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The Effects of Music Entrainment on Postoperative Pain Perception in Pediatric Patients

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Abstract

Using a within-subjects counterbalanced design with random allocation to treatment sequences, this study examined the effects of music entrainment on postoperative pain perception and emotional state in 32 pediatric patients. Patients participated in two music entrainment conditions and one control condition over 2 consecutive days. During the music entrainment condition, live music was created by the music therapist to match the child's pain. Once resonance was achieved between the pain and the music, the music progressed into music predetermined by the child as healing. During the control condition, standard care was provided. Measurements of the dependent variables were taken just prior to and immediately following each condition. The results support the effectiveness of music entrainment as a postoperative pain management technique for children and adolescents.

Keywords

clinical improvisation, entrainment, music therapy, music improvisation, pediatrics, postoperative pain

During the past two decades it has been recognized that research in pediatric pain has been a minority field and that pain in children has been highly undertreated (American Academy of Pediatrics, 2001; Walco, Cassidy, & Schechter, 1997). An overestimation of the risks associated with the use of narcotic analgesics in pediatric patients, added to the frequent underestimation of their pain by both parents and health care professionals, puts children in a very vulnerable position during the postoperative recovery period (Fortier, MacLaren, Martin, Perret-Karimi, & Kain, 2009; P. J. McGrath & McAlpine, 1993). Nonpharmacological pain interventions can provide a counterbalance for this continuing undertreatment of pain in children. However, since most nonpharmacological pain intervention studies have focused on the adult population, there is a need for studies investigating the effectiveness of these treatments with pediatric patients.

With the recognition of pain as a multidimensional phenomenon has come an increased interest in nonpharmacological interventions for pain, such as the use of music. With only a few exceptions, music listening has been the primary type of music experience used with medical patients as reported in the experimental literature. It has been used in pain management for distraction, relaxation, conditioning, and provision of overriding sensory stimulation (according to the gate control theory). It has been reported that these highly interactive functions of music have beneficial effects on dental procedural pain (Anderson & Baron, 1991; Davila & Menendez, 1986), postoperative pain (Burke & Thomas, 1997; Good, Anderson, Stanton-Hicks, Grass, & Makii, 2002; Locsin, 1981), labor pain (Clark, McCorkle, & Williams, 1981; Geden, Lower, Beattie, & Beck, 1989; Hanser, Larson, & O'Connell, 1983), burn pain (Barker, 1991), cancer-related pain (Beck, 1991; Magill, 2001), procedural pain (Davis, 1992), chronic pain in adults (Curtis, 1986; Schwoebel, Coslett, Bradt, Friedman, & Dileo, 2002), and pediatric pain (Fowler-Kerry & Lander, 1987; Pfaff, Smith, & Gowan, 1989). With regard to the use of music for pain reduction in children, clinical reports suggest that active music making may be more effective than music listening because of children's active and creative nature (Bishop, Christenberry, Robb, & Rudenberg, 1996; Loewy, MacGreggor, Richards, & Rodriguez, 1997). Given the need for research on the effectiveness of nonpharmacological pain management techniques for children and adolescents, in particular active music therapy interventions, this study was designed to investigate the effects of music entrainment on postoperative pain perception in pediatric patients.

Music entrainment, an active music therapy improvisation approach, is based on a process in physics whereby two previously out-of-step oscillators lock into phase with one another, replacing the vibrational rate of one system with the vibrational frequency of another system (Saperston, 1995). Physicists have

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found evidence that any atomic matter can be affected by external pulses. Because all the chemical and electrical responses in the body have rhythms (Glass, 2001), many can be entrained by first musically matching their physiological rhythm and then gradually changing the music in the desired direction, modifying the oscillatory patterns of the physiological responses (Rider, 1997). Music entrainment for pain reduction, however, is more complex than simply entraining musical stimuli with physiological responses, and its process has been described by Rider (1985, 1997) and Dileo and Bradt (1999). The music entrainment process for pain reduction begins with asking the child to describe his or her pain in as detailed a fashion as possible. Many verbal pain descriptors, such as "pounding" and "sharp," can easily be translated in musical parameters of rhythm, tempo, timbre, pitch, and intensity. For example, when the child describes his or her pain as stabbing, the therapist asks the child to tap on a drum or show with a hand motion "how fast the pain is stabbing." This helps to establish an accurate tempo of the pain sound. Through experimentation with music and sound, the therapist tries to musically, that is, instrumentally and/or vocally, create as accurately as possible an auditory image of the child's pain. The patient gives new directions and feedback until the music improvisation exactly matches his or her pain. Next, the child is asked what music or which sounds could soothe his or her pain. Again, the therapist and the child explore different sounds and music to create an auditory healing image. After the patient is satisfied with both the pain and the healing sound, the actual music entrainment can start. The music improvisation begins with playing the pain sound. When resonance is achieved, the music slowly progresses into the healing sound. This gradual change in the music has the potential to affect the physiological and psychological responses of the patient in the desired therapeutic direction, reducing pain perception (Dileo, 1997; Rider, 1985, 1997; Roederer, 1975).

As a pain management technique, music entrainment affects several aspects of human functioning simultaneously. Physiologically, the music entrainment of nerve impulses combined with an increased sensory input is of importance for pain reduction. According to the gate control theory, increased sensory, nonpainful input can modify pain perception. Music listening increases the activity of the large diameter sensory nerve fibers, potentially resulting in a partial or total blockage of the passage of noxious impulses (Melzack & Wall, 1965; Melzack, Weisz, & Sprague, 1963). The influence of improvised music on this gating mechanism, although still hypothetical, cannot be neglected in the entrainment process. At the cognitive level, music entrainment has the potential to increase the child's perceived level of control by helping the child to musically "manipulate" the pain. Also, the gradual change in the music, namely, from pain music to soothing music, may possibly create a shift in the cognitive perception of the presence of pain. By its focus on the sensory aspects of the pain, this technique also helps the child to directly confront the pain instead of trying to escape from it. In addition, according to the parallel processing model of pain (Leventhal & Everhart, 1980), processing a noxious stimulus as a primarily sensory experience reduces pain and distress. At the affective level, the creation of auditory pain and healing images provides the child with a means for emotional expression, possibly influencing the experience of the pain. Research has suggested that the expression of emotions is negatively correlated to pain intensity, meaning that increased emotional expressiveness results in a reduction of perceived pain (Kerns, Rosenberg, & Jacob, 2005). The shift from pain sounds to healing sounds may also induce relaxation. It is generally accepted that increased relaxation has beneficial effects on pain perception. Finally, at the social level there is the therapist's resonance with the patient's pain, or "the ability to empathize as fully as possible with the condition of the client" (Dileo, 1997, p. 126). Several studies have found that higher empathy levels in clinicians lead to better pain management results (Tait, 2008). By helping the patient create an auditory reflection of the pain and by taking part in the music improvisation of the pain, the therapist enters directly into the patient's pain and resonates with this pain in a very unique way. This provides enormous support and validation for the patient (Dileo, 1997).

For this study, the following research questions were formulated: (a) Does music entrainment have an effect on the level of perceived pain intensity in pediatric patients? (b) Does music entrainment have an effect on the emotional state of pediatric patients? (c) Are such effects, if any, correlated?

Method

Participants

This study included 32 orthopedic in-patients (mean age = 14.2 years, range = 8-18), including 18 male and 14 female patients, of two major pediatric hospitals in Pennsylvania (United States). All participants were in need of postoperative pain management, as assessed by means of a pain questionnaire. Seventeen patients (53.1%) were spine fusion patients. Other surgical procedures included in this study were centralization of wrist ($n = 2$), scar revision ($n = 2$), osteotomy and placement of external fixator ($n = 2$), tibial rodding ($n = 3$), osteotomy and leg lengthening ($n = 4$), pectus repair ($n = 1$), and hardware removal ($n = 1$).

To be eligible for inclusion, the children needed to be between 8 and 18 years of age; speak English; and have no diagnosis of a cognitive disorder, emotional disorder, musicogenic epilepsy, or hearing loss. Furthermore, the music entrainment intervention requires the child to be an active participant. Therefore, the participants needed to be alert and able to respond verbally but did not need to be mobile. No children were excluded based on gender, ethnic origin, or economic status.

Five participants were African American (15.6%), 11 were Hispanic (34.4%), and 13 were Caucasian (40.6%). Three participants preferred not to disclose their ethnic background. Parents of 18 participants (56.3%) reported that their children had previously played an instrument, and parents of 12 participants (37.5%) reported that their children had not. For 2 participants (6.2%), these data were missing.

Table 1. Treatment Sequences

	Day 1	Day 2
Sequence 1	E1 – C	E2
Sequence 2	C – E1	E2
Sequence 3	E1	E2 – C
Sequence 4	E1	C – E2

E1 = first music entrainment session; E2 = second music entrainment session; C = control condition.

Written consents and verbal assents were obtained in accordance with the declaration of Helsinki.

Procedure

Since previous research (Rider, 1985, 1997) had indicated that music entrainment is effective in reducing patients' pain, withholding the music entrainment treatment from one group of patients was considered unethical. Therefore, a within-subjects counterbalanced design was chosen. Each patient participated in two music entrainment conditions and one control condition over 2 consecutive days, starting within 24 hours of admission to the inpatient floor, following surgery. These three conditions were counterbalanced (Table 1) to control for order and time, resulting in four treatment sequences. Participants were randomly assigned to these treatment sequences using a draw of lots. Lots were drawn in the presence of the study participants, ensuring allocation concealment.

Measures of self-reported pain intensity and emotional state were obtained immediately preceding and following each condition by the researcher. For the outcome pain intensity, participants were also asked to rate the pain felt during the pain-healing music. Time and amount of the last analgesic administered prior to each condition and of the first analgesic administered after each condition were recorded. Blinding of the research participants in this study was not possible since the participants were actively involved in the music-making process. In addition, the use of self-report measures prevented the blinding of outcome assessors.

All sessions took place in the patients' hospital rooms. For the music entrainment sessions, a wide array of music instruments was brought into the participant's room. Each patient was given the opportunity to play each instrument or, where severe pain prohibited movement, to listen to the music therapist play each instrument. After exploration of the instruments, the patient was asked to describe his or her pain in a manner as detailed as possible and was then told, "I am wondering if we could create music that sounds exactly like the pain you are feeling right now."

Questions, each related to a specific musical parameter, were asked to help the child and the music therapist create an accurate auditory image of the child's pain. For example, "Which of these instruments sound most like the pain you're having right now?" "Does your pain have a beat?" "How strong/intense is your pain right now?" Whenever the therapist learned new information about the sensory aspect of the child's pain, she improvised accordingly and asked the child for feedback. The child was told that she or he could direct the therapist to modify the music at any time to better match the pain. Once the patient was satisfied with the auditory image of the pain, an auditory pain-healing image was created in a similar way. The therapist asked the child which sounds or music sounded soothing to him or her. The therapist typically played different instruments in different musical styles, modes, and tonalities, until the child identified specific sounds or music as soothing. After the creation of accurate auditory images—a pain image and a pain-healing image—the patient was asked to recline, close his or her eyes, and find a comfortable position. The therapist then started the improvisation with the pain sounds, gradually moving into the pain-healing sounds. The pain-healing music was played for as long the patient desired. The improvisation itself took approximately 5 to 15 minutes. The music entrainment condition typically lasted for 30 to 45 minutes in total.

For the second music entrainment session, the therapist and patient reviewed the patient's pain and pain-healing sounds. Often, adjustments were needed to have the music accurately match the in-the-moment pain. This session proceeded in a fashion similar to the first music entrainment session. During the control condition (30-45 minutes), standard care was provided. However, the participant was asked not to listen to any music during this time since listening to music was suspected to be a confounding variable. It was requested that no painful routine medical interventions take place immediately prior to and during both the control and the music entrainment conditions. In case a participant was in need of a painful medical intervention during any of the study conditions, she or he was excluded from the study. No interactions with the music therapist took place during the control condition, except for the distribution of the self-report measurement tools at the beginning and the end of the control condition period.

Measurements

Pain intensity was measured by means of a visual analogue scale (VAS). The VAS is the most widely used pain rating scale. The scale consists of a 10-cm line, without markers other than the endpoints. This scale can be used by children over 5 years of age in a reliable manner (P. A. McGrath, 1987; Tyler, Tu, Douthit, & Chapman, 1993).

Eight bipolar descriptor items (5-point scale) were developed by the researcher to measure participants' emotional state (sad-happy, helpless-in control, hopeless-hopeful, tired-energetic, angry-peaceful, tense-relaxed, uncomfortable-comfortable, and nervous/scared-calm). These items were reviewed by several health care professionals with expertise in pediatric care; however, this measurement tool was not a standardized instrument. Each point on the scale was given a numerical value from 1 to 5, with 1 being very negative and 5 being very positive. An index score for emotional state was determined by the sum of responses to these items, with a possible score ranging from 8 to 40. A lower emotional index score indicated a more negative emotional state.

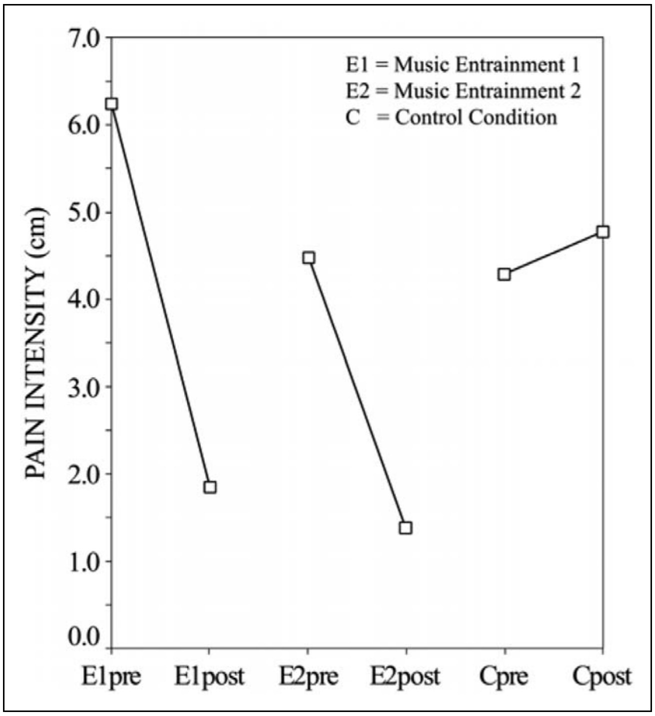

Figure 1. Pain intensity reduction.

Results

Pain Intensity

Two-tailed *t* tests, comparing the pretest pain intensity with the pain intensity felt during the pain-healing music for the first and second music entrainment session, found a mean pain intensity reduction of 4.41 cm ($SD = 2.01$), $t(31) = 12.383, p = .000$, and 3.11 cm ($SD = 2.33$), $t(31) = 7.560$, $p = .000$, respectively (Figure 1). A smaller decrease in pain intensity was observed when comparing pretest pain intensity scores with scores of the postmusic period for the first session ($M = 2.97$ cm, $SD = 2.09$), $t(31) = 8.064$, $p = .000$, as well as the second session ($M = 2.35$ cm, $SD = 1.99$), $t(31) = 6.673, p = .000$. In contrast, the control condition did not result in pain reduction ($M = –0.48$ cm, $SD = 1.79$), $t(31) = –1.499$, $p = .144$. Both music entrainment sessions were more effective than the control condition in reducing pain intensity, and this difference was statistically significant, $t(31) = 8.749$, $p = .000$, for the first music entrainment session, and $t(31) = 5.264, p = .000$, for the second music entrainment session (Table 2).

A greater pain reduction was reported for the first music entrainment session compared to the second session, and this difference (1.29 cm) was found to be statistically significant, $t(31) = 2.489$, $p = .018$. This finding was to be expected, as surgical pain reduces over time. Indeed, the pretest pain intensity ratings of the first music entrainment session were significantly higher than those of the second music entrainment session. Therefore, less absolute pain reduction was possible for the second session. A comparison of the ratios of mean pain reduction to mean maximum pain reduction possible for both sessions, however, revealed that the mean pain reductions were similar: 70.6 % reduction for first music entrainment session and 69.4% for the second music entrainment session.

Table 2. Mean Change Scores for Pain Intensity

Condition	Perceived pain time points	M^a	*SD*
First music entrainment	After music	2.972*	2.085
	During music	4.406*	2.010
Second music entrainment	After music	2.347*	1.990
	During music	3.113*	2.329
Control condition		–0.475	1.792

[a] A positive value represents a reduction in pain intensity.
* $p < .01$.

Additional analyses were conducted to rule out pain medication as a confounding variable. Data from all participants who received pain medication less than 1 hour before the start of the music entrainment sessions ($n = 7$ for the first session, $n = 2$ for the second session) or the control condition ($n = 8$) were excluded, and results indicated that this exclusion had little effect on the reported mean difference scores for pain intensity. A significant difference in pain reduction between the first music entrainment session and the control condition, $t(19) = 7.622, p = .000$, and the second music entrainment session and the control condition, $t(22) = 5.576$, $p = .000$, remained.

Emotional State

A two-tailed *t* test on pretest and posttest emotional state scores found statistically significant improvements in emotional state for the first music entrainment session ($M = 6.16$, $SD = 6.67$), $t(31) = 5.223, p = .000$, and for the second music entrainment session ($M = 3.19$, $SD = 4.58$), $t(31) = 3.935$, $p = .000$; Table 3).

A one-way ANOVA on mean difference scores for emotional state revealed a significant order effect for the control condition, $F(3, 28) = 7.039, p = .001$. Post Hoc Tukey analyses of pretest emotional states for the control condition indicated that those participants who received the control condition in the morning (before the afternoon entrainment session) reported a significantly worse mood than those who received the control condition in the afternoon, following a morning music entrainment session. Research notes indicated that the patients who received the control condition as their first condition of the day often reacted disappointedly when the music therapist entered the room (without instruments) to distribute the pretest pain and emotional state measurement tools. This disappointment may have influenced the pretest mood ratings. In contrast, those patients who received music entrainment first knew that they were to expect one more control session in the afternoon. It is also likely that the mood-enhancing effects of the morning entrainment session carried over into the afternoon control condition.

Table 3. Mean Change Scores for Emotional State

Condition	M^a	SD
First music entrainment	6.16*	6.67
Second music entrainment	3.19*	4.58
Control (morning)[b]	–3.69*	2.94
Control (afternoon)[c]	1.38	4.03

[a] A positive value indicates an improvement in emotional state.
[b] Participants who received the control condition in the morning (see the Results section for further explanation).
[c] Participants who received the control condition in the afternoon (see the Results section for further explanation).
* $p < .01$.

For those participants who received the control condition in the afternoon, there was no significant difference in emotional state change scores between the first music entrainment session and the control condition, $t(15) = 1.697$, $p = .110$, or between second music entrainment session and the control condition, $t(15) = 0.857$, $p = .405$. In contrast, for those participants who received the control condition in the morning, significant differences were found between the first music entrainment session and the control condition, $t(15) = 5.684$, $p = .000$, and between the second music entrainment session and the control condition, $t(15) = 4.380$, $p = 001$.

To examine whether there were significant correlations between the effects of the sessions on pain intensity and their effects on emotional state, a Pearson product moment correlation coefficient was calculated for the difference scores of (a) pain intensity (during music), (b) pain intensity (after music), and (c) emotional state. A statistically significant relationship was found between the emotional state difference scores and the pain intensity difference scores for the first music entrainment session, $r(32) = .465$, $p = .007$, as well as the second music entrainment session, $r(32) = .358$, $p = .044$. A statistically significant correlation was also found between pain intensity and emotional state difference scores for the control condition, $r(32) = .610$, $p = .000$.

Discussion

The data support the efficacy of music entrainment as a pain management technique for postsurgical orthopedic pediatric patients. Large decreases in pain intensity were found for both music entrainment sessions: a 70.6% reduction for the first session and 69.4% for the second session. In contrast, a small increase in pain, although statistically insignificant, was found for the control condition. Music entrainment sessions were significantly more effective than the control condition in reducing postoperative pain. The results furthermore indicate that the pain-reducing effects were the greatest as long as the pain-healing music was present. Still, a large pain reduction remained during the postmusical period. This difference in pain reduction between the musical and the postmusical period was reported by 87.5% of the children for the first session and by 68.75% of the children for second session. One explanation for this finding could be that the sudden absence of music caused an orientation response in the participants, interrupting the state of relaxation, which most patients appeared to have attained during the pain-healing music. Furthermore, by stopping the music, the ongoing sympathetic resonance between the music and the patient, an important principle underlying the music entrainment process, was also terminated; this could have allowed the patient's physiological and psychological responses to begin to return to pretreatment levels. The pain-healing music, furthermore, created an audible presence of empathy and support by the music therapist. In contrast, the silence may have translated into a feeling of decreased support, increasing anxiety. It has been recognized that increased anxiety and lack of social support are likely to increase pain perception (American Academy of Pediatrics, 2001; Chapman & Turner, 1986; Janssen, Arntz, & Bouts, 1998). In addition, to fill out the posttest pain questionnaire, the children had to reposition themselves physically and switch from a relaxed state to a more cognitive mode; this could have contributed to the perception of increased pain after the music had stopped.

Besides pain-reducing effects, results suggested that music entrainment may also have mood-enhancing effects. The children reported higher degrees of happiness, peacefulness, relaxation, comfort, and calmness during both music entrainment sessions but not during the control condition. Most children preferred warm, melodious music in a minor key for their pain-healing sounds. Their entrainment music typically changed from dissonant and sharp sounds (auditory pain image) to peaceful music (pain-healing image). Based on the iso principle (Altschuler, 1948), such musical changes tend to positively influence patient mood. The iso principle is used by many music therapists as a means to facilitate a gradual mood change in patients. To establish a musical iso, music that matches the patient's current mood is played, after which the music is gradually changed in a therapeutic direction. The peaceful nature of the children's pain-healing music clearly translated into a more positive emotional state.

Correlation analyses, furthermore, indicated a strongly positive association between mood improvement and pain reduction. These findings are consistent with reports in the pain literature. Pain perception and emotions are closely related: A significant change in one is most often accompanied by a significant change in the other (Kerns et al., 2005; Oberle, Wry, Paul, & Grace, 1990; Skevington, 1995). The presence of negative emotions such as anxiety, anger, hopelessness, helplessness, sadness, and depression may exacerbate the perception of pain. There is an ongoing debate, however, whether strong emotions cause pain or are an outcome of pain (Skevington, 1995). For this pain management technique, the question could indeed be raised whether music entrainment reduces pain and consequently improves the patient's emotional well-being or, conversely, whether music entrainment foremost addresses the emotional well-being of the patient and, as a result, reduces the patient's pain. It is believed, however, that in music entrainment these are not sequential processes. According to

Dileo-Maranto (1994), "Music elicits psychological, cognitive, and physiological responses simultaneously" (p. 160). The entrainment music and the process of its creation address the patient's pain and emotions simultaneously and directly. The technique calls for a tuning in to the sensory aspects of the pain, but the music entrainment process also creates an atmosphere of intense validation and support by the music therapist. This has direct implications for the patient's emotional state. Maybe the power of music entrainment stems from this simultaneity. The question about the order of effects has, in my opinion, become irrelevant.

The patients benefited equally from the first and second music entrainment sessions. This means that music entrainment as a pain management technique is readily accessible to young children and adolescents and does not require "practice" for a successful outcome. Therapists in medical settings, unfortunately, can no longer afford to extend protocols over several days for an intervention to have an effect. The fast-pace care in hospitals calls for interventions with immediate pain-reducing results, since effective pain management not only is beneficial to the health outcomes for the child but often results in earlier mobilization, shorter hospitalization, and reduced health care costs (Department of Health and Human Services, 1992). Therefore, the immediacy of its pain-reducing effects could make music entrainment especially attractive as a integrative pain management intervention.

Finally, an important anecdotal finding deserves mention. Several children in this study experienced severe abdominal pain due to postoperative ileus. Some chose to focus their attention specifically on their abdominal pain during the music entrainment process, whereas others chose to focus on the site of their incision. It was remarkable how the intestinal motility of many children improved during the session. Once the improvisation had moved into the relaxing pain-healing music, many children experienced flatulence or the need for a bowel movement. It is believed that the entrainment music, typically changing from dissonant, sharp sounds to consonant, peaceful music, promoted muscular relaxation; this, in turn, could have facilitated increased peristalsis. It is recommended that future research studies include gastrointestinal functional analysis. Since effective pain management and effective treatment of postoperative ileus have been linked to reduced length of hospitalization and reduced medication intake, future studies also need to examine whether music entrainment affects the recovery time, the need for analgesics, and length of hospital stay.

This study had several limitations. First, the relatively small sample ($n = 32$) of the present study restricts the generalizability of the results. In addition, the sample used in this study represents solely orthopedic patients suffering from postoperative pain. These results may not generalize to all pediatric patients. Therefore, it is recommended that future studies include a larger sample and a variety of medical conditions and pain etiologies.

Second, the possible influence of experimenter effects and subject motivation in this study should not be ignored. The children's expectations that the music therapist would make them feel better most likely acted as a placebo. However, the placebo effect is an important factor that we should embrace in the treatment of patients. Inherent to the decision to seek therapy is the expectancy to get better. The fact that most children expected or hoped that the music would make them feel better did most likely contribute to the beneficial effects of the music entrainment intervention. Future study designs should attempt to better control for placebo effects and the participant's motivation to comply with the experimenter's expectations. Therefore, it may be desirable to use an intervention for the control condition where the child is told that it may have pain-reducing and mood-enhancing effects.

In addition, the expertise of the music therapist in music entrainment is an important factor to consider. Music entrainment for pain management requires specialized skills. Music therapists wishing to use this intervention should receive training and supervision by a clinician with expertise in music entrainment. Future research studies and clinical applications should be undertaken by music therapists with expertise in this intervention. Furthermore, studies comparing music entrainment to other music conditions are recommended to further separate out the effects of the person of the music therapist.

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