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Music Modulates Behaviour of Premature Infants Following Heel Lance

Michelle L. Butt and Barbara S. Kisilevsky

Les effets physiologiques et comportementaux de la musique pendant le rétablissement suivant un prélèvement par microméthode ont été étudiés chez 14 enfants prématurés, nés 29 à 36 semaines après conception. Des tests ont été effectués dans le cadre de deux situations contrôles : avec musique et sans musique. Chaque situation a été enregistrée sur vidéocassette : avant l'intervention, pendant l'intervention et en période de rétablissement. Pour l'analyse de données, les enfants ont été divisés en deux catégories d'âges : moins de 31 semaines et plus de 31 semaines après conception. Des modèles mixtes d'analyse de variances ont démontré que le prélèvement par microméthode provoquait une réaction de stress (c.-à-d. une augmentation du rythme cardiaque, une diminution de la saturation en oxygène, une augmentation de l'état d'éveil et une augmentation des mouvements faciaux indiquant un état de douleur) chez les deux groupes d'âge. La réaction de stress était plus forte chez les enfants plus âgés. Au cours de la période de rétablissement, le groupe plus âgé a démontré un rythme de rétablissement plus rapide quant au rythme cardiaque, à l'état comportemental et aux expressions faciales de douleur lorsqu'il y a une utilisation de la musique. La conclusion est que la musique constitue un outil d'invervention efficace pour l'unité néonatale des soins intensifs, à la suite d'un stimulus générateur de stress chez les enfants âgés de plus de 31 semaines après conception.

The physiological and behavioural effects of music during recovery from heel lance were examined in 14 preterm infants at 29 to 36 weeks post-conceptual age (PCA). Infants were tested on 2 occasions: during a music condition and during a no-music control condition. Each condition was videotaped during 3 periods: baseline, heel lance, and recovery. Infants were divided into 2 age groups for data analyses: less than and greater than 31 weeks PCA. Mixed model ANOVAs showed that heel lance elicited a stress response (i.e., increased heart rate, decreased oxygen saturation, increased state-of-arousal, and increased facial actions indicative of pain) in both age groups. The stress response was greater in the older group. During recovery, the older group had a more rapid return of heart rate, behavioural state, and facial expressions of pain to baseline levels in the presence of compared to the absence of music. It was concluded that music is an effective NICU intervention following a stress-provoking stimulus in infants older than 31 weeks PCA.

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Advances in medical technology have made survival possible for premature infants of low gestational age and very low birth weight. However, follow-up studies indicate that developmental outcome is often problematic, with 40 to 50% of these infants having major or minor cognitive and/or motor deficits by 5 to 8 years of age (Hack et al., 1993; McCormick, Brooks-Gunn, Workman-Daniels, Turner, & Peckham, 1992; Saigal, Feeny, et al. 1994; Saigal, Rosenbaum, et al., 1994; Saigal, Rosenbaum, Szatmari, & Campbell, 1991). In an attempt to attain more optimal long-term outcomes, the concept of developmentally sensitive care (Als, 1992; Als et al., 1986, 1994) has been introduced into neonatal intensive care units (NICUs). It has resulted in a shift in the focus of care from survival to optimal development, with researchers examining modifications of the environment (e.g., light, sound) and necessary caretaking procedures (e.g., bathing, heel lance) to reduce the stimulation/stress that infants experience in the NICU during their first few weeks or months of life (e.g., Becker, Grunwald, Moorman, & Stuhr, 1991, 1993; Stevens, Petryshen, Hawkins, Smith, & Taylor, 1996; also see review by Oehler, 1993). Towards this end, we examined the effect of a music intervention in reducing the stress associated with a heel lance in premature infants from 29 to 36 weeks post-conceptual age (PCA).

Health professionals in modern NICUs provide highly technological and intensive caregiving to premature infants. Although the care is designed to sustain life and promote growth, researchers (Field, 1990; Peters, 1992, 1998) report a stress response to medical and nursing procedures (Craig, Whitfield, Grunau, Linton, & Hadjistavropoulos, 1993; Fearon, Kisilevsky, Hains, Muir, & Tranmer, 1997; Fitzgerald & Anand, 1993; Grunau & Craig, 1987; Gunnar, Malone, Vance, & Fisch, 1985; Johnston, Stevens, Craig, & Grunau, 1993) and suggest that sophisticated care and the NICU environment are stressful to the preterm infant. Indeed, Peters (1992, 1998) has demonstrated that most NICU environmental stimuli and nursing procedures can result, to a greater or lesser extent, in a stress response.

The concept of stress is defined by Selye (1976) as a biologic response of the body to any demand. Stress can result in the infant exhibiting generalized stereotypic behaviour (i.e., a stress response), including increased heart rate and decreased oxygen saturation. As well, a stress response may include increased intracranial pressure (Field, 1990; Long, Lucey, & Philip, 1980; Peters, 1992), increased facial muscular actions indicative of pain (Craig et al., 1993; Grunau & Craig, 1987; Johnston et al., 1993), increased plasma cortisol levels (Gunnar et al., 1985), and disturbed sleep/wake patterns (Fitzgerald & Anand, 1993). Many studies with newborn or premature infants have focused on issues related to pain (e.g., Johnston, Sherrard, et al., 1999; Johnston & Stevens, 1996; Porter, Wolf, & Miller, 1998, 1999) or interventions to reduce pain (e.g., Johnston, Stremler, Horton, & Friedman, 1999; Stevens et al., 1999). However, pain constitutes only one component of stress. Although both pain and stress have been shown to induce similar physiologic and behavioural responses (e.g., see review by Porter, Grunau, & Anand, 1999), the present study focuses on the more global concept of stress, using multiple response measures including heart rate, oxygen saturation, and behavioural state as well as facial expressions of pain.

Infants in an NICU commonly undergo caretaking routines such as weighing, diapering, and bathing as well as invasive procedures such as subcutaneous or intramuscular injection, intravenous catheter insertion, or heel lance for blood sampling. Werner and Conway (1990) found that infants underwent an average of 58.6 contacts in less than 20 hours. In a study of nursing caretaking routines, Peters (1992) found that infants received 120 to 245 contacts per 24 hours. With regard to invasive procedures, Barker and Rutter (1995) found that 54 infants underwent more than 3,000 invasive procedures between admission and discharge; heel lance for blood sampling was the most common procedure (56%).

Both caretaking and invasive procedures elicit a stress response; infants display crying, increased heart rate, increased body movement, and specific facial indications of pain (Craig et al., 1993; Fitzgerald & Anand, 1993; Johnston et al., 1993). These physiological and behavioural responses result in increased demands on the cardiovascular and muscular systems of the premature infant, which may, in turn, result in an increased amount of energy expenditure necessary to cope with the procedures and a decreased amount of energy available for growth and development. In addition, repeated episodes of increased cortisol levels from a stress response may weaken the infant's immunological status and increase susceptibility to infection (Gunnar, 1989). Many of the stressors to which the premature infant is exposed, such as heel lance for blood sampling, cannot be eliminated. The challenge for the clinical researcher is to identify methods (i.e., interventions) of modulating stress during necessary procedures, thus reducing the potentially negative influence on growth and development. A number of interventions to reduce infant stress have been studied, from sophisticated programs that manipulate multiple factors in the environment and infant caretaking such as developmentally sensitive care (Als, 1992), to simple procedures such as the administration of oral sucrose (e.g., Barr et al., 1994), swaddling (e.g., Fearon et al., 1997), and music (e.g., Standley, 1998; Standley & Moore, 1995). We have chosen to examine music because it is the least invasive intervention and, theoretically, can be used with all infants.

As noted, interventions may be global or specific. Global interventions do not target a specific stressor but rather target the general environment or infant state-of-arousal — for example, developmentally sensitive care (Als, 1992; Als et al., 1994) or skin-to-skin contact (Anderson, 1991; Ludington, 1990; Ludington-Hoe & Swinth, 1996; Ludington-Hoe, Thompson, Swinth, Hadeed, & Anderson, 1994). Music, which has the potential for use with all premature infants, has been used most often as a global intervention to mask aversive environmental stimuli in the NICU (e.g., Standley, 1998; Standley & Moore, 1995) or to soothe infants by modulating behavioural state (Burke, Walsh, Oehler, & Gingras, 1995; Caine, 1991; Collins & Kuck, 1991; Kaminski & Hall, 1996). Generally, exposing infants to music results in increased oxygen saturation (Standley & Moore), decreased agitation and time spent in high-arousal states (Collins & Kuck; Kaminski & Hall), and increased average weight gain (Caine). For example, Caine observed 52 preterm and low-birth-weight newborns in the NICU. Infants in an experimental group received 90 minutes of music stimulation (vocal music, including lullabies and children's music) alternating 30 minutes on with 30 minutes off over a 3-hour period daily from the 4th day after birth until discharge. Infants in the control group received non-contingent auditory stimulation occurring in the NICU environment. In comparison with the control group, the music group had significantly reduced initial weight loss, increased average daily weight, increased formula and caloric intake, and reduced length of NICU stay and total hospital stay. Similarly, Standley and Moore played lullabies through earphones to a total of 20 low-birth-weight infants for 20 minutes on 3 consecutive days. Infants exposed to the music had higher oxygen saturation levels on day 1 but not on days 2 or 3. On days 2 and 3 the infants had depressed oxygen saturation levels when the music was terminated. Subsequently, Standley paired music with a multimodal stimulation provided for 15 to 30 minutes once or twice per week in a group of NICU infants (20 experimental, 20 control) referred for developmental stimulation. Music paired with multimodal stimulation decreased days to discharge for females and increased weight gain/day for both genders. Taken together, these results indicate that music in the environment facilitates growth and development. The mechanism(s) by which music improves outcomes has yet to be identified.

Specific interventions target a particular stressor and focus on modulating the stress response (e.g., heel lance for blood sampling: Fearon et al., 1997 — swaddling; Johnston, Stremler, et al., 1999 — sucrose; Stevens et al., 1999 — EMLA). Only one study (Burke et al., 1995) examining the effectiveness of music following a specific stress-provoking stimulus (i.e., suctioning) was found. Over a 3-month period, Burke et al. studied four preterm infants who required continuous oxygen for respiratory distress. Following endotracheal suctioning, each infant received a total of 18 trials of either: (a) music played for 15 minutes through a Somatron mattress (vibroacoustic condition), (b) music played though a tape player placed at the foot of the crib (acoustic condition), or (c) normal NICU environment (control condition). In comparison to control trials, all four infants experienced a reduction in level of arousal during both experimental music conditions. Also, during the acoustic trials, infants spent more time sleeping compared to the vibroacoustic and control trials. During vibroacoustic trials, three of the four infants spent an increased amount of time in a quiet alert state and had improved oxygen saturation levels. Because the study included only four subjects, the results are more suggestive than conclusive and the present study was designed to further examine the effects of music following a stressor.

Heel lance was chosen as the stressor because this procedure is carried out frequently. A lullaby was chosen as the music because lullabies have been shown to soothe newborn infants (Kaminski & Hall, 1996). Also, because female vocal and instrumental music had been used effectively in other studies, both types of music were included, to determine differential responding.

The following questions were addressed: (1) Does music modulate the physiological and/or behavioural responses of preterm infants when it is played immediately following a stress-provoking event? (2) Are there differences in physiological and/or behavioural responses to music as a function of the type of music played — female vocal compared to instrumental music? (3) Are there differences in physiological and/or behavioural responses to music as a function of PCA? Because the use of music as a global intervention has been shown to decrease the level of agitation and time spent in high-arousal states, we hypothesized that music would have a soothing effect following heel lance — decreasing heart rate, increasing oxygen saturation, facilitating decreased levels of arousal, and reducing facial indications of pain.

Table 1 *Delivery Outcome and Health Status Data of Participants*

Infant	Sex	GA at Birth	Birth Weight	PCA (testing 1)	Weight (testing 1)	Apgar (1 min/ 5 min)	Respiratory Status (testing 1)	Single/Multiple Pregnancy
01	F	31:4	1338g	33:2	1394g	7/9	Room air	Singleton
04	M	32:5	2280g	33:0	—	9/9	Ventilator	Singleton
05	M	29:5	1782g	30:1	1581g	8/9	Ventilator	Singleton
06	M	28:4	1242g	29:5	1117g	7/8	Room air	Singleton
07	F	31:5	1718g	35:2	2160g	5/8	Room air	Singleton
08	M	28:6	590g	30:5	578g	2/7	Ventilator	Singleton
10	F	34:0	1800g	34:2	1754g	6/9	Room air	Singleton
11	F	28:3	1188g	29:6	1143g	5/9	Room air	Twin B
12	M	28:3	1500g	29:6	—	3/1/4	Ventilator	Twin A
13	M	32:0	1459g	32:3	1360g	7/8	Room air	Singleton
18	F	35:6	1589g	36:2	1525g	6/9	Room air	Twin B
20	F	33:1	1741g	33:5	1626g	6/7	Room air	Singleton
24	M	33:6	2195g	34:2	2160g	8/8	Room air	Singleton
28	M	29:5	1219g	30:5	1152g	9/9	CPAP	Singleton

Method

Participants

Sixteen preterm infants were recruited from the NICU of a community teaching hospital in southern Ontario for testing on two occasions. The data for two infants were excluded from analyses because the infants and monitors were obscured and the tapes could not be scored. Table 1 shows the demographic data and health status for the 14 infants included in the analyses. Inclusion criteria were: (1) PCA 29 to 36 weeks, (2) resident in NICU for at least 24 hours, (3) no major congenital anomalies, (4) no history of grade IV intraventricular hemorrhage, (5) no evidence of acute sepsis, (6) not currently receiving paralytic medications or paralytic medications discontinued for at least 24 hours, (7) scheduled to have blood work, and, (8) identified by the staff neonatologist as medically stable. Sample size for this exploratory study was determined from previous perceptual studies in our laboratory (e.g., Easterbrook, Kisilevsky, Hains, & Muir, 1999; Fearon et al., 1997), which clearly demonstrate that data from six infants are sufficient for studies that use experimental and control conditions. The study was conducted with the approval of the University and Affiliated Teaching Hospitals Research Ethics Board. A parent of each infant provided informed written consent prior to participation.

Nursery Environment

The study was conducted in an NICU environment that encompassed Level I to Level III neonatal care. The environment was highly technological, with cardiac monitors at each infant's bedside, environmentally controlled incubators serving as cribs, and computerized pumps for intravenous fluid infusions. Each infant was monitored 24 hours a day by a registered nurse at the bedside. Nursing and medical interventions, including invasive interventions such as heel lance for blood sampling, occurred throughout the 24-hour period.

Although neither consistent nor universal, some aspects of developmentally sensitive care such as covering of incubators to reduce light, nesting of the infant, and lowering of noise levels through limiting loud conversation at the bedside were being implemented by some nursing staff. Noise levels in the NICU varied throughout the day and with activity level. NICU ambient noise levels were measured (average of 3 readings each time) at intervals of 2 to 3 weeks at various times of day during the data-collection period. The average sound level in the NICU ranged from 72 dB during the day to 67 dB during the night or early morning hours. Music was occasionally but not consistently played by staff nurses and some infants had cassette recorders placed in their isolettes. No infant was noted to have music playing in his/her isolette or cot immediately prior to testing.

Stimuli / Equipment / Instruments

The music stimuli included two 10-minute recordings of Brahms' Lullaby (Op. 49, No. 4; key D flat major) generated for this study — an a cappella version sung by a professional vocalist and a piano version played by a professional pianist. The two lullabies were recorded using the same score and the tempo was kept consistent. The music was played on a Sony cassette player (Model WM-FS400) with a Dolby B Noise Reduction System at an average of 76 dB sound pressure level (SPL). All SPLs were measured using the A-Scale of a Bruel and Kjaer Sound Pressure Level Meter (Type 2235). Music stimuli were delivered through two speakers (Sony Active Speaker System – Model SRS-PC21).

Two closed-circuit video systems (one Quasar and one Hitachi) mounted on a dual-mount tripod were used to videotape the infant and the bedside monitors during testing. A stopwatch was used for timing music/no-music periods.

Brazelton's categories of state-of-arousal (Brazelton, 1973) were modified to determine behavioural state. Brazelton's state 1 — quiet sleep — and state 2 — active sleep — were combined to give one state score — sleep. The two sleep states were combined because regular and irregular respiratory patterns were often difficult to differentiate and could not be identified for infants on ventilators. The modification resulted in a scale of 1 to 5, with increasing numbers representing higher states of arousal (e.g., 1 = sleep, 5 = crying).

The Neonatal Facial Coding System (NFCS; Grunau & Craig, 1987) was used to code facial expressions to determine a pain response. The NFCS has good reliability (Craig et al., 1993) and has been shown to be a valid measure of infant pain following invasive medical procedures in both full-term and preterm infants (Craig et al.; Grunau & Craig; Johnston et al., 1993).

Procedure

The study design is displayed in Figure 1. All infants were tested under two conditions — music and no-music control — on two separate occasions — time 1 (T1) and time 2 (T2). Type of music and stimulus/control condition were randomly assigned within each pair of adjacent infants. At each time, infants were videotaped for 10 minutes prior to heel lance, during the heel lance procedure, which lasted from 4 to 13 minutes, and for 10 minutes after the heel lance (with or without music). Type of music — vocal or instrumental — was also counterbalanced over the infants.

Figure 1 *Study Design*

Randomly Assigned for the First of Each Pair

Time 1 ↓ ↓ Time 2

Intervention[a]				Control	
Vocal Music ($n = 7$)		Instrumental Music ($n = 7$)		No Music ($n = 14$)[b]	
PCA <31 weeks	PCA >31 weeks	PCA <31 weeks	PCA >31 weeks	PCA <31 weeks	PCA >31 weeks
Observe (10 min) → Heel Lance (4–13 min) → Music (vocal or instrumental) (10 min)				Observe (10 min) → Heel Lance (4–13 min) → Observe (10 min)	

[a] Vocal or instrumental music were randomly assigned within each pair.
[b] Each of the 14 participants was videotaped in an intervention and a control condition.

Participants were videotaped in their isolette and the timing of the study coincided with regularly scheduled blood work. One camera recorded the infant to obtain body movements and facial expressions while a second camera, synchronized with the first, recorded the bedside monitor to obtain heart rate, respiratory rate, and oxygen saturation. The cassette recorder and the speakers were positioned in the same manner for music and control conditions: the recorder outside the isolette; the speakers inside the isolette just below the infant's feet, approximately 40 cm from the ears.

Behavioural state-of-arousal was scored at 1-second intervals according to the following scale: 1 = Sleep, 2 = Drowsy, 3 = Quiet Awake, 4 = Active Awake, and 5 = Crying. Subsequently, the predominant state-of-arousal in each successive 15-second interval was determined. Using the NFCS, the presence or absence of each facial action indicative of pain was scored for each 15-second interval. A facial-expression-of-pain score was calculated by summing the number of facial actions in each interval, with scores ranging from 0 to 9 (Grunau, Johnston, & Craig, 1990). In this study, a score of 2 typically represented an open, stretched mouth, suggesting minimal pain, and a score of 6 typically represented an open, horizontally stretched mouth, tightly squeezed eyes, bulging brow, deepened naso-labial furrow, and a taut tongue, indicative of a high level of pain.

Heart rate and oxygen saturation were recorded from the bedside monitor at 5-second intervals. A 5-second interval was used because it was the smallest time interval that closely reflected the continuous and constantly changing recording displayed on the monitor.

To assess inter-rater reliability, six of the 28 videotaped sessions (21.4%) were randomly selected and independently coded for state-of-arousal and facial expressions of pain by a second trained observer. Percentage of agreement between the experimenter and the observer for state-of-arousal was 78%. Pearson's correlation coefficient for facial expressions of pain was $r = .77, p < .01$.

Data Reduction

One-minute means for each of the dependent measures (heart rate, oxygen saturation, behavioural state-of-arousal, and facial expressions of pain) were calculated separately by summing 12 5-second readings for heart rate and oxygen saturation and summing four 15-second readings for behavioural state-of-arousal and facial expressions of pain. Next, a mean for the first 5 minutes of the baseline period was calculated for each of heart rate, oxygen saturation, behavioural state, and facial pain measures, to serve as a baseline. This mean was subtracted from each of the subsequent 1-minute scores for the baseline period (a total of 5 minutes), the heel lance period (1 minute prior to heel lance, the minute the heel lance occurred, and 2 minutes immediately following heel lance), and the recovery period (10 minutes). These 19 1-minute difference scores were used in all further data analyses. Since the length of the heel lance period varied with the infant, only that period of time in which data were available for all infants (a total of 4 minutes) was used, to allow for the inclusion of all infants in the analyses. The analyses of each of the dependent measures are presented by period — baseline period (5 minutes), heel lance period (4 minutes), and recovery period (10 minutes).

Results

Initially a 3-way ANOVA with one between-factor (Music Type — Vocal, Instrumental) and two within-factors (Condition — Music, Control; Time — 1–10 minutes) was used to determine whether the type of music elicited a differential response in any of the dependent measures (heart rate, oxygen saturation, behavioural state, or facial expression of pain) during the recovery period. No significant main effects or interactions of Music Type were found in any of the dependent measures except behavioural state. Thus Music Type was eliminated from further analyses of heart rate, oxygen saturation, and facial expression of pain, but was included in behavioural state analyses.

For data analyses, infants were divided into two age groups, according to PCA at the time of initial testing. Infants in the younger age group ($n = 6$) ranged in PCA from 29 weeks, 5 days, to 30 weeks, 5 days ($M = 30.2$ weeks, $SD = 0.4$ weeks). The infants in the older age group ($n = 8$) ranged in PCA from 32 weeks, 3 days, to 36 weeks, 2 days ($M = 34.0$ weeks, $SD = 1.3$ weeks). The chronological ages of the two groups at time of first testing were 3 to 13 days ($M = 8.5$ days, $SD = 3.4$ days) and 2 to 25 days ($M = 6.8$ days, $SD = 8.1$ days), respectively.

Overall Analyses

The data for each of the dependent measures were analyzed using ANOVA, with one between factor (Age — younger group < 31 weeks PCA; older group > 31 weeks PCA) and two within factors (Condition — Music, No-Music; Time — 1–19 min.).

The *heart rate* changes over periods are displayed in Figure 2. The overall ANOVA revealed a significant effect of Time, $F\ (18, 216) = 13.850, p < .01$, as well as Condition by Age, $F\ (1, 12) = 8.277, p < .05$, and Time by Age, $F\ (18, 216) = 4.831, p < .01$, interactions.

For *oxygen saturation* only a significant main effect of Time, $F\ (1, 18) = 17.844, p < .01$, was found. For all groups, there was a decrease in oxygen saturation during the heel lance period, which returned to baseline level in the recovery period.

Changes in *behavioural state scores* are shown in Figure 3. An overall analysis of using a 4-way ANOVA with two between (Age — two levels; Music Type — Vocal, Instrumental) and two within factors (Condition — Music, No-Music; Time — 1–19 min.) revealed a main effect of Time, $F\ (1, 18) = 9.925, p < .01$, and Age by Time, $F\ (1,18) = 5.351, p < .01$, Music Type by Time, $F\ (1, 18) = 2.092, p < .05$, and Age by Music Type by Time, $F\ (1, 18) = 1.671, p < .05$, interactions.

The data for *facial expression of pain* scores are displayed in Figure 4. The overall ANOVA revealed a significant main effect of Age, F (1, 11) = 6.420, $p < .05$, and Time, F (1, 18) = 21.221, $p < .01$, which was qualified by an Age by Time, F (1, 18) = 8.528, $p < .01$, interaction.

Analysis of Each Variable Over Periods

Because Time was significant in all of these analyses, the data for the baseline, heel lance, and post-heel lance periods were examined separately using a 2 between (Age, Condition), 1 within (Time) ANOVA. Post-hoc analyses to explain interactions within periods are included as necessary.

Baseline period. The differences found in the baseline period were confined to *heart rate,* where the older infants were found to have more variability shown by the Condition by Time by Age interaction, F (4, 48) = 3.146, $p < .05$, and *facial expression of pain,* where there was a significant main effect of Time, F (4, 44) = 3.699, $p < .05$. Figure 4 shows that there was increased variability in the pain scores in the older age group.

Heel lance period. Infants showed responses to the heel lance in all measures. For *heart rate,* as seen in Figure 2, the older infants showed a greater increase than the younger infants F (1, 12) = 49.169, $p < .01$. There was also a main effect of Time, F (3, 36) = 7.901, $p <.01$, indicating that heart rate increased following heel lance. *Oxygen saturation* decreased during the heel lance period, F (3, 36) = 14.455, $p < .01$, for both age groups. *Behavioural state* changes are shown in Figure 3. For the vocal music, the older infants responded to the heel lance with more arousal than the younger infants (Age by Time interaction, F (3,15) = 34.449, $p < .01$). Significant main effects of Age, F (1, 5) = 329.551, $p < .01$, and Time, F (3,15) = 87.699, $p < .01$, were also present. For the instrumental music, there was a significant main effect of Time, F (3,15) = 14.845, $p < .01$, but no age effect. During heel lance, *facial expression of pain* scores increased for both age groups, with the older infants exhibiting more expressions of pain than the younger infants, F (3, 33) = 13.424, $p < .01$. Main effects of Time, F (3, 33) = 29.911, $p < .01$, and Age, F (1, 11) = 22.431, $p < .01$, were also present.

Recovery period. For *heart rate,* significant Condition by Age, F (1, 12) = 9.545, $p < .05$, and Time by Age, F (9,108) = 2.163, $p < .05$, interactions were found. To sort out the interactions, the data for the first and the second 5 minutes of the intervention period were examined separately. In the first 5 minutes, immediately following heel lance, an interaction, Condition by Age, F (1, 12) = 9.835, $p < .05$, was present. In the second 5 minutes a significant main effect of Condition, F (1,12) = 5.747,

Figure 2 *Mean Heart Rate Differences as a Function of Music/No-Music*

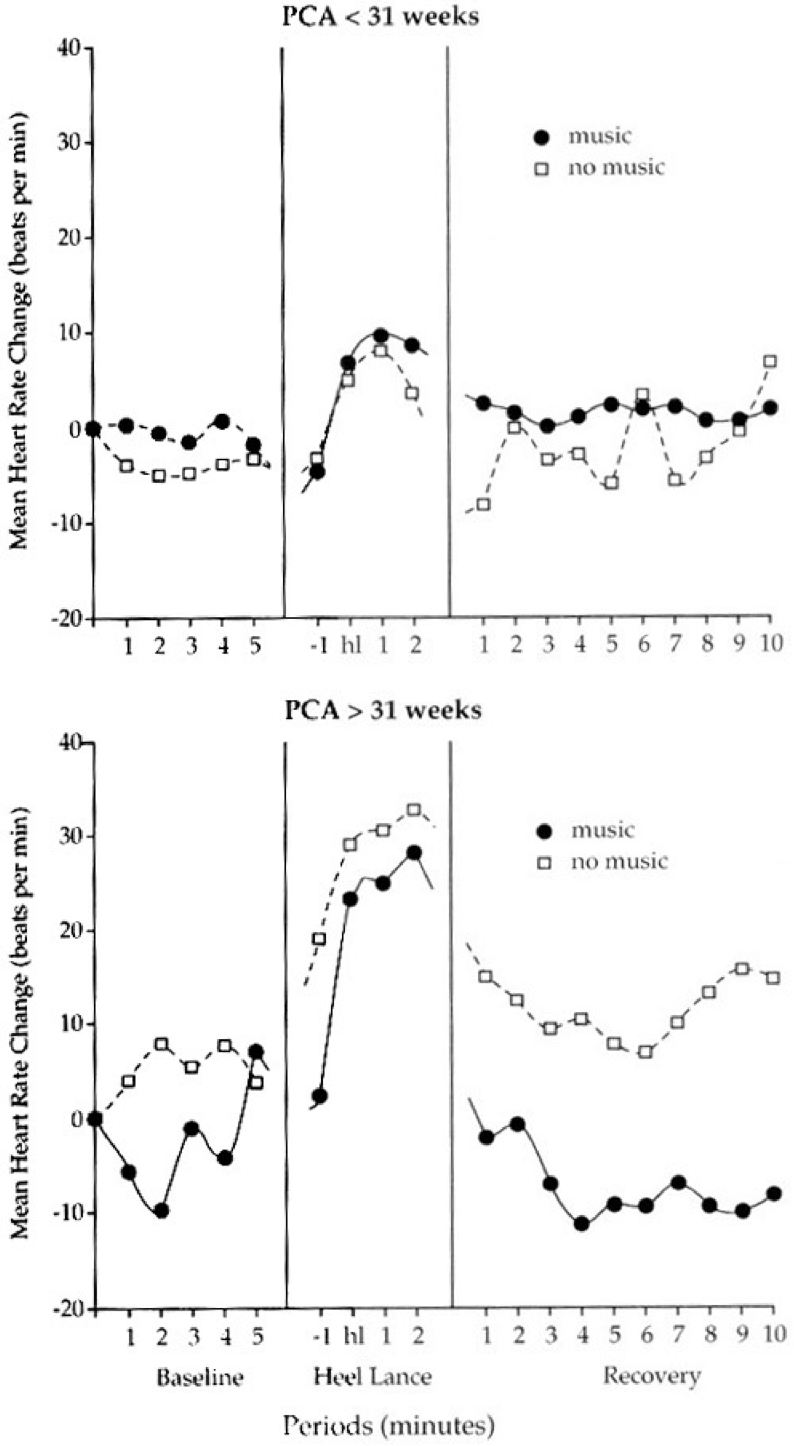


Figure 3 *Mean Behavioural State Differences as a Function of Vocal Music / No-Music and as a Function of Instrumental Music / No-Music*

A) Vocal Music

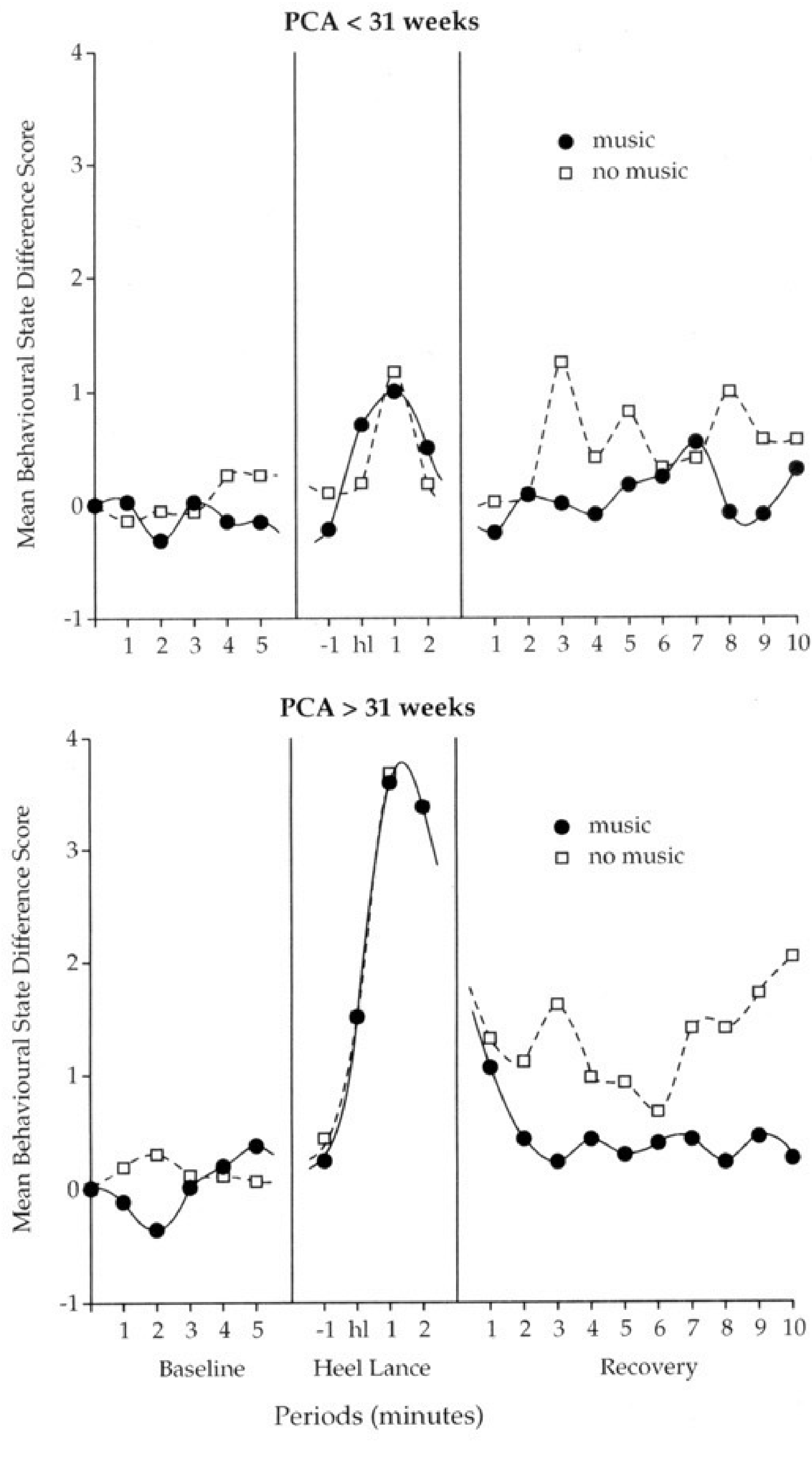


Figure 3 *cont'd)*

B) Instrumental Music

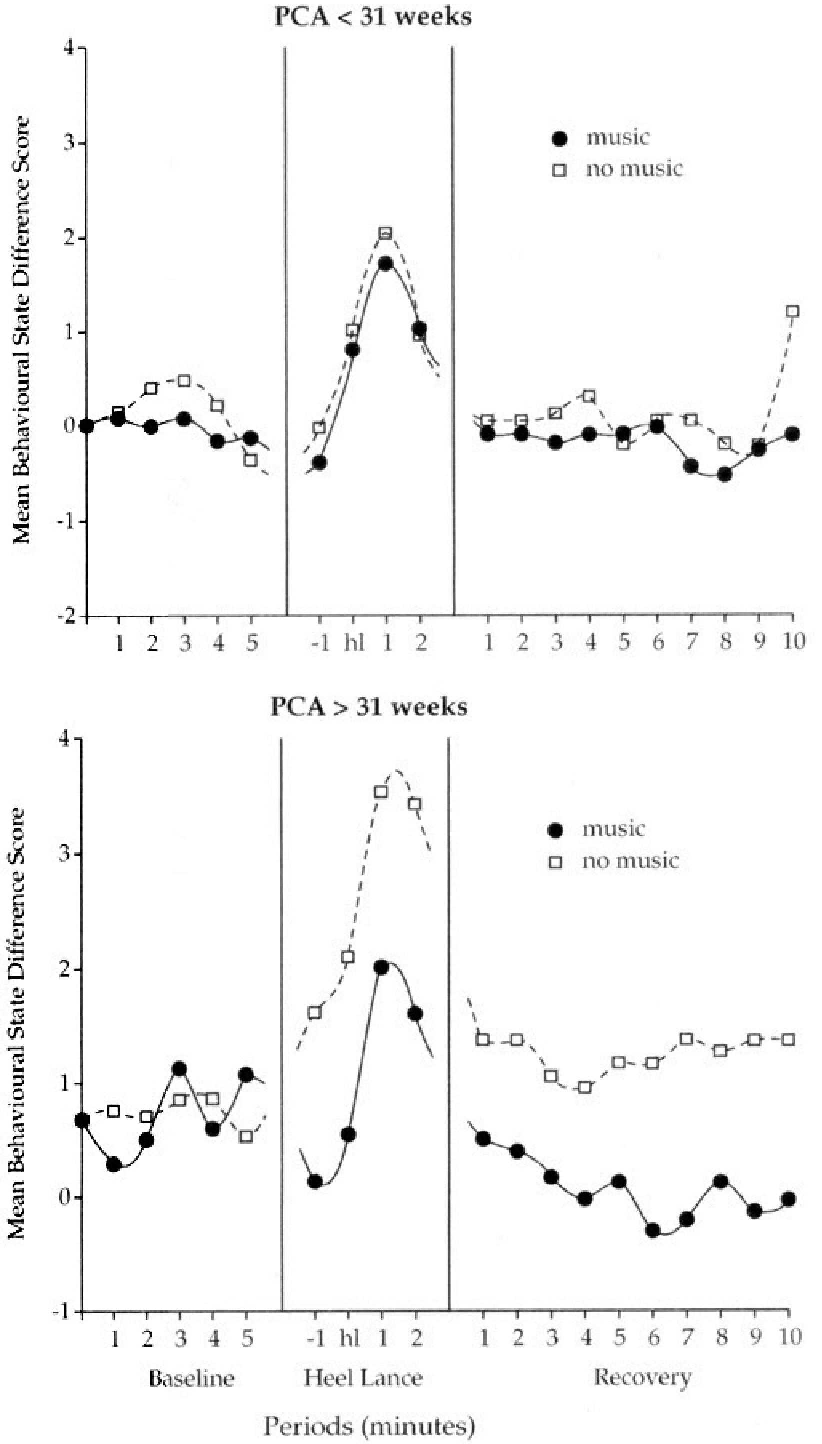
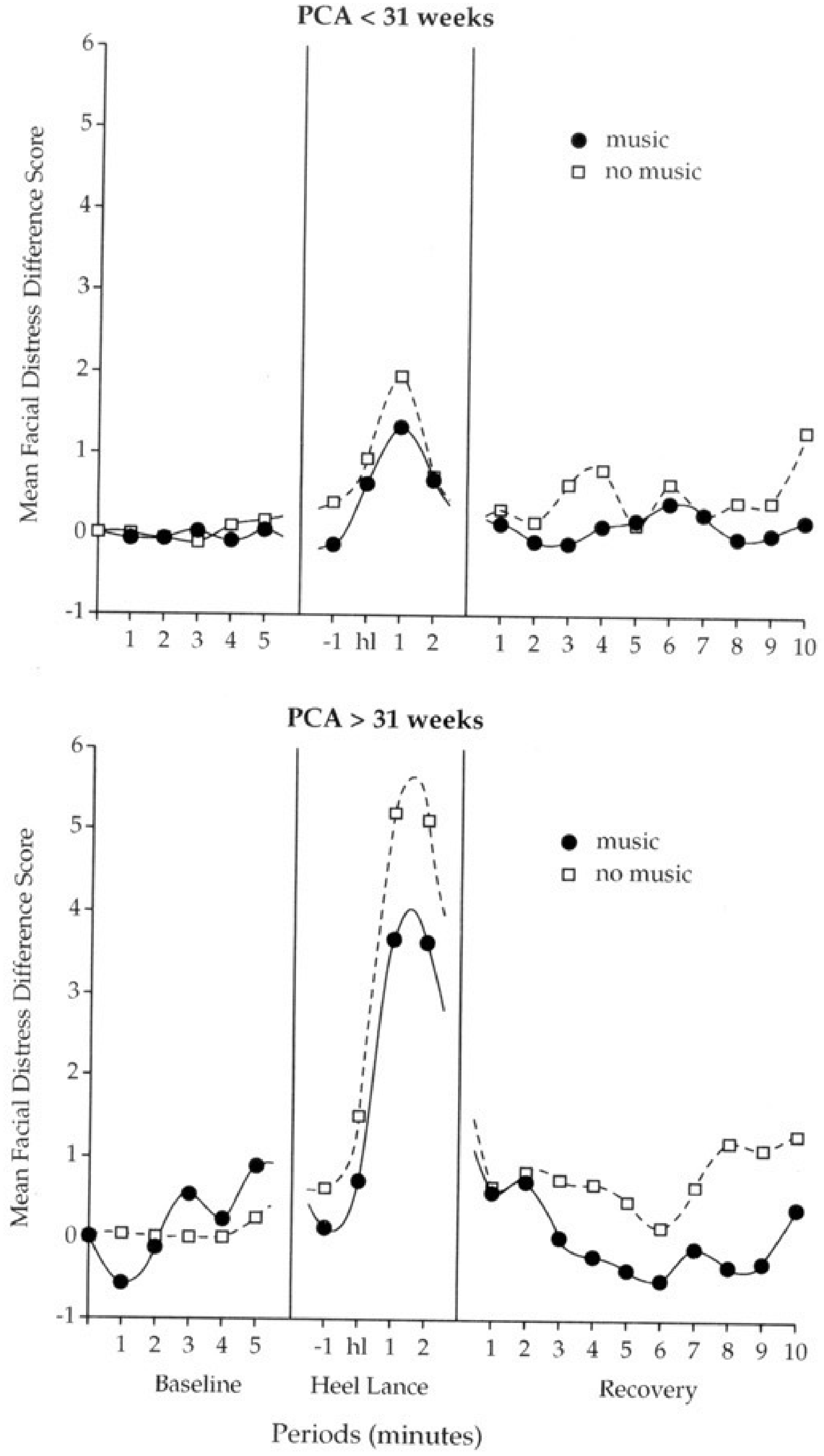


Figure 4 *Mean Facial Expression of Pain Differences as a Function of Music/No-Music*



$p < .05$, and a Condition by Age interaction, $F(1, 12) = 7.403$, $p < .05$, were revealed. As can be seen in Figure 2, during the recovery period the older infants responded with a decrease in heart rate in the music condition while the younger infants showed no effect of music.

The *oxygen saturation* returned to baseline levels during the first 5 minutes of the recovery period, $F(4, 48) = 6.387$, $p < .01$, for all infants, in both control and music conditions, and did not change in the second 5 minutes of the period.

When *behavioural state* was considered, there were no significant main effects in the recovery period for either of the two Music Types. Subsequent analyses revealed no significant main effects or interactions in the first 5 minutes. However, in the second 5 minutes of this period there was a Condition by Time interaction, $F(4,20) = 3.453$, $p < .05$, for the vocal music. Infants were less aroused during the vocal music compared to the no-music control. For the instrumental music, there was a main effect of Time, $F(4, 20) = 3.431$, $p < .05$, and an Age by Time interaction, $F(4,20) = 3.445$, $p < .05$. Figure 3 shows that older infants in the instrumental music condition were less aroused compared to the no-music condition (Sign Test, $p < .01$), with behavioural state scores below baseline in the second 5 minutes.

For *pain*, a significant main effect of Time, $F(9, 99) = 2.091$, $p < .05$, and a Time by Age interaction, $F(9, 99) = 2.135$, $p < .05$, were found. Post-hoc examination showed a significant Age by Time interaction, $F(4, 44) = 2.691$, $p < .05$, in the first 5 minutes and a main effect of Time, $F(4, 44) = 4.019$, $p < .05$, and Condition, $F(1,11) = 4.742$, $p = .05$, in the second 5 minutes. The older infants' facial expressions of pain decreased over time, especially in the first 5 minutes post-heel lance, and remained low in the second 5 minutes for those who experienced music. For those in the no-music group, pain scores remained elevated. The younger infants' facial expressions of pain were similar to baseline.

Discussion

The results of this study clearly demonstrate that music modulates both physiological (heart rate) and behavioural (state-of-arousal, facial expressions of pain) responses of preterm infants older than 31 weeks PCA following a stress-provoking heel lance. The source of the music (voice vs. piano) did not seem to be important for this effect, although some differences were found.

Regardless of PCA, the premature infants responded to heel lance with increased heart rate, decreased oxygen saturation, increased state-of-arousal, and increased number of facial expressions of pain; these physiological and behavioural changes are well described in the literature as constituting a stress response (Craig et al., 1993; Fitzgerald & Anand, 1993; Johnston et al., 1993). The intensity of the response differed with age, with older infants (> 31 weeks PCA) showing more signs of stress than younger infants (< 31 weeks PCA). Moreover, infants under 31 weeks PCA returned to baseline levels of behaviour within the first minute of the recovery period; in essence they did not sustain a stress response beyond the period of the noxious stimulus. At the present time it is unclear whether younger infants are unable to sustain a stress response because of their immature response systems, or whether they perceive a noxious stimulus as less stressful or less painful because of their immature sensory systems. Evidence for the latter comes from the observation that the magnitude of the stress response was always lower for the younger infants than for the older infants. These findings replicate the work of Fearon et al. (1997), who suggest that younger preterm infants show a lower magnitude of stress response because of their more immature neurological system. These findings are also in keeping with those from fetal studies, which describe a transition period at approximately 28 to 31 weeks gestational age with maturational changes in spontaneous behaviours (e.g., increase in rate of cardiac-body movement coupling [DiPietro, Hodgson, Costigan, Hilton, & Johnson, 1996]) and stimulus-induced responses (e.g., shift from heart rate deceleration to acceleration elicited by vibroacoustic stimulation [Kisilevsky, Muir, & Low, 1992]). If the newborn premature infant behaves like an externalized fetus (for a discussion, see Kisilevsky & Lecanuet, 1999), then a decrease in response magnitude would be expected in premature infants born at less than 31 weeks gestational age when tested shortly after birth.

Music as an intervention in the recovery period had differential effects on the infants, depending on PCA at time of testing. Probably because the younger premature infants did not show as much stress or pain during the heel lance period and returned to baseline levels within the first minute of the recovery period, the intervention showed no effects on any of the measures. Replicating Fearon et al. (1997), who found no effects of swaddling following heel lance in a group of infants of similar age and medical history, there appears to be no need for intervention following the heel lance procedure with this age group.

For the older infants, music in the recovery period had different effects, depending on the response system, indicating a need for multiple response measures. Only oxygen saturation returned to baseline levels in the absence of music. Music was an effective intervention, modulating the return of heart rate, behavioural state, and facial expressions of pain to or below baseline levels. In the presence of music, the older infants showed a decrease in heart rate to below the baseline level observed prior to the heel lance, while pain scores returned to baseline within 5 minutes. For these measures, no differential effects were noted between vocal and instrumental music. However, for the behavioural state data, there is some suggestion that the older infants were soothed more by the instrumental than the vocal music. The reason for this is not clear, but it could be related to the subjective perception of several adults that the instrumental music seemed to have less variation in tone and intensity than the female soprano voice. Alternatively, it may be that the human female voice has attention-eliciting properties for newborn infants. The study was not designed to examine these issues and no firm conclusions can be reached without further research.

The finding of a lower state-of-arousal during the recovery period in the music compared to the no-music control condition is consistent with Fearon et al.'s (1997) finding that infants of at least 31 weeks PCA who are swaddled following heel lance return more rapidly to baseline levels. It also replicates the findings of Burke et al. (1995), who observed decreased levels of arousal following suctioning in a music compared to a no-music group of premature infants. In the absence of music during the recovery period, the older infants' heart rate, behavioural state, and pain scores remained above baseline levels, indicating greater general arousal. The greater level of arousal in the control condition indicates that infants are required to expend more energy to cope with the stress of a heel lance procedure. The more rapid modulation of the stress response in the music intervention condition indicates that infants are able to conserve energy for expenditure on growth and development.

In conclusion, in this study music appeared to be an effective intervention for use in the NICU following a stress-provoking stimulus such as heel lance for infants older than 31 weeks PCA. It enabled the infants not only to return more rapidly to baseline levels of heart rate, state-of-arousal, and facial expression but to be soothed to even lower levels of arousal. These findings may have important implications for the care of preterm infants in both attempting to reduce the negative effects of medical and nursing procedures and attempting to promote energy conservation for growth and development. Clearly, the soothing effect of music on premature infant behaviour warrants further study, to determine its usefulness as part of a developmentally sensitive care program.

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