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AUDITORY BEHAVIORAL RESPONSES OF PRETERM INFANTS FOR ENVIRONMENTAL SOUNDS AT HOME

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ABSTRACT

Aims: The study compared the auditory behavioral responses reported by mothers of 3-month term infants with those of preterm infants matched for corrected age, as well as with those of preterm infants matched for chronological age. The research was designed to understand auditory responsiveness in a naturalistic home environment.

Material and Methods: This was a comparative, cross-sectional study with 90 participants, mothers of 3-month term infants (Group 1), mothers of preterm infants with corrected age of 3 months (Group 2), and mothers of preterm infants with chronological age of 3 months (Group 3). A semi-structured interview was conducted to collect information on mothers' observations of their infants' reactions to a list of 10 common household sounds. The Chi-Square test of homogeneity and Fisher's exact tests were used to check the objectives of the study.

Results: Results of Groups 1 differed significantly from those of Group 2, and 3 for responses observed commonly for 4 out of 10 environmental sounds. A greater proportion of mothers of term infants observed responses compared to mothers of preterm infants. However, a significant difference was observed for five types of responses when mothers of term infants were compared with mothers of chronologically age-matched preterm infants.

Conclusion: Term infants exhibit responses to a wider number of sounds when compared to preterm infants of the same age. The results emphasize the importance of using corrected age while assessing preterm infants. The maternal observations can be useful in complementing objective assessments of the auditory system. This is especially helpful in countries like India, where newborn hearing screening is not yet universally implemented.

INTRODUCTION

The auditory system begins functioning before birth and continues to mature rapidly during the first year of life. The physiological maturational changes in the auditory system parallel the emergence of behavioral responses in infants. Observation of auditory behavioral responses in infants helps in understanding auditory development and helps in the assessment of auditory system as well. These auditory responses provide insight into how infants detect, discriminate, and process sounds at a stage when they cannot provide verbal feedback (Northern & Downs, 2014). In term infants, these responses progress in predictable stages. During the neonatal stage, infants display reflexive responses such as startle, eye widening, eye blinking, or state changes, which are mostly reflexive and typically require high-intensity stimuli (Northern & Downs, 2014). Further, as the age progresses, infants exhibit a range of behavioral responses to sound such as more complex orienting, vocal, and social responses (Trehub & Trainor, 1998; Clarkson et al., 1982). Behaviors become more distinct and consistent during the first few months. By three to six months, infants start to orient toward sound sources and smile or quieten in response to familiar voices (Widen, 1993). By the end of the first year, auditory input increasingly supports vocal imitation and babbling, and sound localization becomes more reliable (Olsho et al., 1988).

It is essential to evaluate auditory function during infancy, especially in populations that are at risk, like preterm infants. A preterm birth is one that takes place before 37 full weeks of gestation (World Health Organization [WHO], 2012). The development

of the auditory system and behavior in preterm infants is modified due to their shortened gestation and early exposure to extrauterine environments. When compared to their term counterparts, preterm infants exhibit delayed neural maturation of the auditory pathway (Stipdonk et al., 2016). Histopathological evidence demonstrates that preterm auditory pathways have disrupted myelination and neural organization (Moore & Linthicum, 2007). Furthermore, atypical auditory exposures in neonatal intensive care unit settings may influence auditory processing during a critical developmental period (Philbin & Robertson, 1997; Pineda et al., 2014; McMahon et al., 2012; Graven & Browne, 2008). These biological and environmental factors may alter the auditory responsiveness of preterm infants.

Understanding how an infant responds to sounds in the home environment is clinically valuable in situations where objective tests alone may not capture real-world listening. In addition to this, auditory behavioral milestones offer insights into auditory development and reflect the infant's ability to engage with everyday sounds. Mothers, being the primary caregiver during infancy, are in an advantageous position to observe subtle auditory behaviors in naturalistic contexts. Their daily interactions allow continuous monitoring of how infants respond to speech and environmental sounds. Infants are exposed to a variety of ecologically valid auditory stimuli in their home environments. These include sounds such as music, voices, and common household noises like doorbells, telephones, and running water. Responses to these early exposed auditory inputs are essential for both language acquisition and the development of caregiver-infant relationships. The auditory system develops by the 25th to 28th week of pregnancy, and by the third trimester, a foetus can recognize and react to sounds (Hepper & Shahidullah, 1994; Graven & Browne, 2008). At this point, the foetus is more sensitive to acoustic stimulation from the outside world as well as from the physiological sources of the mother. Speech perception, musical sensitivity, and social bonding that are seen later in an infant are based on these early auditory experiences (Partanen et al., 2013). While several studies have described normative behavioral responses in term infants (Fawer & Dubowitz, 1982; Jacobson et al., 1982), relatively little is known about how preterm infants respond to the same stimuli in home contexts. Most available literature on preterm infants has focused on electrophysiological indices rather than maternal reports of naturalistic behavior. There is a lacuna in understanding the functional auditory responsiveness in infants born preterm. Exploring the auditory behavioral responses of normal hearing preterm infants will provide a baseline for understanding atypical auditory behaviors, and this will help in empowering mothers of preterm infants in early identification of hearing loss. The present research aimed to explore the auditory behavioral response observed by mothers of 3-month-old term infants with those of preterm infants matched for corrected age, as well as those of preterm infants matched for chronological age.

Method

This research was conducted as a comparative study with a cross-sectional approach. The research study was approved by the Research Advisory Committee and the Institutional Ethics Committee of the University.

Participants: A total 90 mothers participated in the study. Group 1 consisted of 30 mothers of 3-month term infants, Group 2 included 30 mothers of preterm infants whose corrected age was 3 months and Group 3 included 30 mothers of preterm infants whose chronological age was 3 months. The gestational age (GA) of term infants considered for the study varied from 37 to 42 weeks while the GA of the preterm infants included in the study varied from 28 weeks to 37 weeks. Infants of both groups had passed the transient evoked otoacoustic emission screening. The study did not include mothers of infants who had been hospitalized for more than a month because of any medical condition, or who had a history, complaint, or indication of conductive pathology, or who had been diagnosed with any neurodevelopmental or neurodegenerative condition or syndrome. The study also excluded mothers who had more than one child, mothers who had been exposed to children with hearing loss at work or at home, and mothers whose infants had a history or complaint of any hearing-related issues.

Material: A list of twenty sounds that infants are commonly exposed in the home environment were listed and five audiologists with at least five years of experience and five mothers with children under two years old were asked to review the list. Mothers and audiologists were asked to mark each sound as either non-relevant, relevant but needing to be rephrased, or relevant. The 20 sounds on the list were narrowed down to the top 10 sounds that infants hear at home. The sounds enlisted were mobile phone ring, doorbell, cooker whistle, calling baby's name, conversational speech, music, hand clapping, utensil falling, vehicle horn and rattling of toys.

Procedure: A semi-structured interview was conducted, where the researcher elicited responses from mothers using specific questions for each sound. Three categories were used to classify the mothers' observations of their children's reactions to sounds, 'response present,' in which the infant displayed a particular reaction to the sound; ' response absent' in which no discernible reaction was seen; and 'response unnoticed,' in which the mother did not attend to the infant's response. If the mother had observed responses, she was requested to describe the responses observed. The researcher took note of the interviewees' responses, coded the information, and tabulated it for additional statistical analysis.

Statistical Analyses: Jeffrey's Amazing Statistical Software (JASP: version 0.19.3.0) was used to perform statistical analyses to investigate the objectives of the study. The difference in the proportions of mothers who have observed the auditory behavioral responses and the type of responses observed by mothers of term and preterm infants was evaluated using the Chi-Square test of homogeneity or Fisher's exact tests. The strength of the difference was calculated using the Phi statistical measure.

Results

The data obtained were tabulated and statistical analyses were carried out. It was observed that the mothers reported only two categories of responses,response present and response unnoticed. The third category of response, 'response absent' was not reported by mothers. Hence, only two categories were considered for analyses. Table 1.1 shows the results of the Chi-Square test of homogeneity comparing the proportion of mothers of Group 1 and Group 2 who have observed behavioral responses for sounds listed by the researcher. The results revealed a statistically significant difference (p<0.05)) between Group 1 and Group 2 for sounds like doorbells, mobile phones, car horns, handclapping, cooker whistles, and toy rattling. A significantly higher number of mothers of Group 1 observed behavioral responses to these 6 out of 10 sounds. The phi coefficient indicated a moderate effect size for mobile phone ring, doorbell, cooker whistler, and the rattling of toys, whereas the effect size was only small for hand clapping and vehicle horn sounds.

Table 1.1.

Results of Chi-Square test of homogeneity comparing the proportion of mothers of Group 1 and Group 2 who have observed behavioral responses of infants

Sr no	Sounds	Response	1 (n=30)	2 (n=30)	Chi square	Phi coefficient	p value
1	Mobile phone ring	Present	19	10	5.41	0.30	0.020*
		Unnoticed	11	20			
2	Doorbell	Present	26	18	5.46	0.30	0.020*
		Unnoticed	4	12			
3	Cooker whistle	Present	20	11	5.41	0.30	0.020*
		Unnoticed	10	19			
4	Calling baby's name†	Present	27	28	--	0.06	†1.000
		Unnoticed	3	2			
5	Conversational Speech†	Present	25	26	--	0.05	†1.000
		Unnoticed	5	4			
6	Music†	Present	25	27	--	0.10	†0.706
		Unnoticed	5	3			
7	Handclapping	Present	22	14	4.44	0.27	0.035*
		Unnoticed	8	16			
8	Utensil falling	Present	20	15	1.71	0.17	0.190
		Unnoticed	10	15			
9	Vehicle horn	Present	16	8	4.44	0.27	0.035*
		Unnoticed	14	22			
10	Rattling of toys	Present	24	15	5.93	0.31	0.015*
		Unnoticed	6	15			

Note. *p value <0.05 **p value<0.01
† p value for fisher's exact test.(--) Indicates not applicable

Table 1.2 shows the results of Chi-Square test of homogeneity comparing the proportion of mothers of Group 1 and Group 2 who have observed different types of behavioral responses. The results show that there is no statistically significant difference in the proportion of mothers observing different types of behavioral responses except for waking up from sleep. Significantly more mothers of term infants observed this response. Though not statistically significant, relatively more mothers of Group 1 observed other types of behavioral responses also.

Table 1.2

Results of Chi-Square test of homogeneity comparing the proportion of mothers of Group 1 and 2 who have observed different types of behavioral responses

Sr no	Type of behavioral responses	Response	1 (n=30)	2 (n=30)	Chi square	Phi coefficient	p value
1	Eye widening	Present	0	0	--	--	--
		Unnoticed	30	30			
2	Eye blinking	Present	13	13	0	0	1.00
		Unnoticed	17	17			
3	Startle	Present	23	22	0.09	0.04	0.766
		Unnoticed	7	8			
4	Stopping of activity	Present	25	23	0.42	0.08	0.519
		Unnoticed	5	7			
5	Waking up from light sleep	Present	23	15	4.59	0.28	0.032*
		Unnoticed	7	15			
6	Smiling	Present	20	19	0.07	0.04	0.787
		Unnoticed	10	11			
7	Eye movement searching for sound	Present	29	26	1.96	0.18	0.161
		Unnoticed	1	4			
8	Turns head partially	Present	14	8	2.58	0.21	0.108
		Unnoticed	16	22			

Note. *p value <0.05 **p value<0.01
† p value for fisher's exact test. (--) Indicates not applicable

Table 2.1 shows the results of the Chi-Square test of homogeneity comparing the proportion of mothers

of Group 1 and Group 3 who have observed behavioral responses of their infants. Overall, more mothers of Group 1 observed responses when compared to Group 3. A statistically significant difference ($p< 0.05$) in the proportion of mothers who observed a behavioral response was found for vehicle horn while a highly significant difference ($p<0.01$) was observed for mobile phone ring, doorbell and cooker whistle. In all, 4 out of 10 sounds showed a significant difference between Group 1 and Group 3. Among the sounds that showed a significant difference between the groups, the effect size was largest for door bell and cooker whistle. For, mobile phone ring and vehicle horn, the phi coefficients showed a moderate to strong effect.

Table 2.1

Results of Chi-Square test of homogeneity comparing the proportion of mothers who have observed behavioral responses for sounds occurring in home environment in Group 1 and 3

Sr no	Sounds	Response	1 (n=30)	3 (n=30)	Chi square	Phi coefficient	*p* value
1	Mobile phone ring	Present	19	8	8.15	0.37	0.004**
		Unnoticed	11	22			
2	Doorbell	Present	26	9	19.82	0.58	< 0.001**
		Unnoticed	4	21			
3	Cooker whistle	Present	20	8	9.64	0.40	0.002**
		Unnoticed	10	22			
4	Calling baby's name†	Present	27	29	--	0.13	†0.612
		Unnoticed	3	1			
5	Conversational Speech	Present	25	22	0.88	0.12	0.347
		Unnoticed	5	8			
6	Music	Present	25	23	0.42	0.08	0.519
		Unnoticed	5	7			
7	Handclapping	Present	22	16	2.58	0.21	0.108
		Unnoticed	8	14			
8	Utensil falling	Present	20	15	1.71	0.17	0.190
		Unnoticed	10	15			
9	Vehicle horn	Present	16	7	5.71	0.31	0.017*
		Unnoticed	14	23			
10	Rattling of toy	Present	24	17	3.78	0.25	0.052
		Unnoticed	6	13			

Note. *p value <0.05 **p value<0.01

† p value for fisher's exact test. (--) Indicates not applicable

Table 2.2 shows the results of Chi-Square test of homogeneity comparing the proportion of mothers of Group 1 and Group 3 who have observed different types of behavioral responses. The results show that there was a statistically significant difference in the proportion of mothers who observed different types of behavioral responses. Behavioral responses, waking up from light sleep, smiling, eye movement searching for sound and turning head partially was observed by significantly more proportion of mothers of Group 1 when compared Group 3. Thus, it was observed that when term and preterm infants were compared at their chronological age, several types of behavioral responses showed a significant difference. However, the results showed no significant difference in any type of responses observed in term and preterm infants at their corrected age, except for the waking up light sleep response.

Table 2.2

Results of Chi-Square test of homogeneity comparing the proportion of mothers who have observed different types of behavioral responses for sounds occurring in home environment in Group 1 and 3

Sr no	Type of behavioral responses	Response	1 (n=30)	3 (n=30)	Chi square	Phi coefficient	p value
1	Eye widening †	Present	0	5	--	0.30	† 0.052
		Unnoticed	30	25			
2	Eye blinking	Present	13	7	2.70	0.21	0.100
		Unnoticed	17	23			
3	Startle	Present	23	23	0	0	1.00
		Unnoticed	7	7			
4	Stopping of activity	Present	25	24	0.11	0.04	0.739
		Unnoticed	5	6			
5	Waking up from light sleep	Present	23	5	21.70	0.60	< .001**
		Unnoticed	7	25			
6	Smiling	Present	20	3	20.38	0.58	< .001**
		Unnoticed	10	27			
7	Eye movement searching for sound	Present	29	22	6.41	0.33	0.011*
		Unnoticed	1	8			
8	Turns head partially	Present	14	0	18.26	0.55	< .001**
		Unnoticed	16	30			

Note. *p value <0.05 **p value<0.01

† p value for fisher's exact test. (--) Indicates not applicable

The comparison of term infants with chronological and corrected age matched preterm infants also showed that consistently sounds of mobile phone ring, doorbell, cooker whistle and vehicle horn exhibited a significant difference between groups. Whereas in both comparisons, sounds of calling baby's name, conversational speech, utensil falling and music showed no difference between term and preterm infants, irrespective of corrected age or chronological age. Both mothers of term as well as preterm infants at their corrected and chronological age did not observe few types of responses of babbling, looking by turning head to the sound, looking and demanding the sound again nonverbally, pointing toward the sound, grabbing the object or going near the sound and imitating behavior.

Discussion

In the present study mothers' observations of auditory behavioral responses in three groups of infants i., e: term infants at three months (Group 1), preterm infants at three months corrected age (Group 2), and preterm infants at three months chronological age (Group 3) were compared. Over, all more proportion of mothers of 3 months term infants observed auditory responses to home environmental sounds compared to mothers of 3 months preterm infants at their chronological as well as corrected age. Few sounds showed a significant difference between the groups and the magnitude of the reported difference in proportion was statistically substantial. Interestingly, when comparing the groups term and preterm at their corrected as well as chronological age, the study did

not find a significant difference in the proportion of responses to more consistent or familiar sounds of conversational speech and music. According to this, term infants might be more sensitive to abrupt, startling noises, but their basic capacity to recognize and react to normal background sounds might be similar for both groups. This is in alignment with other studies on early auditory processing (McMahon et al., 2012).

Due to their full-term in-utero development, term infants may have a more developed central auditory nervous system (Li et al., 2019; Rotteveel et al., 1987), which would enable them to detect and react to external stimuli more reliably (Divon et al., 1985; Voegtline et al., 2013). The full-term development of auditory pathways, which are essential for processing and reacting to a variety of sound stimuli, may be the cause of this response maturity. On the other hand, preterm infants might still be in an auditory immaturity state, in which their nervous systems are less capable of recognizing and processing a variety of complex auditory inputs (Daneshvarfard et al., 2019; Filippa et al., 2023; Retsa et al., 2023; Ragó et al., 2014)

The type of responses did not show significant difference between observations in term infants and preterm infants at corrected age. The exception to this was for response type of waking up from sleep, which was significantly more observed by mothers of term infants. However, a significant difference was observed for more types of responses when term infants were compared pre term infants matched for chronological age. The type of responses like waking up from light sleep, smiling, eye movement searching for sound , and partially turning the head was observed significantly more. The wider range of responses displayed by term infants, which may suggest a more developed state of auditory-motor integration, makes this finding especially significant. These behaviors may appear later in development beyond the three-month corrected age examined in this study, as evidenced by the lack of more complex behaviors of babbling or looking by turning the entire head to the sound source in both groups. Results also showed that irrespective of term or preterm infant, the lack of advanced behavioral responses of pointing, demanding sound, or imitating in all groups further demonstrates that these responses are not anticipated at three months and instead appear later as motor and cognitive maturation progresses (Olsho et al., 1988; Visram et al., 2024).

Eye widening was not observed by mother of term infants and mothers of preterm infants with corrected age of 3 months but it was observed by mothers of preterm infants of 3 months chronological age. This could be a possible example that the less mature auditory behavior fades as the infant grows up, which makes it difficult to observe this specific sound when the infant age progress. The pattern of results also aligns with developmental frameworks which describes how reflexive responses (like startle and blinking) give way to more coordinated orienting behaviors (like head turn and sustained gaze) (Northern & Downs, 2014; Widen, 1993). In one study on mothers' observation of auditory behavior at home showed developmentally expected shifts in auditory behavior between 1 and 3 months term infants. Additionally, as infants show mature more evident behvaioral responses and they are exposed to more variety of environmental sounds as the age progress, mothers of 3 months were able to observe more responses compared to mothers of 1 month term infants (Sruthi & Vanaja, 2025)

The findings present study suggest that by three months corrected age, many auditory behaviors and physiological maturation of the auditory system in preterm infants approximate those of their term peers, consistent with earlier work indicating that developmental catch-up can be demonstrated when corrected age is applied (Eggermont & Salamy, 1988; Gorga et al., 1989; Venkatesh & Shivagirao, 2015). When term and preterm infants were compared at chronological age the difference in auditory behavioral responses was more evident. The results revealed that responses to sounds were observed by significantly fewer mothers of preterm infants. Similarly, multiple type of behavioral responses of smiling, excited body movement, eye movement toward sound, partial head turning, and waking up from light sleep were less by mothers of preterm infants at their chronological age compared to age matched term infants.

It is also clear that mothers of both preterm and term infants could observe the majority of evident behavioral responses as per the development of the infant. There was a reported difference in term and preterm infants at their chronological age in terms of environmental sounds observed and the proportion of mothers observing the type of responses to sounds. This can be attributed to either developmental differences in preterm as well as a lack of opportunity to get exposed to a variety of environmental sounds early in life, which leads to this difference. This study used mothers as observers, which offered a naturalistic perspective on infant behavior. The maternal observations can be useful in complementing objective assessments of the auditory system. This is especially helpful in

countries like India where newborn hearing screening is not yet universally implemented.

Conclusions

It can be concluded that compared to their preterm counterparts at the same age, term infants exhibit a more diverse range of behavioral responses to sound, probably due to a more developed auditory system.The results also indicated that chronological-age matching underestimates the behavioral developmental capabilities of preterm infants. The results highlight the importance of considering corrected age in both research and clinical behavioral assessments.

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