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The Effect of Decibel Level of Music Stimuli and Gender on Head Circumference and Physiological Responses of Premature Infants in the NICU

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The purpose of this study was to examine different protocols with regard to the presentation of music stimuli and compare gender differential reactions to those stimuli. Subjects for this study (N = 63) were premature infants in the Neonatal Intensive Care Unit (NICU) between the gestational ages of 28 and 33 weeks. Half of the experimental infants listened to 20 mins of lullaby music (female voice with orchestral background) on 2 days followed by 20 mins of classical music (Mozart string music) on 2 days. The other half listened to the same music in the reverse order. One quarter of the males and one quarter of the females listened to music presented at an average of 65 dB, one quarter at an average of 70 dB, one quarter at an average of 75 dB, and one quarter did not listen to any music and served as control subjects. Head circumference data were collected four times by the researcher: (a) upon receipt of parental consent, (b) on the first day of music presentation (1 week after consent), (c) on the last day of music presentation, and (d) 1 week after music presentation. Physiological data (heart rate, respiratory rate, oxygen saturation) were recorded by the researcher at 2-minute intervals starting 4 minutes prior to and ending 4 minutes after music presentation. There was a significant difference (p < .0001) in average daily head growth across time, but this seems unrelated to the music condition as the same curvilinear trend (larger gain during days of treatment, smaller gain during baseline before and after treatment) was noted for control infants who did not

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listen to music. Results indicate a significant (p = .002), but biologically unimportant, decrease in heart rate over the course of data collection. No differences due to gender were noted.

Music stimulation has been shown to have multiple benefits for infants in the Neonatal Intensive Care Unit (NICU) (Standley, 2002). Music therapy techniques have had a positive effect on oxygen saturation levels (Cassidy & Standley, 1995; Coleman, Pratt, Stoddard, Gerstmann, & Abel, 1997; Standley & Moore, 1995), rate of head growth (Standley, 1998a), weight gain (Standley, 1998c), nonnutritive sucking responses (Standley, 2000), and earlier successful bottle feeding result (Cevasco & Grant, 2005; Standley et al., 2005) among critically premature infants. Multimodal stimulation also resulted in earlier discharge dates (Caine, 1992; Standley, 1998b).

Appropriate protocol for music listening experiences to insure optimal results among premature infants has not been definitively established (Cassidy & Ditty, 1998) given a myriad of confounding variables. For example, gender appears to differentially affect the outcomes of music therapy. Treatment females were discharged from the hospital an average of 11 days earlier than control females, while this benefit was not found with comparable male infants (Standley, 1998b). Additionally, head growth was greater for treatment females than their control peers, with no noticeable pattern of difference among males (Standley, 1998a). This suggests differential treatment may be warranted based on gender. Given a consistent association with lower head circumference measurements of premature infants at corrected age as compared to term infants, and the link between head circumference and mental outcomes (including disability) (Peterson et al., 2000; Tan, Abernathy, & Cooke, 2008; Wood, Marlow, Costeoe, Gibson, & Wilkinson, 2000), it seems clear that any stimulation with positive benefits introduced early in life would be desirable.

Another possible factor impacting the responsiveness to auditory stimuli is the loudness of the sound. The hearing mechanism of full term males has been found to be less sensitive to auditory stimuli than that of full term females at higher frequencies (Cassidy & Ditty, 2001). However, gender differences on physiological and behavioral measures were not found among healthy newborns, regardless of gender, when comparing decibel level of music stimuli (Dureau, 2005). In reviews of research in fetal and perinatal auditory perception, Lecanuet, Granier-Deferre, and Busnel (1995) and Kisilevsky (1995) concluded that decibel level had an impact on heart rate of both fetuses and neonates. This supports evidence that the intensity of a sound has an impact on motor responses as well as heart rate of fetuses (Patrick, Campbell, Carmichael, Natalie, & Richardson, 1982).

Other variables should be considered as well when measuring the effects of music. Arnon et al. (2006) found that neither 30 minutes of live music nor recorded music had any effect when compared to no music on physiological responses and behavioral states of premature infants. However, 30 minutes after treatment, infants who were treated with live music had significantly lower heart rates and preferable behavioral states (deeper sleep). No differences were noted for recorded music and no music conditions. This is at odds with preferences of medical personnel. In a survey of doctors and nurses staffing a neonatal intensive care unit (NICU), the majority was supportive of music therapy and felt such practice would be beneficial for the infants. (Kemper et al., 2004). However, by a 2:1 margin, presenting recorded music was preferred over live music.

Positioning of the infant during music listening conditions can have an effect on responses of premature infants. Prone position (on stomach) results in improved breathing mechanics and oxygenation over supine position (on back) among premature infants (Bhat et al., 2003; Heimler, Langlois, Hodel, Nelin, & Sasidharan, 1992; Martin et al., 1995). In addition, there is evidence that infants demonstrate greater responses to music presented to the left ear as compared to the right ear shortly after birth (Turkewitz, 1988). Nutrition (amount and type) as it relates to weight gain and head circumference growth (Lucas et al., 1984) and sleep state as it relates to behavioral state and physiological responses (Fifer & Moon, 1995) are also important factors to consider when determining validity of responses attributed to music.

The preponderance of literature supports the positive effects of music therapy with premature infants, yet there is a lack of standard protocol for sound level of the musical stimulus especially in an incubator, and there is a distinct possibility that gender plays a role in its use in the NICU. Therefore, this study was designed to examine different protocols with regard to the presentation of music stimuli and compare gender differential reactions to those stimuli. Additionally, results of this study will add to the very recent and minimal data available observing head circumference change after the presentation of music stimuli.

Method

Subjects for this study ($N = 63$) were premature infants in the Neonatal Intensive Care Unit (NICU) between the gestational ages of 28 and 33 weeks. Parental consent was acquired during the infant's first week of life. Treatment was administered during the second and/or third week of life. Subjects met the following criteria: (a) deemed medically stable by hospital personnel, (b) in an incubator, (c) nonsedated and on room air at the time of music presentation, and (d) in an environment with no other music stimuli until the final head circumference data have been collected. An equal number of females ($n = 32$) and males ($n = 32$) participated in the study, however one female did not pass a hearing screening upon discharge and was dropped from the study.

One quarter of the males and one quarter of the females listened to music presented at an average of 65 dB, one quarter at an average of 70 dB, one quarter at an average of 75 dB, and one quarter served as control participants with no music. Of the infants who listened to music, half listened to 20 minutes of lullaby music on two days followed by 20 minutes of classical music on two days. The other half listened to the same music in the reverse order. These four days occurred within a four or five-day period. Type of music was changed half way through for auditory variety, but was not analyzed as an independent variable.

Lullaby music was from a Grammy nominated, commercially available CD, *A Child's Gift of Lullabies* (Brown, 2002), with a female voice recorded over orchestral instruments. Classical music was a variety of movements from professionally performed and digitally recorded movements from Mozart symphonies that were equivalent in tempo to the lullaby selections. Original selections were digitally edited to remove dynamic contrasts within and across the pieces. Music was faded in and out over a 5 second interval to decrease chances of startling the infant. Music was presented via two small speakers placed inside the incubator on the mattress above the head of the infant, equidistant from each ear. Infants were positioned in such a way that both ears are unobstructed. Speakers were connected to a CD player outside the incubator. Decibel level was measured at the speakers, which were placed approximately 30 centimeters from each ear.

Head circumference data were collected four times by the researcher: (a) upon receipt of parental consent, (b) on the first day of music presentation (1 week after consent), (c) on the last day of music presentation, and (d) one week after music presentation. Physiological data (heart rate, respiratory rate, oxygen saturation) were recorded by the researcher at 2-minute intervals starting 4 minutes prior to and ending 4 minutes after music presentation. Other descriptive information such as gender, gestational age, birth date, and birth weight were recorded from each infant's chart.

Results

In order to observe the effect of music listening conditions on head circumference growth, difference scores were calculated between the first and second reading (prior to treatment), the second and third reading (during treatment), and the third and fourth reading (posttreatment). Those difference scores were divided by the number of intervening days, to result in an average daily head growth for each time interval. A Three-Way ANOVA with Repeated Measures was used to analyze for main effects and interactions of gender, treatment (four levels of loudness), and time (average daily head growth during three time intervals). There was a significant difference due to the main effect of time, $F(2, 110) = 12.45$, $p < .0001$. Overall, average daily head growth was the least during the week prior to treatment ($M = .123$, $SD = .05$) as compared to the 3 or 4 days during treatment ($M = .19$, $SD = .09$) and the week after treatment ($M = .16$, $SD = .05$) (see Figure 1). There were no significant differences ($p > .05$) due to gender or treatment, nor were there any significant interactions ($p > .05$).

The impact of music listening conditions on physiological responses was measured in three ways; oxygen saturation levels, heart rate, and respiratory rate. Data on respiratory rates were inconsistent and, at best, did not reflect true information. The probes attached to the skin of the infants measured chest wall

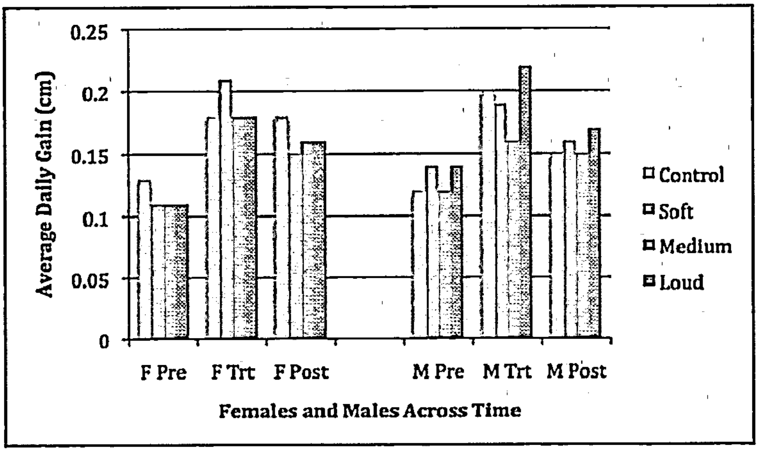

FIGURE 1.
Head circumference.

compressions, an indication of respiratory rate. However, if an infant moved the muscles as in stretching or reorganizing the arms, the probe would pick up extra compressions, which were recorded by the monitor as extra breaths per minute. It is the opinion of the author (the primary data collector) that, while the monitors adequately measure respirations in a general manner for nurses to assess instances of apnea, the precision of the measurement is lacking for research purposes. Therefore, respiratory rates were not analyzed in this report.

Heart rate and oxygen saturation data were collected every two minutes across the 28-minute session from the monitors at the infants' bedside. Data from the four days of treatment were collapsed to provide one average data point per subject for each observation interval resulting in a total of 14 data points per subject for each dependent measure. For statistical purposes, the first two data points for each dependent measure were averaged to provide mean response under pre-treatment baseline conditions; data points 11 and 12 (last 2 data points under listening conditions) for each dependent measure were averaged to provide mean response after the full effect of treatment condition; and the last two data points for each dependent measure were averaged to provide mean response under posttreatment baseline conditions.

A three-way ANOVA with repeated measures was used to analyze heart rate data for main effects and interactions of gender, treatment (four levels of loudness), and time (pretreatment baseline, during treatment, and post-treatment baseline). Results indicate a significant difference due to time, $F(2, 110) = 6.47$, $p = .002$. Mean heart rate steadily decreased across time, irrespective of treatment condition (pretreatment M = 160.69 bpm, SD = 9.64; during treatment M = 159.44 bpm, SD = 9.63; posttreatment M = 158.33, SD = 9.90). There were no other significant main effects or interactions ($p > .05$).

A three-way ANOVA with repeated measures was used to analyze oxygen saturation for main effects and interactions of gender, treatment (four levels of loudness), and time (pretreatment baseline, during treatment, and posttreatment baseline). There were no significant main effects or interactions ($p > .05$).

Discussion

Results from this study do not support the suggestion of music having a greater effect on female infants than male infants (Standley, 1998a). While it is perhaps not surprising that music listening conditions had no differential effect on head circumference growth among the subjects of this study given the short duration of treatment, the curvilinear pattern of development is unusual. Standard biological expectations are that head growth and body weight both have a generally linear progression across weeks as infants age (Riddle et al., 2006). The expectation is that head growth will change approximately one centimeter per week (Riddle et al., 2006). As is evident in Figure 1, the progression across time is curvilinear rather than linear, and has no relationship to musical condition or gender. Infants in all groups had greater head growth during the time of treatment than during baseline conditions before and after. Similar events specific to this study for all infants regardless of treatment condition included placement of speakers in the incubator (even in the nonmusic conditions), positioning the infants on their backs for the 28 minutes of the study, and occasional gathering of head circumference data. Nurses often keep the infants on their stomachs during large parts of the day because they sleep more and breathe easier in that position (personal communication, Melanie Perkins, RN), however supine positioning is an everyday occurrence for these infants. While it is possible that supine positioning provided opportunity for greater than normal stimulation (visual, motor movement) and longer period of time in alert state, and that this extra stimulation may be related to head growth, it seems an unlikely explanation.

Another plausible explanation is related to nutrition and body weight in general. Across the three time intervals, many infants experienced a change in type, quantity, and method of presentation of their diet. Prior to treatment (between the first and second head measurement) a number of infants were receiving nourishment intravenously. This fluid is lower in calorie content than formula, and takes no energy on the part of the infant to "eat" as it is being introduced through the veins. Most infants were on formula or breast milk supplemented with formula during treatment, yet most were being fed by gavage (a tube inserted through the mouth or nose that runs directly to the stomach). In this case, they were receiving a calorie-rich diet, yet expended no energy in the process; in fact infants often sleep during the gavage process. By the post-treatment baseline, many of the infants were nippling regularly, if not exclusively, for all feedings. The coordination of "suck, swallow, breathe" necessary to succeed in drinking from a bottle expends more energy than gavage. It is possible that the introduction of high calorie formula in a low-energy manner during treatment caused a larger than normal weight gain and head growth. Once nippling started, the infants were using more energy and perhaps weight gain and head growth slowed down. Evidence that nutrition has an effect on head circumference growth has been established (Lucas et al., 1984), so it remains of interest in the interpretation of these results, although expected weight gain and head circumference growth is much more linear than the data reported in this paper (Riddle et al., 2006).

Results seem to add to those of the Dureau study (2005), which concluded that, regardless of gender, no differences were found when comparing decibel level of music stimuli. Informal observations of infants in the three music listening conditions indicate that infants acknowledged the presence of music, often opening their eyes or pausing from arm/leg movement when the music started. Nearly all infants fell asleep by the end of the treatment. Behavioral observations might render a differential effect on the loudness of the stimulus and length of time to fall asleep. However, it is clear that soothing music played at relatively soft decibel levels for twenty minutes is not an inhibitor to relaxation and sleep for these infants.

Data gathered for this report do not support previous research indicating a positive effect of music on oxygen saturation levels of premature infants (Cassidy & Standley, 1995; Coleman et al., 1997; Standley & Moore, 1995). It could be that the infants in this study were older and more stable than those in previous studies. Post hoc reflection on the data revealed an equivalent number of younger infants (28–30 weeks gestational age) and older infants (30–33 weeks gestational age) in all treatment groups. However, there were more older males (n = 23) and less younger males (n = 9) than females (older n = 18; younger n = 13). Infants in this study were generally older and healthier than in previous studies (Cassidy & Standley, 1997; Standley & Moore, 1995), which may have had lead to a lack of replication of findings. Perhaps with infants who are not receiving respiratory help in the form of supplemental oxygen, this is not the best dependent measure to identify the calming effect music may have on these fragile infants. Given the lack of cause and effect apparent with heart rate as well, future research may include behavioral analysis and/or hormonal analysis (cortisol or adrenaline) as indicators of relaxation or stress that may be caused by music stimulation. However, with regard to heart rate, measuring changes within seconds of the onset of stimulation might detect measurable responses more effectively than measuring changes over minutes, as was the protocol in this study (Kisilevsky, 1995). Alternative ways of measuring respiratory rate that result in accurate and reliable data should be explored.

Given that these data do not support research in music therapy with premature infants, replication is considered vital. The positive effects of music on physiological responses of premature infants have been documented in numerous publications. Data from this study support the contention that lullaby or orchestral music played at responsible decibel levels does not create unwarranted stress in the infants' auditory environment.

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