Full-Length Article

The Effects of Mothers' Voice on the Long Term Development of Premature Infants: *A Prospective Randomized Study*

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Abstract

Language acquisition appears to begin during fetal life. This is substantiated by the fact that the fetus recognizes and remembers the voice and melody of the mother's language. We hypothesized that Auditory Stimulation of preterm infants with their mothers' voice may also improve their language and overall development. 24 preterm infants were exposed on a daily basis 5 times for 30 minutes to the recorded voice of their mothers for 6 to 10 weeks beginning 1 to 3 weeks after birth. A control group of 24 infants (with comparable intensive care standards) had similar gestational age (24-30 weeks) and birth weight (650-1440g) as the treatment group. Developmental tests were done at the post-term age of 5 and 20 months (Griffiths Development Quotient), at 56 months (Columbia Mental Maturity Scales, active vocabulary; and a logopedic test of understanding) and 6 years (understanding and construct of sentences). Early developmental parameters were logged by the mothers upon discharge, through their use of a daily diary. This included assessment inquiries related to breastfeeding and mood. At 5 months of age, the Griffiths Development Quotient was significantly ($p=0.007$) higher in the stimulated infants (95± 15) when compared with the controls (80±20). Stimulated infants began earlier than the controls to use two-word sentences (17 vs. 20 months), in the same range than time-born infants; at 6 years the subtest "speech understanding" was significantly better in the stimulated group than in the controls ($p<0.05$). The mothers of the stimulated infants reported less burden and showed more stability. They breastfed their babies at 5 months after full term significantly more often as compared to controls (50% vs. 12.5%). Auditory Stimulation of preterm infants using recordings of mothers' voice appears to improve emotional stability of the mothers and development of their preterm infants. In particular, development of speech and understanding appears to improve through 6 years of postnatal age.

Keywords: ***Auditory Stimulation, development, mother's voice, premature infants, speech, breast feeding***

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Introduction

The hospitalized VLBW (very low birth weight) infant is exposed to an environment that risks the potential of both over and under stimulation. Although few studies on long-term effects of early stimulation programs have been published, supplemental stimulation assumed to match the presenting developmental needs has been applied to preterm infants in many neonatal intensive care units. Acoustic stimulation is particularly popular, since it can be applied without presence of parents or other caretakers. However, long-term effects of most of the applied auditory stimulation programs have not been evaluated [1].

The auditory system (cochlea, inner and outer hair cells) appears to function in the fetus at 22 weeks of gestation [2]. Reactions of human fetuses to acoustic stimuli begin at 19 to 27 weeks of gestation [3]. The fetus is accustomed to sound levels of up to 90 decibels due to arterial and venous blood pulsations and bowel movements [4]. Moreover, the fetuses hear their mothers' voice and appear to remember voice and melody of their mothers' language at 33 weeks of gestation [5]. Moon and Fifer, through research came to the conclusion that transnatal auditory learning may play a role in the infant's postnatal acquisition of language [6].

In premature infants, reactions to acoustic stimuli have been noted at 25 weeks of gestation using cortical and brainstem evoked potentials [7]. The premature infant who is cared for in the neonatal intensive care unit is exposed to technical sounds resulting from various sources as the incubator, gas flows and monitor alarms. On the other hand, the preterm infant is often deprived from the stimulation of

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mother's voice and her spoken language. Auditory stimulation of premature infants by their mothers' voice presented intermittently through a recording has been shown to have several beneficial effects such as increase in arterial oxygen saturation, decrease in bradycardia/apnea events, reduction of activity [8], enhancement of maturation and better function of motor, tactile, auditory and visual responses when compared to control groups [9]. If transnatal learning through exposure to mothers' voice facilitates later language acquisition, mothers' voice presented to preterm infants might also improve their development of speech understanding and speaking.

One interesting study that measured the effects of acoustic stimulation on the development of preterm infants [10] applied combined rocking/heart beat stimulation to controls. Compared to the controls, the treated infants scored significantly higher on the Bayley Scales at 24 months of age. In the current study, we chose auditory stimulation with the mother's voice, since the fetus is exposed to her voice for several hours every day. Studies on effects of this kind of stimulation on the long-term development of preterm infants do not appear to exist in the literature. The present investigation was designed to examine effects of exposing premature infants to their mothers' voice and measuring its effect on their development until 6 years of age. Moreover, emotional stability of the mothers was studied.

Methods

Preterm Infants

The study was approved by the local Ethics Committee of the hospital. All infants were treated in the neonatal intensive care unit of the Children's Hospital of the University of Munich. The mother of each infant enrolled in the study was carefully informed on the purpose and the procedures of the study. A total of 48 preterm infants were investigated as part of a regional prospective long-term follow-up study [11]. 24 pairs of infants were matched according to sex, birth weight (± 100g) and gestational age. Infants of each pair were randomly assigned to the group with Auditory Stimulation and to the control group. Table 1 shows that the clinical data were similar in both groups. Socioeconomic status was assessed as a weighted composite score of the three items (1) occupation of the parent with the highest income, (2) maternal and (3) paternal highest educational qualification. Each item was defined as high, middle or low [11,12].

All premature infants had clinical and radiological signs of surfactant deficiency. A neonatal risk score published by Casaer and Eggermont (1985) was applied to assess long-term morbidity [13]. In this approach 3 clinical (level of care, respiratory support, feeding dependency) and 3 neurological parameters (quality of movement, muscle tone, neurological irritability) were scored daily on 4 point rating scales (0 to 3). The mean score of the first 10 days after birth was used as risk score.

Auditory Stimulation with the Mother´s Voice

Before we decided to use maternal voice for stimulation, we piloted several tests (with music of Mozart and/or mother's voice) to rule out negative effects on the infants as increasing restlessness or cardio-respiratory events (bradycardias, apneas).

Auditory Stimulation was transmitted to the infants by 30-minute recordings of their mothers' voice, recorded on a high fidelity tape recorder (frequency of 50 to 10.000 Hz): 30 minutes free talking, reading, and/ or singing/humming for the baby. The original tape was transferred to an endless tape, and the recording was presented via a small loudspeaker in the incubator about 20 cm from the infant's ear at 65 to 75 decibel. The 30 minutes stimulation was played 5 times a day. Stimulation preferably started in the second week after birth or when the infant's condition was sufficiently stable, and went on to 36 weeks postmenstrual age, unless the infant was dismissed earlier. We observed that after that age infants often showed fidgeting during stimulation, as if the infants expected their mothers as persons and not just their voices. Stimulation periods ranged from 6 to 10 weeks. Times of regular manipulations by the nurses were avoided so that the infants were not disturbed during stimulation and did not associate their mothers' voice with nursing procedures. Since the tape should not substitute the mother, the tape recorder was switched off during her visits.

Follow-Up

The assessment program of the follow-up used selected instruments of the Bavarian-Finnish Developmental Study of infants born at risk [11]: The German version [14] of the Griffiths Scale of Babies Abilities [15] was applied at 5 and 20 months of corrected post-term age and expressed as developmental quotients. At 56 months post-term three tests were performed: Performance Intelligence Quotient by means of the Columbia Mental Maturity Scales [16,17]; a picture vocabulary test to assess verbal intelligence [18,19], and a logopedic test of understanding in which the child was given verbal instructions to perform sequences of actions using standard material [20]. At 75 months subtests of understanding and construct of sentences were done using the Heidelberg Test of Speech Development [21]. All developmental tests were standardized with a regional representative normative sample [22]. The following milestones of development were assessed from diaries of the mothers and questions asked during the visits at the Development Clinic: beginning of fixation, smiling, sitting for 30 sec without support, crawling, walking five steps without support, and first use of language milestones (babble, "mama",

2-word sentences). To assess the emotional stability of the mothers and breastfeeding, mothers were interviewed at each visit and by telephone using standardized interviews which included amount of time breast feeding and mood. At each visit, body weight, length and head circumference were measured. Developmental studies and interviews were performed by personnel of the Development Clinic who were not involved in the care of the infants during the first hospital stay. The personnel of the Development Clinic did not know and did not ask the mothers whether the child received Auditory Stimulation. Parents were regularly reminded of the next Development Clinic visit by letter and telephone.

Statistical Analyses

Differences between mean values of the 2 groups were analyzed using an unpaired t-test. Differences between frequencies were statistically analyzed using a X^2-test. Linear regression analysis was used to test the relationships between Griffiths Scales at 5 and 20 months after full-term and postnatal variables (gestational age, birth weight, hospital stay and time of mechanical ventilation) separately for the 2 groups. Significant relationships were assumed if $r>0.404$ ($p<0.05$).

Results

General clinical data of the 24 preterm infants with Auditory Stimulation and the 24 infants without this intervention are summarized in *Table 1*. No significant differences existed between the two groups. Moreover, socioeconomic status was similar in the 2 groups. Hospital stay in the stimulated infants tended to be shorter than in the controls, but the difference was not significant ($p>0.10$). Body weight, body length and head circumference were not significantly different between the 2 groups at birth, at discharge from the hospital and at any of the developmental examinations.

	AS	Control
n	24	24
Sex (fem/m)	16/8	15/9
Gestational age (wk)	28.5 ± 1.6	28.5 ±1.5
Birth weight (g)	992 ± 193	1022 ± 193
CAESAR neonatal risk, score	14.1 ± 2.1	14.0 ± 2.1
Surfactant deficiency (n)	24	24
Chronic lung disease (n)	10	8
Mechanical ventilation (n)	23	24
Mechanical ventilation (d)	32 ± 22	36 ± 27
Hospital stay (d)	103 ± 36	123 ± 96

Table 1. Clinical Data of Preterm Infants with and without Auditory Stimulation; (Mean ± Standard Deviation); None of the mean values or frequencies was significantly different among the two groups

At an age of 5 months after full-term, the Griffith Scales were higher in the stimulated than in the control infants for overall development, personal-social, vision-hand and efficiency development (*Table 2*). At 20 months and at 4 years 8 months, no significant difference in any of the tested areas (cognition, language, visual-motor integration) was found between the 2 groups. Several milestones of communication and motor development reported by their mothers appeared earlier in stimulated infants than in controls (*Table 2*).

Griffith Scales at 5 months	**AS**	**Controls**	**p**
Overall development	95 ± 15	80 ± 20	0.007
Motor	93 ± 20	83 ± 24	0.121
Personal-social	98 ± 18	85 ± 20	0.019
Hearing	97 ± 24	82 ± 30	0.069
Vision-hand	97 ± 21	78 ± 26	0.009
Efficiency	89 ± 21	71 ± 24	0.008
Griffith Scales at 20 months			
Overall development	83 ± 25	78 ± 23	0.424
Motor	85 ± 24	74 ± 33	0.208
Social	80 ± 25	78 ± 23	0.839
Hearing and speaking	83 ± 29	80 ± 22	0.637
Vision-hand	83 ± 25	79 ± 25	0.561
Efficiency	86 ± 27	78 ± 30	0.328
First appearance of milestones (weeks after full-term)			
Fixation	16 ± 4	19 ± 5	0.069
Smiling	18 ± 3	18 ± 5	0.639
Babble	21 ± 4	24 ± 6	0.115
Says "mama"	60 ± 12	62 ± 14	0.580
Two-word sentences	71 ± 14	83 ± 16	0.008
Sitting for 30 s	40 ± 10	49 ± 11	0.006
Crawling	48 ± 12	50 ± 12	0.571
Walking 5 steps	68 + 14	76 + 15	0.065

Table 2. Development of Preterm Infants During the First 2 years after Full-term (Mean ± Standard Deviation)

The developmental neurologists detected motor and mental abnormalities in more control children than in the group with Auditory Stimulation (*Table 3*).

Abnormalities at 5 months	**AS**	**Controls**
Moderate motor	8	4
Severe motor	2	7
Moderate mental	3	8
Severe mental	1	1
Abnormalities at 20 months		
Moderate motor	3	3
Severe motor	5	10
Moderate mental	5	7
Severe mental	6	8

Table 3. Motor and Mental Abnormalities in VLBW Infants with and without A.S. at 5 and 20 Months after Full-Term

Linear regression analysis between postnatal variables and Griffiths Scales showed significant relationships of birth weight and 20-months Griffiths Scales in stimulated children (r=0.446; p<0.05); hospital stay and Griffiths Scales at 5 and 20 months in stimulated infants (r=0.541 and 0.574, respectively), time of mechanical ventilation and Griffiths Scales at 5 and 20 months in stimulated infants (r=0.558 and 0.597, respectively) and in controls (r=0.407 and 0.430, respectively). At given periods of mechanical ventilation Griffiths Scales tended to be higher in infants with Auditory Stimulation. No significant relationships existed between gestational age and Griffiths Scales at 5 and 20 months in the 2 groups. All mothers whose infants received Auditory Stimulation reported that this intervention was extremely supportive for both the mother and the infant. At 5 months mothers of the stimulated infants appeared more stable than the mothers of the controls (*Table 4*). Although crying was reported in similar numbers of infants in both groups, mothers of stimulated infants reported less fear (4 vs. 37%), less discontent with the baby (0 vs. 21 %) and less general burden of the family (0 vs. 25%) than mothers of the controls. Moreover, more stimulated infants were breastfed after hospital discharge than in the control group (50% vs. 12.5%) and for a longer period of time (>= 1 year vs. <= 3 months).

	A S	Controls
Crying of the baby	13	14
Fear	1	9
Discontent with the baby	0	5
General burden of the family	0	6
Breastfeeding	12	3

Table 4. Emotional Stability of the Mothers and Breastfeeding at 5 Months after Full-Term

At the age of 6 years and 3 months, 18 pairs of stimulated and control children could be studied again. The Heidelberg Language Developmental Test (speech and grammar development) as a whole showed that both groups are within the *normal range*. However, the subtest of understanding/comprehension showed a significant higher score in the children with stimulation compared to controls (51 vs. 41; p<0.05; normative sample, 22 vs. 51) (*Table 5*).

HSET-Subtest, mean (SD)	Stimulated	Controls	p
plural - singular	52.89 (10.88)	50.06 (11.82)	.473
understanding of grammar structure	51.72 (11.20)	43.11 (15.02)	.052*
correction of grammar inconsistency	44.94 (6.92)	44.33 (6.53)	.759
sentences	47.29 (6.55)	44.00 (6.02)	.137

Table 5: HSET - Test of Speech Development at 6.2 Years

Discussion

Our results show that Auditory Stimulation of preterm infants with their mothers' voice improved language development demonstrated by significantly earlier use of 2-word sentences (17 vs. 20 months; *Table 3*) with significantly better language understanding at 6 years of age when compared with controls. Moreover, stimulated infants scored better than controls in overall development at 5 months after full-term (*Table 2*) and showed less often severe motor and moderate mental abnormalities than controls at 5 and 20 months of post-term age (*Table 3*). The observed differences in developmental tests between the two groups could not be explained by differences in perinatal and neonatal risk factors (*Table 1*) or by differences in social classes. The mothers of the stimulated infants appeared more stable and less burdened than the mothers of the controls (*Table 4*). The authors assumed that the increase in breast-feeding may result in the mother`s improved stability and bonding.

Two previous studies found beneficial short-term effects of acoustic stimulation with the mothers' voice in preterm infants during hospitalization as increase in transcutaneous oxygen pressure, arterial oxygen saturation, and reduction of apnea-bradycardia events [8,23]. Standley and Moore compared effects of music versus mother's voice on oxygen saturation and frequency of bradycardia/apnea events [8]. They found more pronounced increase in oxygen saturation and decrease in bradycardia/apnea events during music when compared to mother's voice on day 1 and 2 of stimulation. However, after stimulation with music infants had more bradycardia/apnea events and lower oxygen saturation than before stimulation, whereas mother's voice had no rebound effect. A tendency to increased arterial oxygen saturation was also observed during maternal and paternal kangaroo care of preterm infants [24,25].

Caine reported that music therapy shortened hospital stay of premature infants significantly by 16% [26]. We found the same shortening of hospital stay in infants with Auditory Stimulation, but the difference was not significant (*Table 1*).

Several factors may play a role in long-term effects of acoustic stimulation in the neonatal intensive care unit: (1) Auditory Stimulation may, similar to individualized care [27,28], support the development of neurobehavioral functioning of the central nervous system. (2) Stimulated infants were more often and longer breast-fed than the control infants. Human milk contains compounds (e.g. polyunsaturated fatty acids) that may improve brain development [29]. (3) Mothers of infants with Auditory Stimulation appeared to be more emotionally stable than controls. The emotional stability of the mother may influence the development of the prematurely born infant [30]. (4) Mother-infant bonding may be improved due to better emotional stability of the mothers and to the infants' recognition of the maternal voice. Improved stability of the

mother may be a result of active involvement in infant care and to better responsiveness of the infant to the mother

There is evidence that the fetus remembers maternal voice and spoken words presented at 33 to 36 weeks of gestation [5]. It has been suggested that the perinatal constancy of maternal voice and speech may provide a sensory bridge into postnatal life and may play an important role in the cascade of developmental events that contribute to eventual language acquisition [6]. There is no reason to assume that preterm infants are less able than fetuses of same gestational age to learn and to remember language [31]. Thus, lack of stimulation of preterm infants with their mothers' voice may impede their ability to acquire language. Our results of earlier use of two-word sentences, as judged by the mothers, and better speech understanding at 6 years in the infants stimulated with mothers' voice support this assumption.

Some authors are strictly opposed to the use of earphones to deliver music or recorded voice to the infant's ears [31]. In particular, there is concern that the sound levels are not measured and the infants are exposed to excessive sound and that the recordings replace contingent human voice. In our study, recordings were presented via a small speaker in the incubator about 20 cm from the infant's ear, toward midline, at 65 to 75 decibel. We switched off the tape recorder during visits with the mother and/or father and during nursing procedures and we encouraged and helped the parents to speak or sing to their infants independent of the group assignment.

Conclusion

Auditory Stimulation of preterm infants with their mothers' voice in the neonatal intensive care unit may have favorable long-term effects. The infants and their families may benefit from shortened hospital stay and improved developmental function. In particular, speech development may markedly improve as a result of early stimulation with maternal voice. We cannot rule out that this was the result of improved mother-infant relationship rather than a direct effect of early learning of language. However, our results do indicate that at the very least, our procedure of Auditory Stimulation was safe and had several favorable long-term effects.

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