maternal voice in the altered environment of the NICU. Of the studies reviewed, all used decibel levels above current recommendations for preterm infants in the NICU.³ Given these elevated sound levels, only one study identified significant positive effects of additional exposure to maternal voice during NICU care.²⁴ Two studies reported negative effects.^{21, 27} The remaining studies discussed potential positive effects however no statistical significance was met.^{20, 21, 25, 26}

IMPLICATIONS FOR RESEARCH AND PRACTICE

Research

Future research is needed to determine whether use of safe sound levels when exposing the preterm infant to recordings of the maternal voice improve developmental outcomes. As this is done, attention to the developmental timing, or the infant's age when exposure begins, is needed, particularly since the auditory and visual sensory systems are undergoing functional

development during the time period infants are cared for in the NICU and the only study reviewed that reported a positive finding and reached statistical significance,²⁴ provided longest duration of exposure.^{1, 8}

The studies reviewed here examined the effect of exposure to maternal voice on oxygen saturation, limb movement, heart rate, and behavioral development at 9 months of age. Further, explorations of variables related to successful graduation from the NICU are needed. For example, does exposure to maternal voice reduce the number of days to achieve oral feeding or transition from nasal cannula to room air?

Practice

Until substantial evidence is collected, caution must be taken when exposing the preterm infant to recordings of the maternal voice. The majority of studies reviewed were historical, thereby requiring replication within current NICU settings and use of recommended standards for sound levels.^{3,30, 31} Positive developmental findings were noted but few studies reached statistical significance. Further, since these historical studies were conducted, NICUs have moved from strict adherence to visitation schedules to open visitation. This change may be attributed to a substantial body of literature demonstrating positive developmental outcomes resulting from interventions in which parents (not specifically, mothers) are encouraged to interact with their preterm infants.^{32–37} This substantial body of literature related to preterm infant interventions involving parents, along with studies reviewed here, underscores the need for future studies addressing responses to maternal voice.

CONCLUSION

Preterm infants lose significant contact with their mothers' voices late in prenatal development and are cared for in a hospital environment that necessitates elevated light and sound levels. All this happens due to the need for prolonged hospitalization and the daily care provided within the NICU. Thus, these infants are not only deprived of the cushioning properties of the womb, but of a possibly critical aspect for normal development—the *mother's voice*. Based on this review, effects have been equivocal and used sound levels greater than those recommended for safe practice. This, along with the fact that these infants are at increased risk for developmental delay,^{13, 15, 38, 39} suggests the need for further investigation of the relationship between preterm infants' early altered sensory experiences, exposure to maternal voice, and developmental outcomes.

Acknowledgments

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Table

Review of Studies Investigating Preterm Infants' and Maternal Voice

Author	Age at birth	Age at test	Stimulus	Dose	Sound (dB)	Outcome	Statistical Significance
Effects of Exposure to Maternal Voice							
Chapman (1978)	26-33	31-38	Maternal Voice, Lullaby	5 min every 2 hours for approx. 34 days	70-75	Limb activity at discharge, Days to discharge	None
Malloy (1979)	26-33	31-38	Maternal Voice, Lullaby	5 min every 2 hours for approx. 34 days	70-75	Weight gained by discharge Developmental tests at 9 months	None
Segall (1972)	28-32	36	Maternal Voice	30 min each day for 4-8 weeks	85	Heart rate, Habituation	Yes
Standley & Moore (1995)	NR	NR	Maternal Voice, Music	20 min each day for 1-3 days	65-70	Oxygen saturation, Oximeter alarm frequency	None
Johnston et al (2007)	32-36	32-36	Maternal Voice	10 min 3 times a day for 2 days	70	Oxygen saturation, Facial expression, Sleep-wake state	Yes
Preterm and Term Infant Comparison of Response to Maternal Voice							
deRengier et al., (2002)	35-38	36-39	Maternal Voice Stranger	100 presentations	80	Event-related potentials	Yes
Therrien et al (2004)	28	40	Maternal Voice\Stranger	120 presentations	78	Event-related potentials	None

Note: Age at birth and at test is in post-menstrual weeks; NR=not reported; dB=decibel level. Significance is only for findings related to exposure to maternal voice