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The Effect of Music Listening on Physiological Responses of Premature Infants in the NICU

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In this study 20 low birthweight infants of 24–30 weeks gestation age, who were being oxygenated in a Neonatal Intensive Care Unit (NICU), served as subjects during their first week of life. Ten infants listened to lullabies through Bio-logic insert earphones with ALGO Ear Couplers® and 10 infants served as control subjects. All subjects passed an auditory brainstem response (ABR) procedure to insure that audiological responses were consistent with normal hearing. Experimental treatment occurred across 3 days and was conducted in an ABABABABA design, with data collected during five segments of four minutes each of silence alternating with four segments of four minutes each of music. Oxygen saturation levels, heart rate, respiratory rate, and number of apnea/bradycardia episodes were recorded once per minute for the duration of baseline and treatment conditions (36 minutes). Results indicated that music was not contraindicated in the first week of life for these very low birthweight infants for whom sensory stimulation is usually restricted. In fact, music had noticeably positive effects on oxygen saturation levels, heart rate, and respiratory rate. No increase in apnea/bradycardia episodes following music treatment were observed.

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Singing lullabies is an established custom within our culture to soothe, comfort, and pacify newborns. Research studies have documented these soothing effects and have shown that the typical neonate is an active recipient of these and other audiological stimuli at all stages of development, even prenatally (Standley & Madsen, 1990). All prolonged auditory stimuli with a regular rhythm (lullabies, metronome, heartbeat) seem to pacify normal infants equally well. Initially, it was believed that heart beat was a superior calming stimulus for infants due to claims by Salk (1960), but this theory has been rejected by more contemporary research (Detterman, 1978).

It has been learned that one to two day old newborns attend to and discriminate auditory stimuli (Blass, 1987), learn to suck differentially for the preferred stimulus of their mother's voice (DeCasper & Fifer, 1980), quiet to sustained auditory sounds (Brackbill, Adams, Crowell, & Gray, 1966), and recognize stories that were read to them in the womb (Kolata, 1984). Polverini-Rey (1992) demonstrated that fetuses not only respond to external auditory stimuli, but learn from and remember them long after birth. In this study lullabies played daily during the nine weeks prior to birth differentially decreased the crying of the newborns at four weeks of age.

Recently, neonatology personnel have become interested in the use of music to reduce the distress of fragile, premature infants (White-Traut & Tubeszewski, 1986). Such infants often demonstrate a high risk for complications and a failure to thrive (Leonard, 1993; Oehler, 1993; Standley, 1991). Their behavioral state affects their physiological well being. Infant distress is indicated by frequent sleep disruptions, easily elicited startle responses, frequent agitation and crying, and, subsequently, decreased blood oxygenation levels (Gordin, 1990). Some premature infants are so fragile that even the approach of medical rounds to their isolette causes increased bradycardia and apnea episodes (Gorski, Davison, & Brazelton, 1979).

Despite their neurological immaturity and overresponsiveness to all stimuli, premature infants are necessarily treated in isolettes with average, sustained decibel levels of 70–80 dB. Intermittent increases of 15–20 dB due to equipment alarms, personnel voices, and knocks on the isolette to arouse apneic infants are common (Gottfried & Hodgman, 1984). It has been assumed that sustained environmental auditory stimulation at this decibel level is aversive and distressing to the premature infant. Some research has investigated whether music played loudly enough to mask these aversive auditory stimuli might function to reduce distress and help infants thrive. Caine (1992) demonstrated that lullabies played between 70–80 dB in the NBICU (Newborn Intensive Care Unit) isolettes three times per day significantly reduced the total length of hospital stay by an average of 5 days. Lorch, Lorch, Diefendorf, and Earl (1994) demonstrated that infants 33 to 35 weeks post conception showed differential physiological responses to music heard at 78 dB.

Aversive auditory stimuli are especially detrimental to oxygenated, low birthweight infants since respiratory regularity and subsequent oxygen saturation levels are directly affected by the infant's behavioral state and degree of pain (Gordin, 1990). Keeping oxygen saturation levels high with the lowest amount of oxygen possible is an important medical objective since extended reliance on high levels of oxygen can cause retrolental fibroplasia, permanent damage to the infant's eyes (Mullins, 1986). Additionally, weaning from use of a respirator to unaided breathing, usually accomplished as quickly as possible, is particularly stressful for the infant, and is usually accompanied by extensive distress symptoms (Field, 1987).

Research has now begun investigating the effects of music listening on physiological responses of premature infants. Collins and Kuck (1991) observed 17 premature infants (gestational age 24–37 weeks) who were within the first two weeks of their life. The infants were stimulated to an agitated state and observed for 10 minutes during silence followed by music combined with intrauterine sounds for 10 minutes. Results showed that the babies' oxygen saturation levels were significantly increased by this one 10-minute trial of auditory stimulation, though arterial pressure and heart rate were not significantly affected. This study utilized no control group, however, so it cannot be determined whether music or the passage of time alone accounted for the infants becoming calm and having increased oxygen saturation levels.

Standley and Moore (1993) conducted a similar study to determine the effectiveness of music versus newborns' preferred auditory stimulus, their mother's voice (DeCasper & Fifer, 1980).

Effects were also measured across several days. Two groups of NBICU low birthweight infants heard the selected auditory stimuli for 20 minutes for each of three days via earphones intended to focus the auditory stimuli. Effects on oxygen saturation levels and frequency of Oximeter alarms were observed. Results showed differential responses to the two auditory stimuli as time progressed. On the first day, music infants had somewhat higher oxygen saturation levels, but these effects disappeared by Days 2 and 3 of the study. Infants hearing music had fewer occurrences of Oximeter alarms than did those hearing their mothers' voice. It was also noted that the very premature infants (gestational age prior to 30 weeks) seemed to have increased episodes of apnea and bradycardia following music stimulation. It was theorized that perhaps the duration of the music or the decibel level via earphones was overstimulating these most fragile infants. Results of this study support the suggestion that determining age protocols, decibel levels, and presentation schedules for music stimulation of the premature infant is an important clinical consideration (Schaefer, Hatcher, & Barglow, 1980).

Prior research in this area raises the following questions. Is there a minimum gestational age criterion for therapeutic benefit from auditory stimulation? It is known that the human cochlea forms by the 20th week of gestation. It has been observed that the fetus actively responds to external auditory stimuli from the 26th week (Marlowe, 1982) with consistent responses present after 28 weeks (Birnholz & Benacerraf, 1983). Auditory brainstem responses are obtained as early as 26 weeks gestation (Cox, Martin, Carlo, & Hack, 1993). How does the newborn of only 26–30 weeks gestational age respond to music stimulation intended to mask aversive environmental auditory stimuli?

Would an intermittent schedule of music presentation reduce overresponsiveness, increase awareness, and prolong any calming effects during the first week of life for very low birthweight infants? Though evidence suggests that environmental factors influence dendrite growth in the brain, research has not yet isolated how early in the premature infant's development any auditory stimuli might be utilized therapeutically (Campbell, 1985).

The purpose of the current study was to ascertain the effect of an intermittent schedule of music stimulation (4 minutes on/4 minutes off) via Bio-logic insert earphones and ear couplers on physiological responses of 24 to 30 week gestational age, oxygenated infants in their first week of life.

Procedures

Twenty premature infants served as subjects in this study. Infants were patients in a 24 bed Level III Neonatal Intensive Care Unit (NICU) designed to provide a consistently supportive and nurturing environment that promotes the optimal developmental outcome for each infant. Minimum stimulation is a standing requirement for all infants in this unit. All infants were observed during the first week (but not during the first 24 hours) of life. All infants were receiving prophylactic, ototoxic drugs. Once infants were off assisted ventilation, an auditory brainstem response (ABR) procedure was completed by a certified audiologist (CCC-A) to insure that auditory responses were consistent with normal hearing. Prior to data collection, parents or guardians of each child were given a written and oral description of the purpose and procedures for the study. Equipment to be used during the listening treatment was demonstrated and parents received the opportunity to listen to the music. At this time, permission for each child to be a subject in the research project was solicited and obtained.

Criteria for selection of subjects included being of 24 to 30 weeks gestational age, weighing less than three pounds, and receiving oxygen to assist breathing. Seventy-four babies meeting these criteria were identified over the eleven month data collection period. Infants who were removed from ventilation during the course of data collection or were sedated during the 4 hours prior to data collection on any given day (n = 34) were dropped from the study. Infants were not included if they were sedated due to the impact of such medications on their physiological responses and behavioral state (Paap & Nahata, 1990). Other infants were not included because parents did not sign the consent form (n = 8), they were deemed medically unstable by hospital personnel (n = 6), a researcher was unavailable for three consecutive days during the first week of life (n = 5), or the ABR test was failed (n = 1). Of the remaining infants, 10 listened to recorded music and 10 served as control subjects. Groups were balanced with regard to gestational age, chronological age, weight, and sex.

Subjects were individually observed for three consecutive days while on radiant warmers. In order to keep conditions constant and to accommodate the regular routines of hospital personnel, observations were made exclusively during the hours of 3 p.m. and 6 p.m. daily. No other interventions were performed during the observation periods.

The music stimulus tape used in this project was 30 minutes in duration and consisted of six commercially recorded original lullabies sung by a female vocalist with orchestral accompaniment. The selections included *Drift Away*, *Rhapsody in Baby Blue*, *Nightlights*, *I'll Love You Forever*, *Dreamship*, and *Loving My Baby Goodnight*.

Auditory stimuli for experimental subjects were presented binaurally via a battery-operated Sony Walkman (WM-D3) stereo cassette recorder placed outside of the radiant warmer and connected to Bio-logic insert earphones with an insert earphone cable which was placed alongside the radiant warmer. The tips of the insert phones were then attached to ALGO Ear Couplers®. These sterile, disposable couplers, which serve the same purpose as adult headphones, consist of a hard flat shell which is outlined on the inner side with foam rubber. The outside of this foam rubber is coated with a sticky substance which, when placed against the head of an infant, seals around the pinna. Secure placement of these couplers reduces background noise by 14 dB SPL at 2000 Hz (Kileny, 1988). The music was played at an average 80 dB SPL to mask aversive auditory stimuli and to facilitate attentiveness (Caine, 1992; Lorch et al., 1994). At each initiation and cessation of music, sounds were faded in or out over two seconds to avoid causing sudden extreme changes in auditory stimuli.

Experimental treatment was conducted in an ABABABABA design, with data collected during five segments of four minutes each of silence alternating with four segments of four minutes each of music. Data were collected on control subjects for 36 minutes as well.

Data collection occurred once per minute for the duration of baseline and treatment. Data included oxygen saturation levels (estimation of the amount of oxygen carried by the blood) read from an Ohmeda Biox 3700 Pulse Oximeter and heart rate and respiratory rate read from a Dyna Scope DS 3300 monitor. Data were also recorded on the number of apnea (a pause in breathing) and bradycardia (extreme decrease in heart rate) episodes lasting 10 seconds or more as charted by nurses in the 24 hour period prior to and following observations.

Results

The purpose of this study was to observe physiological responses of severely premature infants under music listening conditions as compared to normal environmental sounds. Every minute for 36 minutes during three consecutive days data were collected on oxygen saturation levels, heart rate, and respiratory rate. Also noted from the medical charts were instances of apnea and bradycardia for the 24 hours preceding and following data collection.

Important to the use of music with premature infants whose neurological development is incomplete is whether or not auditory stimuli are too stimulating and therefore contraindicated. Contraindicators based on physiological responses could include continuous large differences between mean rates with music subjects being less healthy or less stable than control subjects and greater variability among subjects in the music group during data collection. Therefore, both means and standards deviations were compared between groups and across time.

A two-way ANOVA with repeated measures (treatment group by minute) was calculated on each day for each dependent measure. Of these nine statistical tests there was only one result indicating statistically significant differences ($p < .05$) due to treatment, either as a main effect or interaction. On Day 1 there was a significant difference due to treatment for the dependent measure of oxygen saturation [$F(1, 18) = 7.7$, $p = .0125$]. As is clearly seen in Figure 1, infants in the music condition consistently had higher (more preferable) oxygen saturation levels (M = 95.8%) than infants in the control group (M = 93.8%). Means for both groups were well within an acceptable clinical range.

Close inspection of means and standard deviations across dependent measures, days, and minutes reveals further infor-

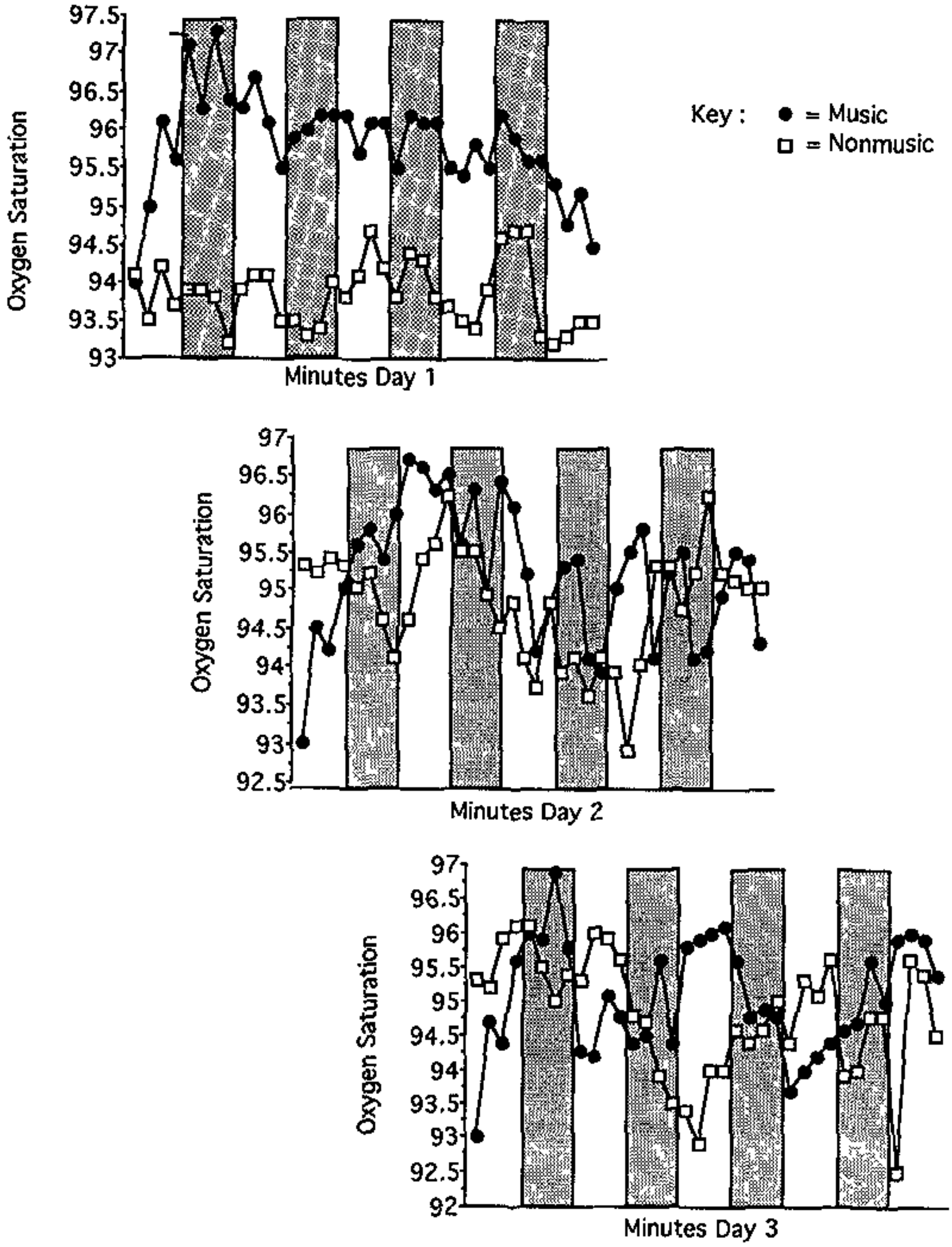

FIGURE 1.
Mean oxygen saturation levels across minutes and days.

mation. Mean oxygen saturation levels for the 20 subjects (n = 10 per group) are displayed in Figure 1. Each of the three days is represented by a graph which defines the 36 minutes of data collection. Shaded areas of the graphs indicate 4-minute intervals during which the experimental subjects listened to music.

It is clear on Day 1 that from the second minute of data collection, experimental subjects experienced a dramatic increase in oxygen saturation levels. This increase was exaggerated during the first episode of music listening, then remained high and stable across the remaining minutes. On Days 2 and 3 the levels were similarly variable for both groups, however, the same trend of dramatic increase for music subjects at the start of data collection each day was apparent. During the majority of time intervals throughout the study, music subjects had higher oxygen saturation levels than did nonmusic subjects.

Comparisons of standard deviations between groups both within each minute and across the 36 minutes on each day for oxygen saturation indicate no differential effect due to treatment. Inspection of graphs in Figure 2 indicate that one group is not consistently more homogenous at each minute nor more stable across the duration of data collection.

Mean heart rates by group across 36 minutes for each day are displayed in Figure 3. Again, shaded areas of the graphs indicate music listening intervals for the experimental subjects. On Day 1, all subjects were similar during the first baseline interval. Once the music conditions began, the subjects listening to music experienced a dramatic decrease in heart rate that remained lower than that of control subjects for the majority of subsequent time intervals on Day 1. The opposite was apparent on Days 2 and 3 with music subjects experiencing predominantly higher heart rates than nonmusic subjects.

Standard deviations across the 36 minutes for heart rate are presented in Figure 4. Deviations for the music group are clearly consistently lower and more stable than for the control group after the initial baseline on Day 1 and Day 2 of data collection. The differences between groups are less obvious on Day 3.

Graphs of respiratory rate means are displayed in Figure 5. On Day 1, from minutes 4 to 15, experimental infants experienced lower respiratory rates than did control infants. This became less clear during the last 21 minutes. On Day 2, the mean rates were primarily lower for the experimental infants and their rates were much more stable across the 36 minutes than were the rates of control infants. On Day 3 both groups experienced similar variability in respiratory rates (although the range is smaller than that of the previous days).

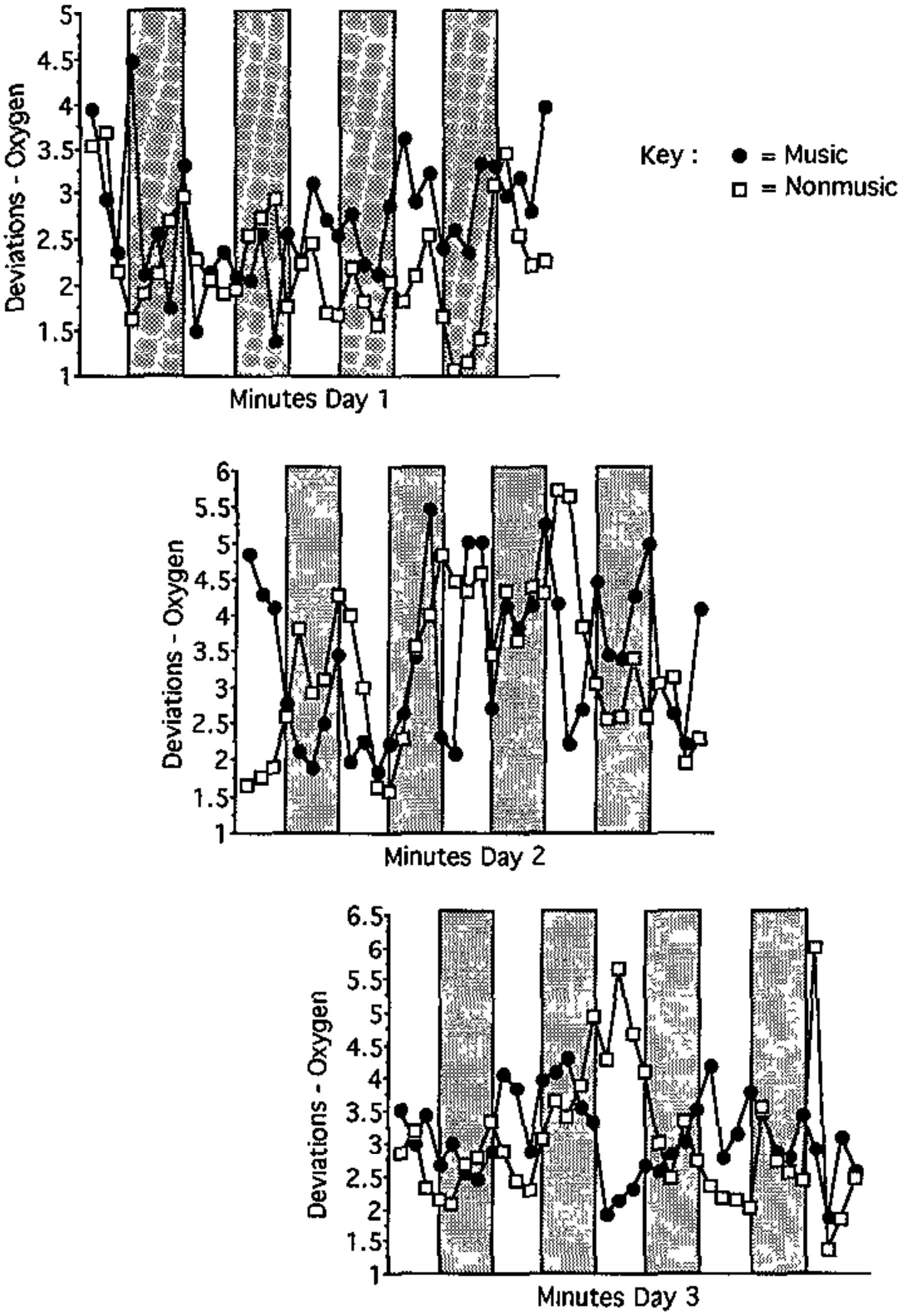

FIGURE 2.
Standard deviations of oxygen saturation levels across minutes and days.

Graphs of standard deviations for respiratory rate are displayed in Figure 6. On Day 2 music subjects had consistently lower and more stable deviations than control subjects from the first minute of baseline. On the other days there was no clear difference.

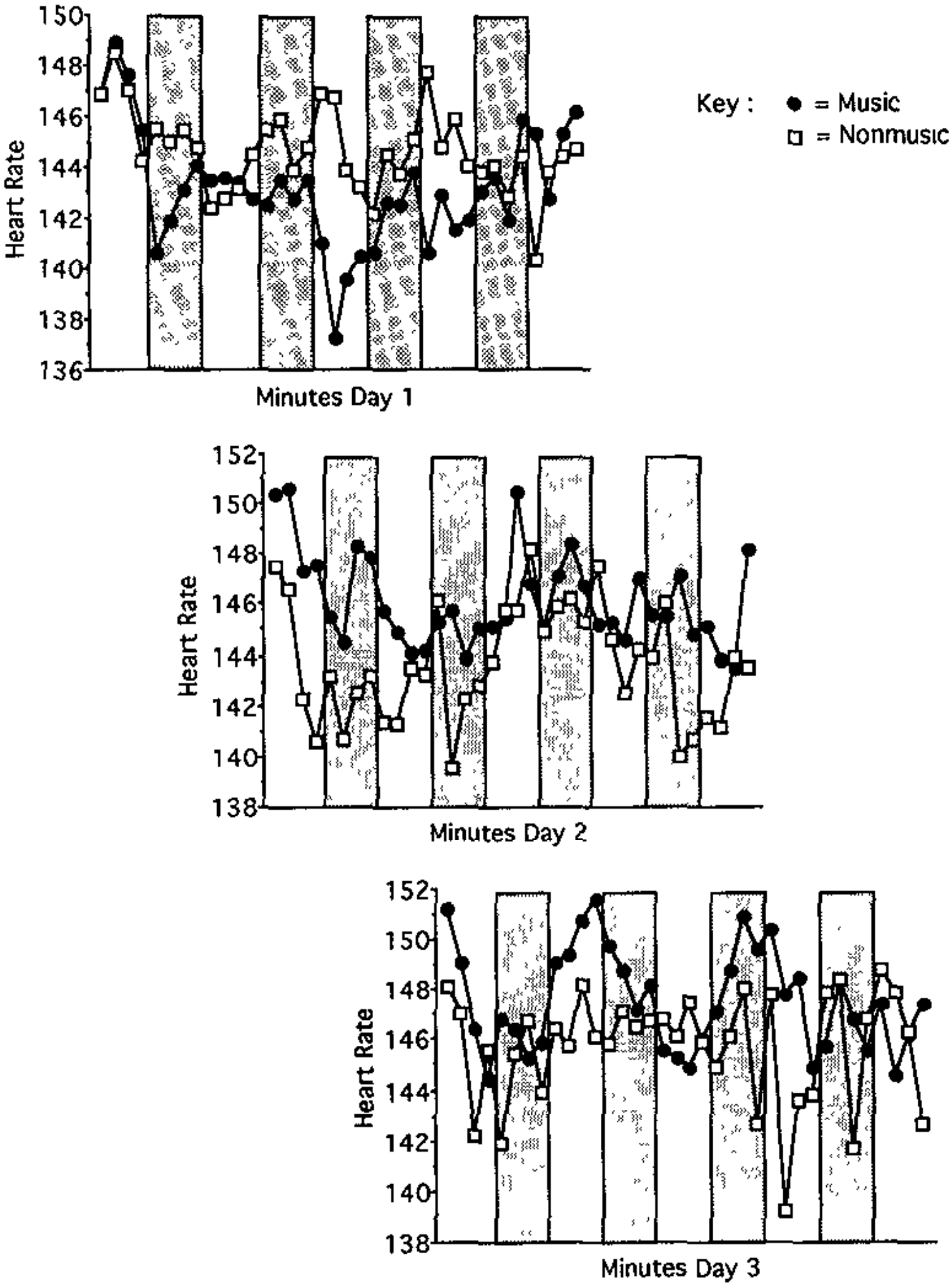

FIGURE 3
Mean heart rates across minutes and days.

Information from the infants' medical charts is presented in Table 1. Included in this table are the sex of each infant, gestational age (40 weeks is considered full term), weight in grams on first day of data collection (approximately 28 grams is equal to one ounce), day of infant's life on the first day of data

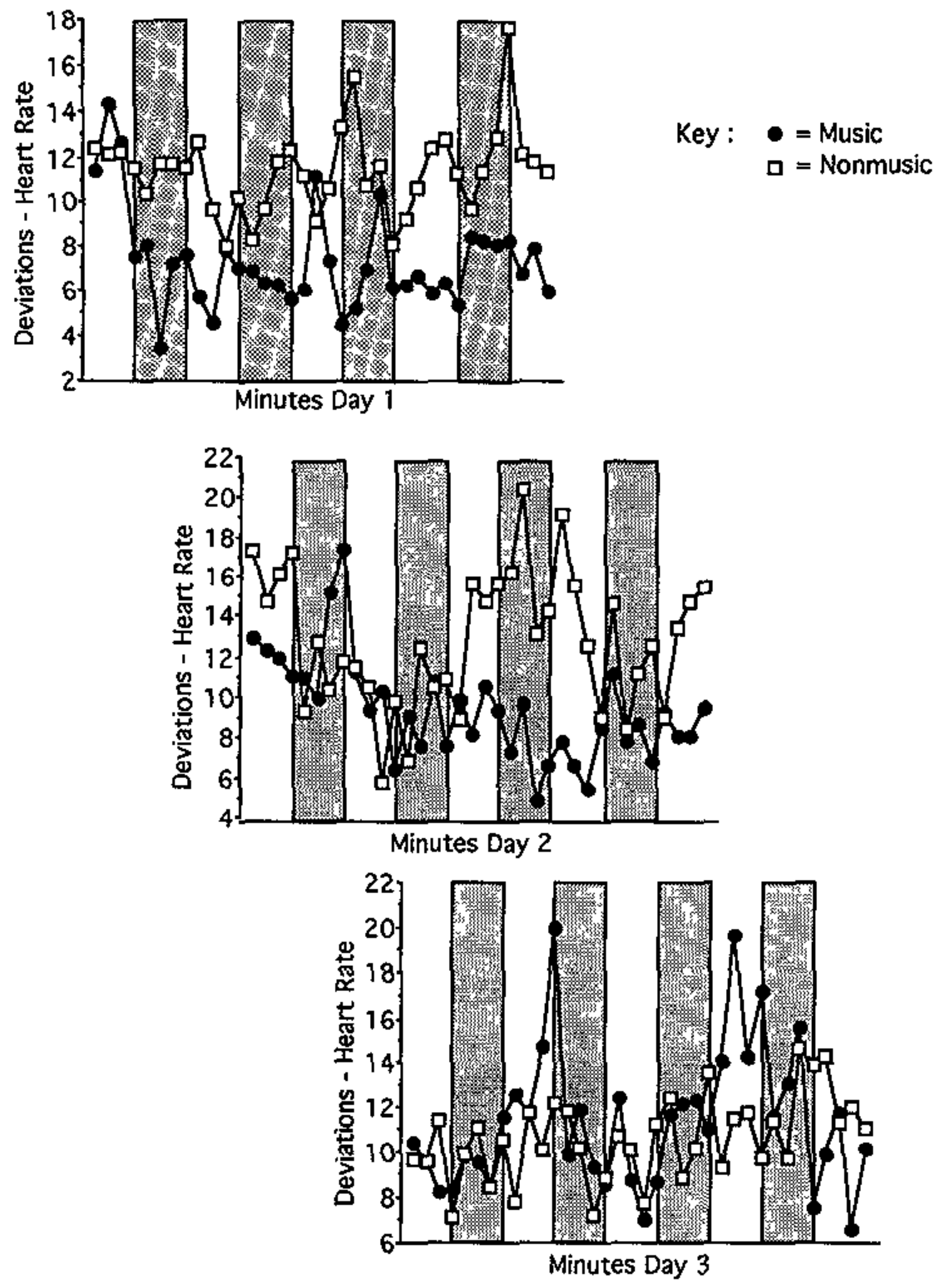

FIGURE 4.
Standard deviations of heart rates across minutes and days.

collection, and the number of instances of apnea (A) and bradycardia (B) for the 24 hours preceding each day of data collection and following the last day. The groups are similar in the mean gestational age, birth weight (slightly more than one ounce difference between means), and day of life on first day of data collection. Mean instances of apnea/bradycardia are

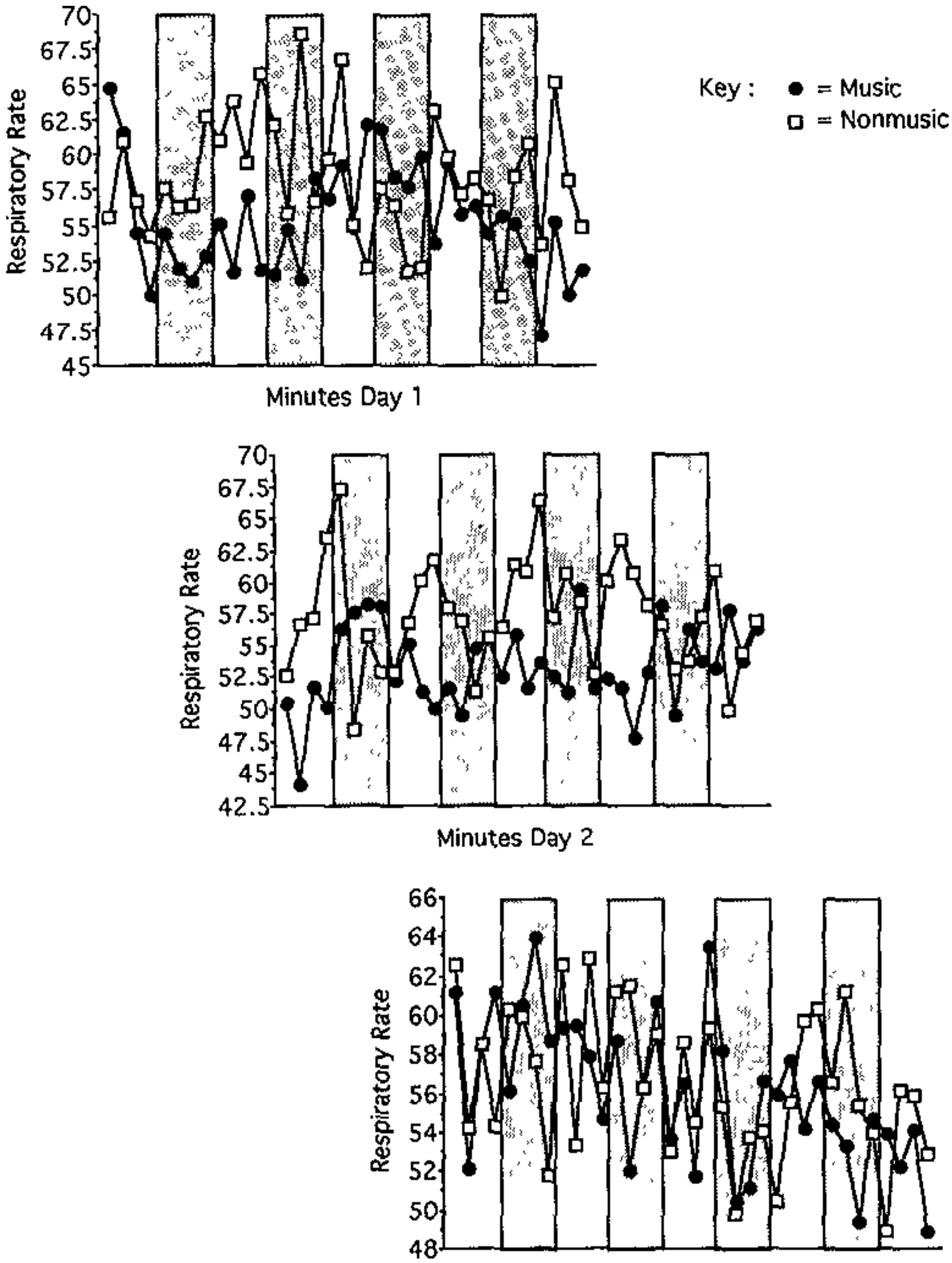

FIGURE 5.
Mean respiratory rates across minutes and days.

similar across days and between groups. There was little difference between groups in apnea/bradycardia levels with three music versus two nonmusic subjects who experienced more than two episodes of bradycardia in a given 24 hour time span.

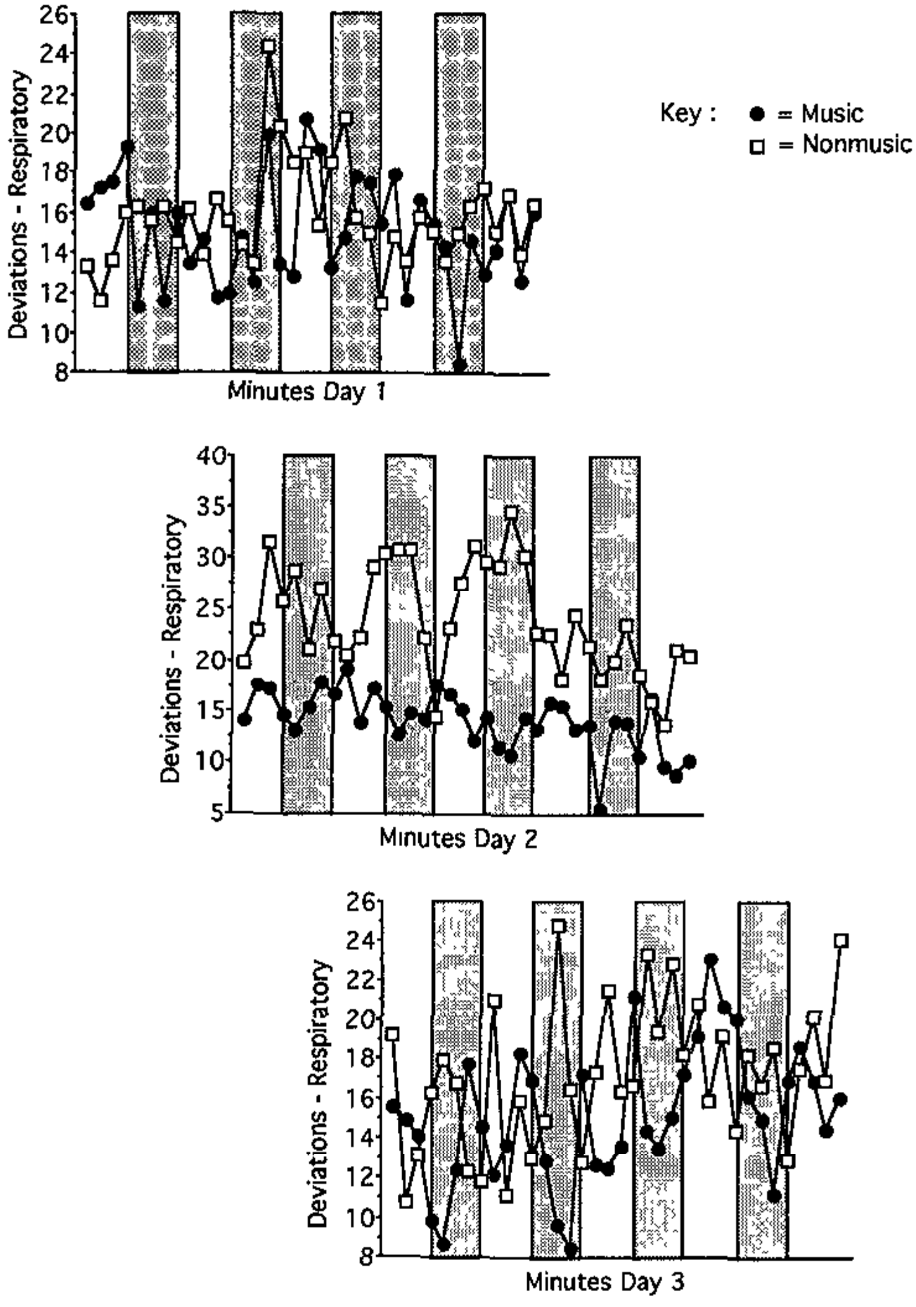

FIGURE 6.
Standard deviations of respiratory rates across minutes and days.

Instances of apnea were almost nonexistent since the majority of subjects were receiving machine assisted ventilation. Subjects who experienced apnea were those who were being weaned from machine assisted ventilation.

TABLE 1
Instances of Apnea/Bradycardia and Demographic Data

Sex	Gest Age (weeks)	Weight (grams)	Age on 1st Day of Data	A/B Pre Day 1	A/B Pre Day 2	A/B Pre Day 3	A/B Post Day 3
			Music Subjects				
F	29	1,100	3	0	0	0	0
M	27	720	3	0	0A/1B	0	0A/1B
M	27	875	3	1A/1B	0	2A/3B	0
F	28	885	5	0	0	0	0
M	28	1,242	2	0	0	0	0A/2B
M	28	1,175	2	0	0	0	0
M	27	950	2	0	0	0	3A/3B
M	27	880	3	0	0	0	0
F	24	545	4	0	0A/1B	0A/4B	0A/2B
F	27	1,015	2	0	0	0	0
Mean	27.2	938.4	2.9				
			Nonmusic Subjects				
F	24	555	4	0	0	0	0
F	28	925	5	0	0A/1B	6A/9B	5A/7B
M	29	1,325	3	0	0A/2B	4A/7B	0A/1B
M	27	998	2	0	0	0	0
M	26	900	3	0	0	0	0
M	28	810	3	0	0	0	0
F	30	1,200	3	0	0	0	0
F	26	645	3	0	0	0A/1B	0
F	26	910	2	0	0	0	0
M	26	925	2	0	0	0	0
Mean	27	919.3	3.0				

Discussion

Music immediately and positively affected oxygen saturation levels, heart rate and respiration rate on Day 1. Acclimation to the music stimuli resulted in more minimal effects on these physiological responses on Days 2 and 3. These findings are consistent with prior research in this area. This study demonstrated no negative effects on apnea/bradycardia. It also clarifies several issues for clinical application of music in the NICU.

The most important information for music therapists from these data may be that music listening is not contraindicated in the first week of life for even these very fragile premature babies. In fact, when there were consistent differences between groups, music subjects had more medically acceptable responses and were more stable. Inspection of standard deviations gives added clinical importance to these results. From a homeostasis perspective (referring to the ability of the physiological system to maintain internal stability) it is clinically important that there appears to be less variability among music subjects on the three dependent measures and the effect of music does not deteriorate across days as quickly or as much as is apparent from the means. Under peaceful sleeping conditions, neonates exhibit higher and more stable oxygen saturation levels, slower and more stable respiratory rates, and more stable heart rates (although the actual heart rate is dependent on numerous variables including gender and medication). To the extent that these trends are noticeable in these data, music appears to relax and comfort these usually irritable infants.

As in the Standley and Moore study (1993) it seems that music has its greatest effect on the first day of presentation. After the novelty has worn off, effects appear less noticeable as perhaps these infants are acclimating to their normally noisy environment by "turning off" sound perception. Since it appears that music is not contraindicated, it may be one tool to nurture bonding under conditions where new parents are unable to hold, feed, bathe, and in many cases touch their critically ill infants. In providing tapes of favorite music and a small tape recorder (with carefully controlled duration of stimuli, tempos, and dynamic levels), parents can experience some control over their child's environment. These infants also may respond positively long term to the calming influence of familiar music as did the infants in the Polverini-Rey study (1992) who, as fetuses with similar gestational ages to the infants in this study, listened to lullaby music.

Unlike the findings of Standley and Moore (1993), comparable infants in this study did not experience an increase of apnea and bradycardia following the cessation of music. This may be due to a larger sample of severely premature infants in the current study. Some infants, due to myriad medical problems, experience higher rates of apnea/bradycardia. However, there were two other major differences between the studies: the presentation schedule for music stimulation and the mode of presentation.

Perhaps in the previous study the 20-minute duration of the music listening experience was overstimulating for some of these sensitive infants. As a rule, all critically premature infants are placed on minimal stimulation during the early weeks of life, however, environmental auditory stimulation is much more difficult to control in an intensive care unit than other sensory stimuli. Therefore, one might expect that presentation of music would, at the very least, be no more stimulating than a normal environment and at best would be soothing, be predicable, and would mask other environmental sounds. In this study, reducing the total music listening time to 16 minutes and presenting it in 4-minute segments alternating with 4 minutes of silence did not appear to negatively affect instances of apnea and bradycardia. Perhaps a tape constructed such that each piece was faded in and out and rest time was provided between each selection would be the most appropriate stimulus. This issue of controlling music duration as well as tempo and dynamic changes to avoid overstimulating very low birth weight infants is certainly one that music therapists should consider carefully in clinical NICU applications.

In the present study, ear cups attached to audiological insert phones were used to present the music stimulus to infants. With this equipment we were insured that each infant was being presented the stimulus at the same carefully controlled decibel level and that the decibel level was comfortable for the infant. In previous studies music has been presented via phonopad earphones (Standley & Moore, 1983) and free field (Caine, 1992; Collins & Kuck, 1991; Lorch et al., 1994). While phonopad earphones and ear cups serve the same function, different considerations must be given to the stimuli presented via each piece of equipment.

Phonopad earphones are positioned over each ear in the fold of the infant's knitted cap. Using this mode of presentation the ear canal is blocked off thereby creating a very small resonating chamber. Results from research in audiology indicate that an average of 7–15 dB correction is necessary for more accurate approximations of real-ear measurements of newborns and infants due to differences in ear canal volume (Stelmachowicz, 1991). This means that an adult ear with a relatively large ear canal (i.e., resonating chamber) would hear an 80 dB sound as

80 dB, whereas a newborn would hear that same tone as anywhere from 87 to 95 dB, or 7 to 15 dB louder. Premature infants' ear canals are even smaller and therefore the difference is probably greater. The use of ear cups in the present study eliminated this problem by expanding the resonating chamber to include the ear canal and the ear cup itself. Using the ear cups, decibel levels could be set without regard to the size of ear canals.

Obviously, presentation mode needs to be carefully considered with this population and all modes have some inherent drawbacks. Audiological insert phones are exorbitantly expensive as are the ear cups which are sterile and need to be discarded after each infant has used them. Phonopad earphones are difficult to place in exactly the same position for all infants, and ear canal sizes vary by infant making calculations of appropriate dB levels very difficult. A tape recorder placed free field in a radiant warmer may not mask environmental noise as effectively as ear couplers or earphones.

Music in the NICU appears to be immediately beneficial on the physiological responses of very low birthweight infants, though acclimation to the auditory stimulus is evident. It is becoming clearer, through empirical data, that carefully controlled musical stimuli have no short term detrimental effects as measured by physiological responses. Further research is warranted to refine clinical techniques and procedures and to determine long term effects.

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