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ARTICLE

Music interventions and pain: An integrative review and analysis of recent literature

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ABSTRACT

Music interventions offer a low-cost, low-risk adjuvant to traditional therapies. However, scarce physiological evidence exists to explain how music relieves pain. In this integrative review, we provide a summary of results in the recent literature regarding music-induced analgesia and provide a critical analysis of methodological patterns. We then describe the need for robust theoretical explanations that could account for the observed effects of music on pain. We completed a broad electronic search using common search engines to identify recent experiments and literature reviews that represented the current understanding of potential causal relationships between music and pain. Thirty-one articles were synthesised in this review – 23 were individual experiments and eight were literature reviews. The results show that music-induced analgesia is a consistently observable phenomenon in clinical settings, although a minority of articles report inconclusive results. The magnitude of pain relief is small to modest and results become less conclusive when derived from indirect measures of pain. Limitations of the recent literature revolve around operational definitions of pain, varieties of pain examined within articles, over-reliance on self-reporting scales, rigour in demographic reporting, diversity and size of samples and weak experimental designs. Theoretical explanations for the effect of music on pain are varied but undeveloped and lacking in physiological evidence. We conclude that music-induced analgesia is a persistently observable phenomenon. To advance the field of study, more rigorous methodological practices need to be applied and more attention needs to be focused on finding underlying physiological mechanisms for the relationships between music and pain.

KEYWORDS

music interventions,
music therapy,
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INTRODUCTION

Pain is a widespread problem but difficult to treat. Surgeries are often needlessly invasive, medications often have dangerous side effects or risk of addiction and physical therapies are often time-intensive. Music interventions1 offer a low-cost, low-risk adjuvant to traditional therapies (Good et al., 2002). Encouragingly, music-induced analgesia has consistently been observed in music intervention studies (American Music Therapy Association, 2010). However, scarce physiological evidence exists to explain how music relieves pain. Furthermore, persistent methodological shortcomings undermine the results of music intervention studies (e.g., Zeller, Good, Anderson & Zeller, 1997) and many unresolved questions remain about what types of music interventions achieve optimal therapeutic goals (Engwall & Duppils, 2009).

Previous reviews have largely emphasised the aggregation of studies to inform clinical practices rather than advance theory about how music relieves pain (Klassen et al., 2008). This integrative review provides a brief analysis of the methodological characteristics and aggregates results of recent articles published from 2006 to 2016 but its broader purpose is to make recommendations for future research that could inform theoretical explanations of music-induced analgesia. The review of results and methodological characteristics included in this paper serves as context for discussing the theoretical mechanisms that have been proposed in the literature. The objective of this integrative review, in accordance with the general aim of integrative literature reviews, is "[…] to create a consistent and comprehensive panorama of complex concepts" (De Souza, da Silva & de Carvalho, 2010, p. 103) involved in the study of the effects of music on pain (see also Hanson-Abromeit & Moore, 2014). First, we will summarise evidence for music-induced analgesia as evinced through measures such as self-report scales, physiological measures and medication usage. In the discussion section, we briefly describe common methodological inconsistencies and weaknesses observed in the literature. In doing so, we highlight difficulties of defining and measuring pain, controversies about the optimal structure of music interventions, problematic aspects of experimental designs and the lack of physiological evidence in the literature. We conclude by offering suggestions for future research and describing a need for robust theoretical frameworks that could explain music's effects on pain.

METHOD

De Souza, da Silva and de Carvalho (2010, p. 103) suggest that an "integrative review is the most comprehensive methodological approach of reviews", while Hanson-Abrameit and Moore (2014, p. 9) state that integrative reviews are undertaken for "directing future research by summarising current knowledge and highlighting gaps in knowledge". We conducted an electronic search of the literature in the autumn of 2016 using the following research search engines: Academic Search Premier, RILM Abstracts of Music Literature, Google Scholar, PsychInfo, Medline, Psychlit; to identify recent experiments and literature reviews that represented the most current understanding of the relationship

[1] For the purposes of our review, 'music intervention' refers to any use of music in clinical or experimental settings to achieve therapeutic goals (such as music-induced analgesia). We use 'music intervention' to encompass the many uses of music present in the literature, such as passive listening sessions, active participation in live music-making and sessions with or without the facilitation of a trained music therapist.

between music and pain. Rather than producing an exhaustive catalogue of the extant research in this area, our goal was to provide a summary of the recent literature regarding the potential causal effects of music on pain. As such, our inclusion criteria consisted of true and quasi experiments as well as literature reviews published in English between the years 2006 and 2016. We used the following search terms: music, music therapy, music listening, pain, analgesia, analgesic, ache, fibromyalgia, opioid, intervention, random controlled trial and experiment.

There were no limitations imposed on the search regarding theoretical frameworks, types of pain studied, sample characteristics, intervention approaches, or dependent measures. We found that 2006 was a reasonable starting year to find a representative sampling of papers without being overly redundant with similar existing literature reviews. Following De Souza, da Silva and de Carvalho's (2010) recommendation, we examined both original empirical studies as well as literature reviews. We also examined empirical studies that represented a range of methodological rigour and strength. For each empirical study, we extracted information pertaining to the theoretical framework, sample size, study design, pain experienced / reported by participants, type of musical stimuli used, dependent measure(s) and a general summary of the findings regarding the positive effects of music on pain (i.e., null, mixed, significant). Summaries of the data extracted can be found in the Appendix as well as Tables 1, 2, and 3.

FINDINGS

Ultimately, we examined 23 empirical studies published between 2006 and 2016. The majority (thirteen) of the empirical studies we found were conducted in hospitals rather than in laboratory settings and were designed to inform clinical practices. The most common experimental design was a randomised controlled trial, engaging adults in passive music listening experience2 as they underwent or recovered from surgical procedures. However, six of the empirical studies that were identified focused on patients with chronic pain, and four empirical studies utilised laboratory stimuli such as noxious heat or cold pressors. One study (Dobek, Beynon, Bosman & Stroman, 2014) investigated the effects of noxious pain in laboratory conditions that included functional MRI imaging as a dependent measure. In addition to the 23 empirical studies, we also considered eight previous literature reviews to aid in our analysis of methodological trends and theoretical frameworks.

The 31 articles explore music's effects on pain, although many also include research about music and psychological/behavioural variables such as depression or functional mobility. This review focuses solely on findings about pain, given our purposes and that the primary objective of most of the research we reviewed was to demonstrate music-induced analgesia. Table 1 summarises the prevalence of significant, mixed, and null effects of music on pain as measured by patient self-reports, physiological measurements, and medication usage (see Table 1).

[2] 'Passive' here indicates that the participants were left to listen to pre-recorded music without involvement of a music therapist during or surrounding the listening session.

Outcome category	Significant	Null	Mixed
Pain	18	3	10
Physiological measurements	2	2	4
Decrease in medication usage	0	2	2
Efficacy of researcher-selected vs. participant-selected music	2	1	0
Efficacy of active vs. passive music interventions	0	2	0

Table 1: Counts of articles in the current review that concluded significant, null, or mixed results pertaining to the positive effect of music according to outcome category

Self-reported measures of pain

All empirical studies included in this review asked participants about pain levels using self-reporting measures such as the Visual Analog Scale (Crichton 2001) or the McGill Pain Questionnaire (Melzack 1975). Out of the 23 empirical studies included, eighteen used more than one self-reporting measure. Table 2 summarises the wide array of self-report scales found in the empirical studies and literature reviews included in this integrative review.

Of the 23 empirical studies in this review, 65% (15) concluded that participants in music intervention groups reported significant decreases in pain. Huang, Good and Zauszniewski's (2010) study serves as a good example of an experiment demonstrating results with self-reporting scales as the dependent measure. The authors conducted a randomised controlled trial examining the effects of passive music listening on the pain of 126 cancer patients in Taiwanese hospitals. Participants were assigned to either a control group or experimental group in which they were asked to complete 30-minute listening sessions, choosing music from a researcher-supplied selection of Taiwanese and American music. All music selections provided by the researchers were at a tempo of 60 to 80 beats per measure and did not contain lyrics. Participants in the experimental group completed Visual Analog Scales (VAS) before and after listening sessions to measure pain and emotional distress. In the control group, participants completed the VAS before and after 30-minute intervals of usual daily activities. Huang, Good and Zauszniewski's (2010) results showed significant reductions in reported pain for the music intervention group. In the control group, 8% of participants reported pain relief at or exceeding 50%. In the music intervention groups, 42% of participants reported pain relief at or exceeding 50%. On average, experimental participants reported pain 1.5 units lower on the VAS than control participants.

However, not all studies demonstrated such clear and consistent results from patient self-reports. Of the 23 empirical studies included in this review, 22% (5) published mixed results from self-reports of pain. For example, two reported significant decreases in short-term pain, but not long-term pain (Vaajoki et al., 2012; Finlay, 2014). One of the five with mixed results only found significant reductions in pain on two of three self-reporting scales used in the study (Gutgsell et al., 2013). The last two with mixed results found significant decreases in pain among participants from one demographic group but not others. In Mitchell and Hons (2006), female participants reported

Categories of measures	Title of measure	Description of measure	Studies using the measure
Measures of pain	Visual Analog Scale (VAS)	Horizontal line (usually 100 mm in length) with word descriptors anchoring each end (e.g., 'no pain' and 'worst pain'). Participant marks on the line the place that reflects their current pain level. Numerical score is determined by number of millimetres from left point of line to the participant's mark (Crichton, 2001).	Alam et al. (2016); Allred, Byers & Sole (2010); Engwall & Duppils (2009); Finlay (2014); Good, Ahn & Payne (2008); Guetín et al. (2016); Guetín et al. (2012); Hsieh et al. (2014); Huang, Good & Zauszniewski (2010); Korhan et al. (2014); Lee (2016); Linneman et al. (2015); Man et al. (2015); Mercadíe, Mick, Guetin & Bigand (2015); Mitchell, MacDonald & Knussen (2008); Mitchell & Hons (2006); Mitchell, Macdonald & Brodie (2006); Siedliecki & Good (2006); Tam, Lo & Hui (2016); Vaajoki, Pietila, Kankkunen & Vehvilainen-Julkunen (2012) Total: 20
	McGill Pain Questionnaire (MPQ)	Numerical ratings in response to questions in three sections: "What does your pain feel like?'" "How does your pain change with time?" and "How strong is your pain?" (Melzack, 1975).	Allred, Byers & Sole (2010); Finlay (2014); Lee (2016); Mitchell, MacDonald, Knussen & Serpell (2007); Mitchell, MacDonald & Knussen. (2008); Mitchell & Hons (2006); Mitchell, Macdonald & Brodie (2006); Siedliecki & Good (2006) Total: 8
	Numeric Rating Scale (NRS)	Participant selects an integer (usually between zero and ten) that best reflects their pain intensity. Commonly placed on a horizontal line or anchored with verbal descriptions such as 'no pain' or 'worst pain' (Hawker, Mian, Kendzerska & French, 2011).	Bradt et al. (2016); Dobek et al. (2014); Engwall & Duppils (2009); Finlay (2014); Gutgsell et al. (2013); Lee (2016) Total: 6
	Faces Scale (FS)	Participant chooses a drawing of a face that best represents their pain intensity (Wong & Baker, 1988).	Engwall & Duppils (2009); Liu & Petrini (2015); Yu, Liu, Li & Ma (2009) Total: 3
	Likert Scale	Participant selects response from one of 5 to 7 pre-coded answers in linear succession of intensity (for example "strongly agree, agree, undecided, disagree, strongly disagree") (Likert, 1932).	Fredenberg & Silverman (2014); Linneman et al. (2015) (perceived control over pain) Total: 2
	Functional Pain Scale	Participant selects numbers to represent intensity of pain sensations, activity levels, mobility, and other functions (Gloth et al., 2001).	Gutgsell et al. (2013); Lee (2016) Total: 2
	Face, Legs, Activity, Cry, Consolability Scale	Assigns numbers to behavioural signs of pain in five categories such as 0 = 'no particular expression' 1 = 'occasional grimace' and 2 = 'frequent clenched jaw' in the 'Face' category (Voepel-Lewis et al., 2002).	Gutgsell et al. (2013); Lee (2016) Total: 2

	WHO Quality of Life Scale	Participant chooses numerical ratings about pain, mobility, personal and environmental health, social ties, etc. (WHO, 2004).	Mitchell et al. (2007) Total: 1
	Children's Hospital of Eastern Ontario Scale (CHEOPS)	Observation scale for measuring pain in children ages one to seven. The scale includes six categories of pain behaviours, each of which has three or four numerical grades of intensity (Hesselgard et al., 2007).	Lee (2016); Yu et al. (2009) Total: 2
Measures other than pain	Visual Analog Scale (VAS)	See above but applied to anxiety, distress, fatigue, and satisfaction.	Allred et al. (2010) (anxiety); Good, Ahn & Payne (2008) (distress of pain); Guetín et al. (2016) (satisfaction); Mercadíe, Mick, Guetin & Bigand (2015) (fatigue); Tam, Lo & Hui (2016) (anxiety) Total: 5
	State-Trait Anxiety Index (STAI)	Participants select numerical ratings with verbal descriptions (such as "almost never" or "almost always") in response to statements such as "I feel tense" or "I am a steady person" (Spielberger et al., 1983).	Alam et al. (2016); Engwall & Duppils (2009); Garza-Villarreal et al. (2014); Liu & Petrini (2015) Total: 4
	Hospital Anxiety and Depression Scale (HADS)	Participants select numerical ratings with verbal descriptions (such as "not at all" or "very definitely and quite badly") in response to statements such as "I get a sort of frightened feeling as if something awful is about to happen" or "I have lost interest in my appearance" (Zigmund & Snaith, 1983).	Bradt et al. (2016); Finlay (2014); Guetín et al. (2012) Total: 3
	Likert Scale	See above but applied to stress.	Linneman et al. (2015) Total: 1
	Center for Epidemiology Studies Depression Scale	Scale asks if "during the past week" participant has felt conditions such as "I had crying spells" or "I felt that people disliked me" from "rarely" to "most of the time" (Radloff, 1977).	Garza-Villarreal et al. (2014); Siedliecki & Good (2006) Total: 2
	Numerical Rating Scale	See above but applied to anxiety.	Guetín et al. (2016) (anxiety) Total: 1
	Patient Global Impression of Change Scale (PGIC)	Participant rates on scale from 1-7 perceived change in activity limitations, symptoms, emotions, and overall quality of life (Busner & Targum, 2007).	Bradt et al. (2016) Total: 1
	Positive and Negative Affect Scale	Participants rate feelings of positive affect ("enthusiastic, active, and alert") and negative affect ("sadness and lethargy") (Watson & Clark, 1988).	Fredenberg & Silverman (2014) Total: 1
	Expectancy of Relief Scale	Description unavailable.	Hsieh et al. (2014) Total: 1
	WHO Quality of Life Scale	See above.	Mitchell et al. (2007) Total: 1

	Power as Knowing Participation in Change Tool (version II)	A 52-question profile that asks about awareness, choices, freedom to act intentionally, and involvement in change (Barrett 2009).	Siedliecki & Good (2006) Total: 1
	Modified Yale Preoperative Anxiety Scale for children (mYPAS)	A 4-item assessment tool for children's anxiety in perioperative settings (Jenkins, 2014).	Yu et al. (2009) Total: 1
	Pain Catastrophizing Scale (PCS)	Participant selects answers on numerical scales measuring "ruminating, magnification, and helplessness" (Sullivan, Bishop & Pivik, 1995).	Garza-Villarreal et al. (2014) Total: 1
	Interference Scale	Description unavailable.	Bradt et al. (2016) Total: 1
	General Activities Scale of the Westhaven-Yale Multidimensional Pain Inventory (MPI)	Tailored to assess psychological and behavioural manifestations of chronic pain (Kerns, Turk & Rudy, 1985).	Bradt et al. (2016) Total: 1
	Timed Up and Go Task	Patients are seated comfortably in a chair, then asked to get up at the sound of the word "go" and walk three meters, turn, walk back, and sit down (Podisadlo & Richardson, 1991).	Garza-Villarreal et al. (2014) Total: 1
	Pain Disability Index	Numerical rating scales to determine the extent chronic pain interferes with daily activities.	Siedliecki & Good (2006) Total: 1

Table 2: Summary of self-reporting scales found in the literature

significant decreases in pain but males did not and in Siedliecki and Good (2006) European-American participants reported pain relief reaching statistical significance but African-American participants did not. It is worth noting that the five aforementioned empirical studies still concluded that music interventions could be beneficial for pain under certain conditions.

Around 13% of empirical studies included in this review (3) attained null results from patient self-reports during music interventions for pain. For example, a descriptive study by Linneman et al. (2015) examined the relationship between daily music listening and pain among fibromyalgia patients. Researchers asked the participants to listen to music as they normally would in their daily lives and had them fill out a VAS for pain intensity five times daily for 14 days. There were no associations demonstrated between music listening and perceived pain intensity as reported through the VAS.

In summary, a majority of the 23 empirical studies included in this review published significant decreases in participant pain using self-reporting scales. However, a minority contained mixed results and a handful reported only null findings. Effect sizes were generally small to moderate, especially when sample sizes were also small. However, the effect sizes in the study by Huang, Good and

Zauszniewski (2010) were relatively large even amongst the 65% of empirical studies with significant results, perhaps because the sample size of n = 126 was also larger than average.

The eight literature reviews we consulted described similar trends. Only two literature reviews concluded that their sampled studies demonstrated consistent, significant decreases in pain during or after music interventions (Clements-Cortés, 2016; Tam, Lo & Hui, 2016). The remaining six reviews expressed cautious optimism that music interventions are an effective pain management tool but included caveats about the persistent presence of inconclusive results in the literature. For example, Bernatzky, Presch, Anderson and Panksepp (2011) reviewed 15 randomised controlled trials examining music and post-operative pain in adults. The authors asserted that these studies demonstrated “consistent positive trends” but that there were instances of studies with inconclusive results (Bernatzky et al., 2011, p. 1992). Furthermore, the authors noted that the effect size of music interventions on self-reported pain was moderate or small in many of the trials.

A 2009 literature review by Engwall and Duppils reached similar conclusions. The authors synthesised the findings of 14 randomised controlled trials (RCTs) and four quasi-experimental studies of the effects of music on post-operative pain in adults. The authors found that 15 of the 18 studies showed robust evidence of music-induced analgesia. Overall, Engwall and Duppils (2009, p. 382) concluded that music “seems to have a beneficial effect on post-operative pain,” but noted that the range of surgeries in the studies was quite broad and that such a lack of control could be problematic when attempting to generalise these effects.

The synthesis provided by Klassen et al. (2008) also depicts a mixed picture. These authors reviewed 19 randomised controlled trials with children undergoing medical and dental procedures. Only nine studies significantly favoured music intervention groups over control groups, and an additional two studies favoured “passive” but not “active” music interventions.[3] The authors write, “our results show that music is effective in reducing anxiety and pain during clinical procedures in children and youth”, but they also note the substantial heterogeneity of medical procedures and the fact that the results “do not definitively indicate for which procedures music therapy will be most beneficial” (Klassen et al., 2008, p. 126).

The eight literature reviews and 23 empirical studies included in this integrative review provide extensive documentation of music-induced analgesia through self-reporting scales but the prevalence of mixed and null results gave many researchers pause. The following sections summarise findings about music-induced analgesia from physiological measures and monitoring medication usage.

Physiological measures of pain

Only six out of the 23 empirical studies in our review measured physiological response during music interventions for pain. The type of physiological data collected varied from study to study. Vital signs (e.g., mean arterial pressure, oxygen saturation, heart rate, and respiratory rate) were the most common physiological measures (Alam et al., 2016; Allred, Byers & Sole, 2010; Liu & Petrini, 2015; Yu

[3] According to Klassen et al. (2008, p. 118): “Studies were classified as using active MT [music therapy] if a music therapist was involved and the therapeutic sessions included interactive communication using music as a medium. Passive MT was defined as listening to music—whether recorded or live—without the involvement of a music therapist”.

et al., 2009). However, vital signs are only an indirect measure of pain and stress levels, as Allred, Byers and Sole (2010, p. 16) write: “Pain causes stress, which in turn causes the cardiovascular system to respond by activating the sympathetic nervous system, resulting in increased heart rate, blood pressure, and oxygen demand”. Linneman et al. (2015) also took samples of participants’ salivary cortisol and alpha-amylase as indications of stress. In contrast, one study (Dobek et al., 2014) looked for direct evidence of pain relief by taking fMRI images of the brain, brain stem, and spinal cord. These images captured blood oxygenation level dependent (BOLD) response changes in areas known to be involved in descending analgesic pathways.

Only the study involving fMRI images (Dobek et al., 2014) reported physiological results that were statistically significant and indicated reductions in pain for participants in music intervention groups. Three empirical studies (all involving vital signs) reported mixed results: Allred, Byers, and Sole (2010), Liu and Petrini (2015), and Yu et al. (2009) reported statistically significant improvements to some but not all the vital signs measured. Two empirical studies, one taking vital signs (Alam et al., 2016) and the other taking saliva samples (Linneman et al., 2015), reported only null results.

Only three of the eight literature reviews we surveyed included substantial discussion of physiological data collection (Clements-Cortés, 2016; Lee, 2016; Tam, Lo & Hui, 2016). All three reviews reported that only some of its included studies included physiological measurements and showed improvements in these measurements. Given the trends in both the individual empirical studies and the literature reviews, we conclude that very few researchers included these types of measures in their studies, and the results were often inconclusive among the studies of those who did gather physiological data in an effort to searching for biological evidence of pain or stress relief.

Medication usage

Only three empirical studies (13%) in our review reported data about participant medication usage (Allred et al., 2010; Guétin et al., 2012; Liu & Petrini, 2015). None of the empirical studies found statistically significant reductions in analgesic medication usage during or after music interventions. Guétin et al. (2012) measured participant use of analgesic, antidepressant and anxiolytic medications but found significant decreases only in the use of anxiolytics. Two other individual empirical studies (Allred et al., 2010; Liu & Petrini, 2015) measured participant use of pain medications, but found no statistically significant changes during or after music interventions. Given that most of the empirical studies we reviewed were conducted in clinical settings, data about participant medication usage was probably available to many more than the three empirical studies in our sample. However, most researchers did not include medication usage as a measurement of pain relief.

The eight literature reviews we consulted also lacked information about medication usage during music interventions. Only two reviews (Engwall & Duppils, 2009; Lee, 2016) included studies that measured patient use of analgesic medications. Engwall and Duppils’s (2009) literature review included 18 studies, but only 11 of those studies reported data about patient use of opioid medications. Five of these 11 studies (around 45%) reported statistically significant decreases in patient use of opioids in music intervention groups. A 2016 literature review by Lee included seven studies that reported data about the use of anaesthetics, 23 studies that reported on opioid usage, three studies that measured use of non-opioid analgesics, and seven studies that reported data on the use of sedatives. Lee (2016) found that on average the studies reported statistically significant decreases in use of analgesic medications, with sedatives being the only exception. However, the effect size for opioid medications was small, and the effect size for anaesthetics and non-opioid analgesics was moderate at most.

Summary of findings

In summary, this body of research demonstrates that music-induced analgesia is a consistently observable phenomenon in clinical settings. Decreases in self-reports of pain are the most robust trend to emerge from the research but there is still a sizeable minority of articles that reported inconclusive results. The magnitude of pain relief is also worth noting – in many articles, the self-reported decreases in pain reached statistical significance but were still modest. Furthermore, the results become far less conclusive when derived from indirect measures of pain, such as vital signs or use of medication, rather than self-reporting scales. Although most authors of the articles concluded that music interventions produce pain relief, questions remain about why results continue to be mixed.

DISCUSSION

Critical analysis of methodological approaches

The following section consists of an analysis of methodological inconsistencies and weaknesses observed in the recent literature. First, we will discuss the difficulty of defining and measuring pain. Next, we will discuss controversies in the recent literature about best practices when structuring music interventions. Finally, we highlight concerns about trends in experimental design (e.g., small sample sizes, lack of randomisation, threats to internal and external validity).

Defining and measuring pain

Defining and measuring pain is a notoriously troublesome task. Similarly, defining music and delineating common characteristics that make certain music 'therapeutic' is fraught with challenges. These challenges are to be expected when approaching a complex subject like music-induced analgesia. However, certain methodological choices can be more helpful than others when it comes to clarifying the complex relationship between music and pain.

For example, we found no unified operational definition of pain in the literature. Some researchers chose a standard definition to use, such as Sin and Chow (2015) who reference a statement from the International Association for the Study of Pain (2012, p. 979): "Pain is described as an unpleasant sensory and emotional experience resulting from actual or potential tissue damage". Others opt for a description of pain's physiological effects, such as Allred, Byers and Sole (2010, p. 16) who write, "Pain causes stress, which in turn causes the cardiovascular system to respond by activating the sympathetic nervous system, resulting in increased heart rate, blood pressure, and oxygen demand". However, many authors did not provide any definition of pain whatsoever – not even descriptions of the specific type of pain involved in the study.

Although some aspects of pain may seem obvious, the way that researchers define pain can, in fact, be a point of contention. Many in the scientific community assert that not all pain is the same phenomenon—that chronic pain is a process distinct from acute pain, or that pain can be classified as somatic, visceral, or neuropathic and behave in completely different ways (Melzack, 1999; Perron & Schonwetter, 2001). Others posit that most pain is a perceptual construct of the brain and would reject the idea that pain is a product of actual or potential tissue damage (Macknik & Martinez-Conde, 2013). Different definitions of pain can inform how we ask questions about pain and what mechanisms we might investigate to explain pain relief. Assuming that pain does not need to be defined is poor scientific practice.

To further complicate the issue, the articles included in this review address an enormous range of pain conditions. For example, articles included post-surgical pain (e.g., knee arthroplasty, hysterectomy, blood and marrow transplant), procedural pain (e.g., bronchoscopy, dental work, acupuncture), chronic pain (e.g., fibromyalgia, neuropathy, musculoskeletal pain) and experimental pain (e.g., cold pressor, noxious heat). Most articles selected one, specific pain condition, but sometimes the categories were broad enough that divergent pain experiences were included in the same study. For example, Good, Ahn and Payne (2008) conducted a quasi-experimental study to examine the effects of music on patients recovering from gynaecological surgery. However, the category of "gynecological surgery" included such vastly different experiences as Caesarean sections and laparoscopic surgeries for malignant tumours. Even the authors of the study noted that their participants' physical and emotional experiences varied widely and could have influenced the results.

The heterogeneity of pain types makes comparing results within and between articles quite challenging. Some authors expressed concern at trying to use the same research methods to detect pain relief across such heterogeneous types of pain. For example, Engwall and Duppils (2009) conducted a literature review of 18 studies involving music and post-operative pain. However, the surgeries ranged "from major abdominal and open-heart surgery to ambulatory surgery" (Engwall & Duppils, 2009, p. 381). Engwall and Duppils noted that the levels of pain, duration of pain, and timeline for music interventions varied drastically between these procedures. However, most researchers applied the same methods to all pain conditions—short, passive listening sessions (without a music therapist) with self-reports before and after music interventions. Engwall and Duppils concluded that the types of pain included in any given study could noticeably impact the findings. For example, in their review, most of the empirical studies without significant findings involved minimally-invasive laparoscopic procedures. Engwall and Duppils state: "It is possible that the laparoscopic surgery might have caused a limited extent of pain. Low pain ratings among the participants before the intervention might have had an influence on the result because initial pain scores were not severe" (Engwall & Duppils, 2009, p. 381). In other words, the lack of significant results in some empirical studies may have been because researchers used the same interventions for invasive and non-invasive surgeries. This begs the question — does music provide more relief to certain types of pain than others? In our observations, the literature does not provide much insight into these nuances. An equally complex methodological issue is how to measure pain. Without exception, the empirical studies included in this review used self-reporting scales to measure pain. Some used self-reports in conjunction with other measurements such as medication usage or vital signs, however, most relied entirely on self-reports.

Moreover, the majority of significant outcomes in the literature were found with data gathered via self-reporting scales. While data from self-reporting scales are valuable, they present limitations when used almost exclusively as an outcome measure. Given that self-reporting scales cannot provide a measure of physiological changes that could produce real or perceived reductions in pain, it is important to consider what self-reporting scales do measure.

A growing cadre of researchers are critiquing the efficacy of self-report measures in music intervention studies. A literature review by Klassen et al. (2008, p. 127) questioned the accuracy of using self-reporting scales with young children, stating "self-report scales of pain, although reliable and valid among older children, show bimodal distribution with younger children, indicating that they may not have the cognitive ability to grade pain on a scale". Engwall and Duppils (2009) conducted a literature review of music intervention studies involving adults recovering from surgeries and pointed out that much of the data collection using self-reporting scales occurred when patients were heavily medicated, and sometimes even emerging from anaesthesia. Engwall and Duppils questioned the ability of patients emerging from anaesthesia to accurately self-report using these scales, stating, "the potent effect of the drugs that are used during general anesthesia could have a negative influence on the ability to report pain immediately postoperatively" (Engwall & Duppils, 2009, p. 381). Yu et al. (2009) pointed out that scales used in their study had not been proven effective specifically for children with cerebral palsy (the focus demographic of the study). Vaajoki et al. (2012) raised concern that their results came from non-objective outcome measures. Although many of the scales used in the literature have been rigorously tested for efficacy and accuracy, whether they are being applied in a valid manner in all situations is clearly a question that has implications for the quality of results.

The assumption that a scale is psychometrically sound may be flawed, however, if the tests of its efficacy excluded certain medical conditions or demographic populations. A study by Bradt et al. (2016) is a prime example of this measurement validity problem. Bradt et al. conducted a mixed-methods feasibility study involving vocal music therapy for people suffering from chronic pain. Their randomised controlled trial employed a number of self-reporting scales for pain, emotion, and general functioning. They then held exit focus group interviews to collect qualitative data about participants' experiences in the trial. Their participants were almost exclusively African-Americans who resided in low-income, inner-city areas. Bradt et al. (2016) questioned the ability of certain self-reporting scales to accurately capture the experiences of this particular demographic. For example, they write:

> For physical functioning, responses on the General Activities Subscale of the Multi-dimensional Pain Index showed no improvement. This subscale asks questions related to social activities (e.g., visit friends, go to the movies) and chores (e.g., do laundry). In contrast to the quantitative ratings, participants shared that since participating in the vocal music therapy treatment program they felt less isolated, had the desire to be around people again, and experienced joy when being with others. When asked about the discrepancy of these statements with their questionnaire scores, they provided three main explanations. First, they stated that many items on the scale did not capture the benefits they received from VMT. Second, they reported that they refrained from participating in several items listed on the scale (e.g., going to the movies, taking a trip) because of financial constraints, bringing the social validity of this scale

> into question for inner-city, low-income African Americans. Third, participants explained that chronic pain had ruined their social relationships and that it would take more than 8 weeks to restore these. (Bradt et al., 2016, p. 21).

Self-reports also raise the risk of bias in experiments during which the participants cannot be blinded, as is the generally the case with music intervention studies. Some researchers even informed participants of possible pain benefits before the music interventions, raising the risk of bias and other threats to experimental validity such as the Hawthorne effect (Engwall & Duppils, 2009).

After gathering these and other criticisms of self-reporting scales, we conclude that our understanding of music-induced analgesia will not progress substantially if researchers continue to rely exclusively on these scales to document the effects of music on pain. While useful, self-reporting scales can only capture parts of the phenomenon that is music-induced analgesia. More consistent measurement of medication usage, vital signs, and biomarkers of stress (not to mention further experiments using brain imaging) would help address the questions left unanswered by self-reporting scales. While so many of these questions remain (how do we define pain? Are all pains the same phenomenon? How does music induce pain relief in the brain and body? Under what conditions is music most effective in reducing pain? etc.) diversifying measurement approaches would undoubtedly be beneficial.

Controversies in structuring music interventions

Our review of the extant literature found a number of unresolved controversies about which types of music interventions are most therapeutically effective. The two prominent debates were whether researcher-selected or participant-selected music are more likely to lead to reductions in pain and whether ‘active’ or ‘passive’ music interventions are more clinically valid. Most researchers chose to have participants listen to either researcher-selected or self-selected music and appeared to have strong convictions for one approach or the other. Proponents of self-selected music commonly argued that a participants’ emotional connection with a piece of music provides great therapeutic value. Proponents of researcher-selected music asserted that certain musical characteristics such as tempo, range, and timbre, are key to the therapeutic value of music interventions. However, we found few articles that actually compared the effects of researcher-selected vs. participant-selected music within the same trial.

Only two empirical studies in our sample (Mitchell & Hons, 2006; Mitchell, Macdonald & Brodie, 2006) demonstrated statistically significant differences between participants who selected their own music versus participants who had music selected for them by researchers. Both of these studies were conducted in laboratory conditions and exposed young adult participants to cold pressor pain. Results from both studies indicated that participant-selected music was more effective than researcher-selected music in reducing pain and increasing tolerance to cold pressor pain. However, we recommend caution generalising broad conclusions from such a small sample of studies.

Another unresolved debate in the literature was that of ‘active’ versus ‘passive’ music interventions. Generally, ‘active’ interventions consisted of participatory music-making sessions or listening activities facilitated by a trained music therapist. ‘Passive’ music interventions, on the other hand, usually consisted of participants listening to pre-recorded music without the presence of a therapist or facilitator. The vast majority of the empirical studies included in this review involved passive music interventions. Moreover, some researchers assert that the involvement of a trained music therapist is required to be considered "music therapy" (American Music Therapy Association, 2010). Our integrative review found only two literature reviews (Klassen et al., 2008; Lee, 2016) that analysed studies comparing the presence or absence of a music therapist in the same trial. No statistically significant differences between the types of interventions were found in either analysis.

Lee (2016) conducted a comparative analysis of 87 studies with 'passive' music interventions and ten studies with 'active' music interventions, contrasting their effects on self-reported pain scales. Lee found that on average the ten 'active' studies (referred to in the literature review as 'music therapy', all involving a music therapist) resulted in a -1.50 decrease on numerical rating scales of pain. The 87 'passive' studies (referred to in the literature review as 'music medicine', all without the presence of a music therapist) showed -1.08 decrease on numerical rating scales of pain. The difference was not statistically significant but heterogeneity was much higher for 'passive'/'music medicine' studies than 'active'/'music therapy' studies. Additionally, as Lee (2016, p. 468) points out,

> Gallagher, Liebman, and Bijur (2001) reported that the minimum change required for achieving a clinically meaningful change is 1.3 on 0 to 10 VAS scales. Based on that recommendation, music therapy is found to be clinically significant, whereas music medicine is not.

Determining whether specific musical characteristics are inherently therapeutic is also important to our understanding of music and pain. Understanding the importance of musical features such as tempo or frequency adds to our knowledge of how music relieves pain. Similarly, knowing if self-selection of music or active participation in music-making provide the best foundation for pain relief is highly relevant to clinical practice. However, more research is needed to resolve the controversies surrounding the various forms that music interventions can take.

Experimental design characteristics

A common theme in the recent literature is the questionable methodological rigour in many music intervention studies. Six of the eight literature reviews discussed in this paper concluded that the methodological quality of the studies reviewed was poor (see Clements-Cortés, 2016; Engwall & Duppils, 2009; Klassen et al., 2008; Lim & Locsin, 2006; Sin & Chow, 2015; Tam, Lo & Hui, 2016). Common methodological critiques included small sample size, strong potential for bias and placebo effect, lack of true control groups, lack of randomisation, inadequate reporting of methodology, and inability to double-blind.

These and similar points of critique were echoed by some authors of the individual empirical studies discussed in this review as well (Allred, Byers & Sole, 2010; Good, Ahn & Payne, 2008; Guétin et al., 2012; Gutgsell et al., 2013; Hsieh et al., 2014; Linneman et al., 2015; Mitchel & Hons, 2006; Vaajoki et al., 2012). For example, Allred, Byers and Sole (2010) compared the effects of a music intervention versus a quiet rest period on the pain of 56 adults recovering from total knee arthroplasty. However, no statistically significant differences between the two experimental groups on self-reports or vital signs were found. The authors concluded that "since the quiet rest period became an intervention, the actual effect size was small for both pain and anxiety, resulting in a sample size that was too small to detect any differences" (Allred, Byers & Sole, 2010, p. 24). The lack of a true control group along with small sample size (e.g., low statistical power) may have prevented any significant results.

Sample size emerged as a consistent concern among the authors cited in this review. Of the 23 individual empirical studies included in this review, only six had samples of over 100 participants. Eight studies had between 50 and 100 participants, and nine studies included fewer than 50 participants. A number of authors listed sample size as a concern, either calling for their experiments to be replicated with a larger number of participants or listing small sample size as a factor that may have influenced results.

A number of literature reviews also noted the trend of small sample sizes. For example, Clements-Cortés (2016, p. 127) conducted a review of music interventions in palliative pain care and stated, "One of the main issues with the quantitative studies to date surrounds small sample sizes and an intensified need for studies with increased control and randomization of participants as well as meta-analyses". Engwall and Duppils (2009, p. 381) note that in their review of studies involving post-operative pain in adults, "the sample sizes were generally small […] Larger samples are desirable to gather more evidence on the effect of music intervention on postoperative pain". Lim and Locsin (2006) conducted a literature review of nine studies examining music interventions for pain in five Asian countries. Lim and Locsin note that

> a sample of 30 participants for experimental and quasi- experimental studies is considered small (Burns & Grove 1997). Nonetheless, four studies had sample sizes equal to or less than 30 participants […] The mixed and inconsistent results may be explained by the limitations and weaknesses of the studies, such as small sample sizes and lack of strict control of threats to validity. (Lim & Locsin 2006, p. 194)

Overall, the literature indicates a clear need for larger samples.

Two concerns pertaining to participants' demographic characteristics emerge from the literature: (a) insufficient collection of relevant demographic data and (b) inadequate representation of certain populations in music therapy research. Many studies did not collect (or report) data about race/ethnicity, socio-economic background, or musical training of their participants. However, those few studies that examined these variables found that all three can influence the outcomes of music interventions for pain. For example, Siedliecki and Good (2006) found that the effect of their music intervention was only significant for the European-American participants in the study, whereas the results for the African-American cohort were inconclusive. The authors call for greater attention to ethnic, racial, and cultural differences in the field of study and for methodologies that better capture diverse experiences of pain, emotional distress, and music.

The second concern is that certain populations are over-represented in music and pain research while others are underrepresented. For example, most of the articles included in this integrative review focused on middle-aged adults (40 to 60 years old). Only one literature review (Klassen et al., 2008) and one empirical study (Yu et al., 2009) focused exclusively on children and only three empirical studies targeted young adults (Dobek et al., 2014; Mitchell & Hons, 2006; Mitchell, Macdonald & Brodie, 2006). Similarly, most empirical studies included predominantly female participants. The only studies in which males outnumbered females were studies conducted in China and Taiwan (Huang, Good & Zauszniewski, 2010; Liu & Petrini, 2015; Yu et al., 2009). However, the only study to control for fluctuating pain thresholds during the course of menstrual cycles was Dobek et al. (2014). Additionally, there were no studies that included sexual orientation, gender identity, or intersex status in data collection.

The research included in this integrative review presented methodological limitations, including a lack of operational definitions of pain, utilising the same experimental tools despite the variety of pain, over-reliance on self-reporting scales, lack of rigour in demographic reporting, lack of diversity among samples, small sample sizes and weak experimental designs. Taken together, these concerns could be potential reasons for the prevalence of mixed results, threaten the generalisability of the claims made within the existing research and present substantial challenges for moving the field of research forward.

Theoretical explanations for therapeutic effects of music on pain

Most of the research included in this review was clinical in focus. The researchers were predominantly concerned with studies demonstrating the effects of music in clinical settings and exploring implications for the practical work of music therapists. However, very little research has focused on theoretical frameworks to explain this phenomenon. As Yinger and Gooding (2015, p. 72) state, "music-based intervention studies have been criticized for the absence of a theoretical framework guiding the intervention content". The paucity of research into neurological and physiological mechanisms that could explain the effects of music on pain is a salient concern in the field and has broad implications for the future of this line of research.

Given the current lack of an existing evidence base, the question of how music might induce pain relief is largely unanswered. There is an unfortunate scarcity of evidence for any specific physiological mechanisms that could underlie a causal relationship between music and pain. General theories about pain abound and some articles included in this review cite these theories as plausible frameworks for music-induced analgesia. However, a surprising number of researchers failed to describe any theoretical underpinnings in their articles, and sometimes those who did demonstrated an outdated or oversimplified understanding of pain theories. These problems point to issues in research culture and a possible information gap between cutting-edge pain research and music practice.

An evidence-based theoretical framework for music-induced analgesia could help resolve many of the unanswered questions about pain and music interventions. An understanding of underlying mechanisms could provide insight into the continued prevalence of mixed results in clinical settings. It could also provide explanations for why some music interventions work better than others for certain types of pain, ages, demographics, and musical backgrounds. Furthermore, it could shed light on the controversy about passive versus active music interventions. As Yinger and Gooding (2015, p. 72) state, future research should focus on finding and explaining physiological mechanisms "in order to better articulate how and why music is selected and applied, and to promote a greater understanding of the mechanisms of change at work" in music-induced analgesia. Much more attention should be placed on studies that investigate a biological basis for how music affects pain, not just if music relieves pain.

More specifically, further research is needed to pit theoretical frameworks against one another and to accumulate evidence for and against certain underlying mechanisms. Many factors are known to be involved in the perception and modulation of pain, and any number of these factors could produce music-induced analgesia. Additionally, research that explores what mechanisms might be involved in different types of pain (such as chronic vs. acute) or in different types of music activities (such as active vs. passive) would paint a much clearer picture of how the brain and body interacts with painful and musical stimuli. In the meantime, even promising explanations of music-induced analgesia remain unconfirmed.

The empirical studies and literature reviews included in the current paper dealt with theoretical frameworks in a variety of ways. Six articles failed to describe any theoretical framework at all or did so in a perfunctory way, such as briefly describing that music's effects on pain are physiological, behavioural, and emotional but then declining to elaborate (Vaajoki et al., 2012). There seemed a surprisingly high number of researchers who did not provide a theoretical framework for how music influences pain or even how pain functions more generally.

However, an equal number of empirical studies and literature reviews commented on the general lack of discussion about theory. The authors of this review counted six articles in which authors lamented the lack of understanding about physiological mechanisms involved in music-induced analgesia and the subsequent absence of robust theories explaining the phenomenon. For example, a literature review by Bernatzky et al. (2011) discusses possible explanations for music's effects on pain, then points out that the field of research has not advanced far enough to confirm or deny their propositions. For example, the authors hypothesise that if research into physiological mechanisms progresses, they "anticipate" evidence that endogenous opioids and other neurochemicals such as oxytocin might be involved in music-induced analgesia (p. 1990). However, they opine that "the science of [music therapy's] benefits has not progressed as rapidly as its acceptance" (p. 1990).

Bernatzky et al. (2011) conclude that many clinical studies point towards music being an effective adjuvant therapy but note that this evidence is limited when not accompanied by knowledge of underlying mechanisms:

> In sum, evidence is accumulating that music can be used to promote feelings of wellbeing and to facilitate therapeutic objectives […] but to most effectively employ music in [pain-management], the physiological sources and neurological pathways that give rise to music's power need to be explored. (Bernatzky et al., 2011, p. 1992)

Bernatzky et al. (2011, p. 1989) call for further research to "focus both on finding the specific indications and contra-indications of music therapy and on the biological and neurological pathways responsible for those findings". The other articles that highlighted the lack of theoretical frameworks applied in the literature reached similar conclusions.

Two such articles, an experiment by Garza-Villarreal et al. (2014) and a study by Linneman et al. (2015), offer a prime example of competing theoretical frameworks in action. Both studies examined the effects of music on fibromyalgia patients. Garza-Villarreal et al. (2014) compared pain-scale ratings and timed up-and-go (TUG) tasks between a control group listening to "pink noise" and an experimental group listening to self-selected music. Linneman et al. (2015) asked participants to listen to music as they normally would in their daily lives but to fill out reports five times per day for 14 days. The reports included rating scales for pain intensity, perceived control over pain, stress, and frequency of music listening (among other variables). These reports were also supplemented with saliva samples as biomarkers of stress. Garza-Villarreal et al. and Linneman et al. advance very different underlying mechanisms for music-induced analgesia, only to then caution the reader that these hypotheses have yet to be verified.

For example, Garza-Villarreal et al. (2014) assert that fibromyalgia sufferers will experience relief from music because of primary analgesic pathways in the central nervous system (possibly involving dopamine) and because of secondary cognitive and emotional processes (such as distraction):

> Listening to music reduces acute and chronic pain (Guétin et al. 2012; Roy et al. 2012; Korhan et al. 2013). Several studies have suggested that the analgesic effect of music (or music- induced analgesia) may be secondary to cognitive and emotional effects that arise from listening to music… Distraction is a well-known cognitive analgesic mechanism (Tracey et al. 2002; Villemure & Bushnell 2009) that is present when listening to music. Also, listening to music has been related to dopamine release from the caudate and the nucleus accumbens (Salimpoor et al. 2011), and dopamine itself is known to have a role in central analgesia (Wood, 2008). […] All this evidence suggests that music-induced analgesia may be regarded as a "central" type of analgesia, as the effect seems to occur in the brain stem, secondary to cognitive and emotional brain processes and by means of central neurotransmitters (i.e., dopamine). (Garza-Villarreal et al., 2014, p. 1)

However, later in the study Garza-Villarreal et al. (2014) acknowledge that "it is not yet known which are the specific mechanisms behind music-induced analgesia" (p. 4) and that the music-induced pain relief experienced by some fibromyalgia sufferers in their study was not "directly measured" (p. 6). The explanation that music-induced analgesia is the result of processes in the central nervous system with secondary cognitive and emotional effects is a logical leap from prior research. However, as the authors concede, it is a theory that has yet to be directly corroborated.

Linneman et al. (2015) also recruited participants suffering from fibromyalgia but opted for a completely different explanation of music-induced analgesia. The authors present prior research showing that music can stimulate the limbic system, reduce cortisol levels (a biomarker of stress) and impact the autonomic nervous system (ANS). They also summarise well-known facts about pain's interactions with stress involving the hypothalamus-pituitary-adrenal axis (HPA axis) and ANS. Following from this research, the authors assert that music reduces pain by stimulating the limbic system, which can down-regulate both the HPA axis and ANS:

> On a neurobiological level, music listening exerts effects in the central nervous system that are critical to the modulation of both pain and stress. The limbic system can be regarded as a key structure in this context, which further impacts on neuroendocrine and autonomic functioning. (Linneman et al., 2015, p. 434)

Similar to the hypothesis stated by Garza-Villarreal et al. (2014), the explanation posited by Linneman et al. (2015) flows logically from previous research. However, it involves completely different brain structures, chemicals, and physiological responses. As with Garza-Villarreal et al. (2014), Linneman et al. (2015) qualify their assertions with heavy caveats:

> Nevertheless, the exact mechanisms underlying the pain- reducing effect of music remain unclear. One open question concerns whether music listening can reduce pain per se (i.e., direct effect) or whether it facilitates coping with pain (i.e., indirect effect). Bernatzky et al. (2012) state that music exerts effects in the brain that directly impact on the relevant pain circuits, which in turn reduce the perception of pain intensity. However, the empirical evidence is not consistent in this regard, as there are also studies showing no music-induced reduction in perceived pain intensity (i.e., MacDonald et al. 2003). (Linneman et al., 2015, p. 434)

Linneman et al. used the hypothesis of HPA-axis/ANS down-regulation to guide their study (specifically the decision to take saliva samples for biomarkers of stress). However, like Garza-Villarreal et al., they clearly understand that the underlying mechanisms of music-induced analgesia are an open question.

This comparison of the Garza-Villarreal et al. and Linneman et al. studies demonstrates that there are multiple plausible theoretical explanations for music-induced analgesia. However, without more evidence, we cannot say definitively that dopamine is any more or less responsible for the analgesic effects of music than down-regulation of the HPA axis via the limbic system. Given the current state of the research, two teams can approach the exact same population (fibromyalgia patients) with the same research target (music's effects on pain) and use completely different frameworks to understand the results.

Bernatzky et al. (2011), Garza-Villarreal et al. (2014), and Linneman et al. (2015) balance the promising logic of their proffered theoretical frameworks with the acknowledgement that they are as yet unconfirmed. However, many of the remaining empirical studies and literature reviews that cited a theoretical framework did so without qualifiers about the scarcity of evidence for or against it. Furthermore, there was an abundance of theories cited, revealing a lack of consensus in the field of research. Table 3 provides a summary of all the theories referenced in our sample as possible explanations for music's effects on pain. Some of these theories are more robust than others, and some reveal a more nuanced understanding of pain than others.

For example, one of the most frequently cited theories was gate-control theory. Gate-control theory states that certain stimuli (such as music) can close neural 'gates' in the spinal cord that transduce painful sensations, thereby relieving pain. Psychologists Ronald Melzack and Patrick Wall (1965) proposed this theory in the 1960s, and it has since become a widely-accepted model applied in

Theory	Summary	Citations using this theory
Name: Gate-control theory *Discipline*: Psychology / neuroscience	*General theory*: certain stimuli can close neural 'gates' in the spinal cord that transduce painful sensations, thereby relieving pain. *Relation to music*: music somehow closes pain 'gates' in the spinal cord and reduces sensations of pain.	Engwall & Duppils (2009); Finlay (2014); Good, Ahn & Payne (2008); Guétin et al. (2012); Klassen et al. (2008); Lee (2016); Mitchell, MacDonald, Knussen & Serpell (2007); Lim & Locsin (2006); Mitchell & Hons (2006); Mitchell, Macdonald & Brodie (2016) Total: 10
Name: Attention/perception of pain (cognitive pain modulation) *Discipline:* Psychology / neuroscience	*General theory:* Distraction can be used to relieve pain or other unpleasant emotions. *Relation to music*: music channels attention towards a pleasant stimuli and distracts away from painful stimuli, thereby decreasing sensations of pain.	Bradt et al. (2016); Garza-Villarreal et al. (2014); Guétin et al. (2012); Mitchell, MacDonald, Knussen & Serpell (2007); Lim & Locsin (2006); Mitchell & Hons (2006); Mitchell, Macdonald & Brodie (2016); Mitchell, Macdonald & Knussen (2008) Total: 8
Name: Endogenous opioids/descending analgesic pathways *Discipline:* Neuroscience	*General theory*: Descending analgesic pathways in the brain and spinal cord use endogenous opioids (beta-endorphin, met- and leu-enkephalins, and dynorphins) and other neurochemicals to diminish painful sensations. *Relation to music:* Music triggers the release of endogenous opioids (or other neuro-chemicals) in the brain and relieves pain via descending analgesic pathways.	Bernatzky et al. (2011); Bradt et al. (2016); Dobek et al. (2014); Garza-Villarreal et al. (2014); Good, Ahn & Payne (2008); Hsieh et al. (2014) Total: 6
Not specified	N/A	Clements-Cortes (2016); Guétin et al. (2016); Liu & Petrini (2015); Man et al. (2015); Vaajoki et al. (2012); Yu et al. (2009) Total: 6
Name: Stress (HPA axis, autonomic nervous system) *Discipline*: Neuroscience	*General theory*: Pain interacts with the hypothalamus-pituitary-adrenal axis (HPA axis), which controls the body's stress response. Stress leaves physical traces, such as increased cortisol levels or stimulation of the sympathetic nervous system (resulting in quickened heartbeat, increased blood pressure, etc.) Pain and stress can form a self-reinforcing feedback loop. *Relation to music*: music acts in some way to mitigate stress via down-regulation of the HPA axis, thereby decreasing pain.	Alam et al. (2016); Linneman et al. (2015); Bernatzky et al. (2011); Allred, Byers & Sole (2010); Tam, Lo & Hui (2016) Total: 5
Name: Neuromatrix theory Discipline: Psychology / neuroscience	*General theory*: perception of pain is not the brain's passive response to peripheral stimuli, but an active generation of a subjective experience in a network of neural processing loops (called the 'neuromatrix'). *Relation to music*: music acts in some way to influence the construction of this subjective pain experience and mitigate the perception of pain.	Finlay (2014); Mitchell & Hons (2006); Mitchell, Macdonald & Brodie (2006) Total: 3

Name: Limbic/paralimbic affective pain modulation *Discipline*: Neuroscience	*General theory*: areas of the brain that process emotion and mood interact with perceptions of pain. *Relation to music*: music is a powerful modulator of emotion and may interact with limbic structures that also influence pain perception.	Bradt et al. (2016); Guétin et al. (2012); Linneman et al. (2015) Total: 3
Name: Pleasure, reward, and motivation centres of the brain *Discipline*: Neuroscience	*General theory*: over time, pain changes the way that pleasure, reward, and motivation centres of the brain responds to stimuli. *Relation to music*: music is known to activate these areas of the brain and could potentially serve to mitigate the effects of pain in these brain regions.	Hsieh et al. (2014); Linneman et al. (2015) Total: 2
Name: Good and Moore theory of acute pain management and middle-large pain management *Discipline*: Nursing	*General theory*: outlines guiding principals of clinical pain management (for example, the idea that non-pharmacological adjuvants to analgesic medication can reduce pain). *Relation to music*: Music is worthy of exploration as a non-pharmacological adjuvant to medication.	Huang, Good & Zauszniewski (2010), Lim & Locsin (2006) Total: 2
Name: "Neurosignatures" and chronic pain *Discipline*: Psychology / neuroscience	*General theory*: as a corollary to neuromatrix theory, each person's brain produces a unique participative experience of pain called a "neurosignature." These neurosignatures often change when people undergo chronic pain. *Relation to music*: Music may disrupt or restore certain aspects of neurosignatures in chronic pain sufferers.	Finlay (2014) Total: 1
Name: Meyer's theory of music and emotion *Discipline*: Music theory	*General theory*: conceptualises the affective power of music. *Relation to pain*: the emotional influence of music can be harnessed to process pain.	Lim & Locsin (2006) Total: 1
Name: Roger's science of unitary human beings *Discipline*: Nursing	*General theory*: views nursing as both a science and an art that must insert itself into the life processes of unified (i.e., not divisible into unconnected parts) human beings. *Relation to music*: music interacts with many patterns in the unified human and should be explored as an adjuvant therapy in nursing.	Siedliecki & Good (2006) Total: 1
Name: Barrett's theory of power *Discipline*: Nursing	*General theory*: defines power as the knowing participation in change. *Relation to music*: music interventions can increase power through participation in change (i.e., pain relief).	Siedliecki & Good (2006) Total: 1

Table 3: Summary of theoretical frameworks presented in the literature to explain music-induced analgesia

pain research. However, a number of issues remain with this theory. Although there is evidence that certain stimuli do seem to 'turn off' or at least dampen pain signals, researchers have yet to discover the physical manifestation of the metaphorical 'gates' in the spinal cord. Despite our rapidly-increasing knowledge about how neurons function in the brain and spinal cord, we have yet to identify a specific mechanism that correlates with the premises of gate theory.

Furthermore, gate-control theory has been modified, enriched and augmented significantly since the 1960s. For example, Ronald Melzack (1999) himself proposed the complementary 'neuromatrix theory' to help explain observations about subjective pain experiences that could not be accounted for with gate-control theory, such as the way that pain thresholds change over time in people who suffer from chronic pain. Additionally, the knowledge that we now possess about the brain and body far surpasses that of the 1960s, and current theories of pain tend to embrace a wide array of complex variables. Gate-control theory remains an elegant model but is limited in its ability to accurately describe the physiological mechanics of a brain processing pain.

It is not surprising that many researchers would look to music as a type of stimuli that can close pain 'gates' in the spinal cord. However, we found many researchers referencing gate-control theory without caveats about the theory's limitations or questions about how to find physiological evidence for gate-control theory in action. At a certain point, referencing gate-control theory as an explanation for music-induced analgesia raises more questions than it does answers.

The literature included in this integrative review demonstrates a need for better understanding of the mechanisms involved in music-induced analgesia. Fortunately, some researchers have acknowledged this need and have also called for extensive inquiry to these ends. However, this review found only one study that produced evidence of potential underlying mechanisms for music-induced analgesia: an experiment by Dobek et al. (2014) which claims to be the first to use neural imaging to investigate music-induced analgesia.

Dobek et al.'s (2014) randomised controlled trial introduced participants to noxious heat stimuli and asked them to rate their pain on a 100-point scale with verbal descriptions. The experimental group brought in a self-selected piece of music at least 215 seconds long to listen to via headphones while undergoing the noxious heat. However, Dobek et al. (2014) also took fMRI images of both control and experimental groups during the course of the experiment. The fMRI images of the brain, brain stem, and spinal cord were taken to examine changes in BOLD responses in parts of the brain that are known to be involved in nociception, pain modulation, and audition of music.

The results of the subjective pain ratings showed an average of five points difference between the control and experimental group or roughly a 10% pain reduction in the experimental group. The results of the fMRI images supported the findings that participants in the experimental group were experiencing pain relief. As would be expected, the experimental group's fMRI images showed activity in brain areas involved in pain perception and music audition. However, the images also showed significant changes to BOLD responses in areas of the brain that are known to play a role in pain modulation. As Dobek et al. (2014, p. 1066) state,

> Results of this study are consistent with the hypothesis that pleasurable music evokes opioid release that may act on the limbic system, dorsolateral prefrontal cortex, and periaqueductal gray matter to activate the descending analgesia pathway. Subsequently, music produced a lower response magnitude in the dorsal horn of the spinal cord, which may have contributed to reduced pain perception.

These findings offer evidence to the theory that endogenous opioids/descending analgesic pathways are a primary mechanism for music's effects on pain.

Dobek et al.'s (2014) study was certainly limited in scope as it only included 12 participants, all of whom were females between the ages of 18 and 40. Replicating Dobek et al.'s results with a larger and more diverse sample size would certainly strengthen the evidence. Furthermore, as Dobek et al. (2014, p. 1066) note, "Future studies are needed to specifically probe whether music reduces pain by attention or emotion, or by another mechanism entirely". Additionally, future studies could examine other variables in pain modulation such as the HPA axis and stress responses. Although limited in scope, the Dobek et al. (2014) study is a step towards greater understanding of underlying mechanisms and provides a launching point for future investigation into music-induced analgesia.

Research into music's effects on pain has historically focused on clinical settings. Although this focus is essential for practice, it may also lead to a lack of emphasis on accruing physiological evidence that could point to the underlying mechanisms behind music's effects on pain. In addition to contributing to the therapeutic goals, future researchers should focus on pitting theories against one another and accumulating evidence for and against specific physiological explanatory mechanisms. The results from such studies should shed light on many of the unanswered questions in the field and provide helpful guidance for researchers concerned with clinical applications of music interventions. As Bernatzky et al. state in their 2011 literature review, "Finding the basis of the neurophysiological effects of the affective power of music may allow us to more fully harness the utility" of music in therapeutic settings (p. 1990). Without this evidence, "the controversies over the magnitude of musically promoted therapeutic effects are bound to continue" (p. 1990).

CONCLUSION

The existing literature provides extensive documentation of music-induced analgesia. However, opportunities to further the body of knowledge are abundant given that many questions about music and pain remain unanswered. Researchers can advance the field of study by creatively approaching unresolved debates (e.g., how best to measure pain, what types of music interventions are most therapeutic, what are underlying mechanisms of music-induced pain relief). This may require more extensive cross-disciplinary conversations between experts in music therapy, music medicine, neuroscience, and clinical practice and the potential for such collaborations should be embraced. Improving the methodological quality of music and pain research should also be a primary focus of future studies. Researchers should aim to increase sample sizes, employ more rigorous randomisation and blinding techniques, and report demographic details more carefully. All of these methodological improvements will help to accumulate evidence for and against competing types of music interventions and theoretical frameworks. The more we understand how and why music relieves the pain, the better we can employ music interventions as a low-risk, low-cost adjuvant to traditional pain management.

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APPENDIX

The table below offers a summary of individual empirical studies included in this integrative review.

Author	N	Design	Pain experience	Type of musical stimuli	Summary of findings
Alam et al. (2016)	155	Single-blinded randomised control experiment. (Measured outcomes for both patients and surgeons)	Excisional surgery for basal and squamous cell carcinoma	Relaxing music, guided imagery. Music was standard across all subjects. Described as soothing and featuring nature sounds. 30:25 recording at 60 to 70 bpm.	Results inconclusive for patient pain but showed decreases in surgeon anxiety.
Allred et al. (2010)	56	Randomised but not controlled. Adult subjects.	First ambulation on day 1 after total knee arthroplasty	Celtic Flutes, World Flutes, Beethoven's Moonlight, Native American Flute and Guitar, Peaceful Harp, Chopin's Nocturne. Twenty minutes before and after ambulation.	Results inconclusive because music intervention group was compared to quiet rest group (itself an intervention). Both groups demonstrated improved anxiety and pain.
Bradt et al. (2016)	55	Mixed methods feasibility study.	Benign chronic pain	Active music therapy (choral group experience).	Quantitative and qualitative results overwhelmingly positive (patients reported relief).
Dobek et al. (2014)	12	Randomised control experiment and brain imaging study.	Noxious heat (Medoc TSA-II thermal sensory analyser)	Self-selected piece of music at least 215 seconds long with listening via headphones.	Participants reported 10% decrease in pain and imaging found BOLD activity in areas of the brain involved with pain relief as well as expected areas of pain perception and music audition.
Finlay (2014)	23	Longitudinal study of chronic pain sufferers vs. controls with no chronic pain or emotional problems.	Chronic, non-malignant pain	Listening to the same musical excerpt for 28 days. Subjects were given the choice between two unfamiliar jazz excerpts (60-90 bpm) and listened to that excerpt the entire trial.	Some evidence of short-term pain relief but not long-term relief.
Fredenburg & Silverman (2014)	32	Randomised control experiment.	Blood and marrow transplant	Session with a music therapist who designed live activities based on patient preferences. Sessions lasted 30 minutes.	Results indicate positive changes in pain perception and affect (positive and negative) for music group.
Garza-Villarreal et al. (2014)	22	Within-subjects experimental design.	Fibromyalgia	Self-selected piece of relaxing, pleasant music vs. 'pink noise'.	Relaxing, pleasant music reduced pain and increased functional mobility.
Good, Ahn & Payne (2008)	73	Quasi-experimental, pre-test / post-test experiment.	Genealogical post-operative pain	Korean or American music (self-selected from among a number of options) listened to for 15 minutes at four checkpoints.	Music plus analgesics reduced pain more than analgesics alone.

Guétin et al. (2012)	87	Single-blinded randomised control study.	Chronic pain	Two daily sessions of music listening for 60 days.	Music group had significant reduction in use of anxiolytic agents and reported less anxiety and depression.
Guétin et al. (2016)	53	Descriptive, quasi-experiment.	Mixed	Smart-phone based app called *Music Care,* each patient used the application at least once.	Listening to self-selected music for 20 mins reduced pain.
Gutgsell et al. (2013)	200	Randomised control experiment.	Palliative care (majority cancer patients)	1 session with a music therapist engaging in listening and live music activities.	Less pain reported in music therapy group. Increase in functional pain scale scores in music therapy group.
Hsieh et al. (2014)	48	Randomised control experiment.	Noxious heat	Self-selected music that met certain criteria about length, mood, etc.	Rating lowest at post-test for music condition.
Huang, Good & Zauszniewski (2010)	126	Randomised control experiment.	Cancer	Music selected from a number of Taiwanese and American options. 60 to 80 bpm, no lyrics. 30min listening sessions.	Music group experienced more pain relief than controls.
Korhan et al. (2014)	30	Within-subjects experimental design.	Neuropathic pain	Classical Turkish music played via MP3 player; 60 to 66 bpm, Nihavend mode. 60 mins.	Decrease in pain for music condition that indicated a cumulative dose effect over time.
Linnemann et al. (2015)	30	Descriptive quasi-experiment.	Fibromyalgia	Daily listening habits (self-selected by the participants.) On average, participants listened to music for two hours per day.	Improved perceived control over pain, especially when music was positive in valence. Effects of music not mediated by biomarkers of stress.
Liu & Petrini (2015)	112	Randomised control experiment.	Thoracic surgery	30min soft music listening sessions ('melodious' 'soft' and 60-80 bpm) for three consecutive days	Decrease in pain anxiety, systolic blood pressure and heart rate for music group.
Mercadíe et al. (2015)	22	Quasi-experimental design (participants chose condition)	Fibromyalgia	Music selections available from the Guétin "Music Care" smartphone app vs. miscellaneous environmental sounds. Passive or active listening conditions.	Reduction in pain and fatigue when listening passively.
Mitchell & Hons (2006)	54	Within-subjects experimental design.	Cold pressor pain	White noise, researcher-selected "relaxation" music, or participant-selected music.	Preferred music listening results in more tolerance to pain and greater perceptions of control.
Mitchell et al. (2006)	44	Within-subjects experimental design.	Cold pressor pain	Participant-selected music vs. humour tapes (chosen from among a selection provided by researchers) vs. verbally administered arithmetic tasks.	Preferred music listening results in more tolerance to pain and greater perceptions of control.
Mitchell et al. (2008)	80	Within-subjects experimental design.	Cold pressor pain	Participant-selected music vs. visual art distraction vs. silence.	Preferred music listening results in more tolerance to pain, less anxiety, and greater perceptions of control.

Siedliecki & Good (2006)	60	Randomised control experiment.	Chronic, non-malignant pain	Participants were designated to either 'patterned music' or 'standard music' groups and made selection from provided songs within those groups. Listened one hour a day for seven days.	Music intervention led to improvements for pain, power, depression, and disability. No differences between patterned and standard music.
Vaajoki et al. (2012)	168	Quasi-experimental design.	Abdominal surgery	Participants chose music from 2000 popular and classical Finnish songs downloaded onto an iPod.	Short-term decreases in pain and pain distress for music group. No effects after second postoperative day.
Yu et al. (2009)	60	Randomised control experiment.	Acupuncture treatments for patients with cerebral palsy	Music: 30 Chinese or English popular kids' songs, 20 educational songs, 15 Christmas songs, 15 lullabies, ten nursery rhymes, 12 folk songs, and ten school songs. Patients selected ten songs they liked. Listened for 30mins.	No effect of music and acupuncture on pain. Music group reported reduced anxiety.

Ελληνική περίληψη | Greek abstract

Μουσικές παρεμβάσεις και πόνος: Μια περιεκτική ανασκόπηση και ανάλυση της πρόσφατης βιβλιογραφίας

Hannah Fidler | Peter Miksza

ΠΕΡΙΛΗΨΗ

Οι μουσικές παρεμβάσεις προσφέρουν μια χαμηλού κόστους, χαμηλού κινδύνου επικουρική συνδρομή στις παραδοσιακές θεραπείες. Παρόλα αυτά, τα υπάρχοντα βιο-φυσιολογικά ευρήματα [physiological evidence] που εξηγούν το πώς η μουσική ανακουφίζει από τον πόνο είναι σπάνια. Σε αυτή την περιεκτική ανασκόπηση παρέχουμε μια περίληψη των αποτελεσμάτων από την πρόσφατη βιβλιογραφία σχετικά με τη μουσικά-προκληθείσα αναλγησία [music-induced analgesia] καθώς και μια κριτική ανάλυση των μεθοδολογικών επιλογών. Στη συνέχεια περιγράφουμε την ανάγκη για ισχυρές θεωρητικές διευκρινήσεις που θα μπορούσαν να εξηγήσουν τις παρατηρούμενες επιδράσεις της μουσικής στον πόνο. Ολοκληρώσαμε μια ευρεία ηλεκτρονική αναζήτηση χρησιμοποιώντας κοινές μηχανές αναζήτησης για τον εντοπισμό πρόσφατων πειραματικών μελετών και βιβλιογραφικών ανασκοπήσεων που αντιπροσώπευαν την τρέχουσα κατανόηση των πιθανών αιτιακών σχέσεων μεταξύ μουσικής και πόνου. Τριανταένα άρθρα συγκεντρώθηκαν σε αυτή την ανασκόπηση – 23 ήταν μεμονωμένες πειραματικές μελέτες και οκτώ ήταν βιβλιογραφικές ανασκοπήσεις. Τα αποτελέσματα δείχνουν ότι η μουσικά-προκληθείσα αναλγησία είναι ένα σταθερά παρατηρήσιμο φαινόμενο σε κλινικά πλαίσια, αν και μια μειονότητα των άρθρων καταγράφει ασαφή αποτελέσματα. Το μέγεθος της ανακούφισης του πόνου είναι από μικρό έως μέτριο και τα αποτελέσματα γίνονται λιγότερο καταλητικά όταν προέρχονται από έμμεσα εργαλεία αξιολόγησης του πόνου. Στους περιορισμούς της πρόσφατης βιβλιογραφίας περιλαμβάνονται οι λειτουργικοί ορισμοί του πόνου, τα είδη του πόνου που εξετάζονται στα άρθρα, η υπερβολική χρήση εργαλείων αυτο-αναφοράς, η αυστηρότητα στην αναφορά δημογραφικών στοιχείων, η ποικιλομορφία και το μέγεθος των δειγμάτων και των αδύναμων πειραματικών ερευνητικών σχεδιασμών. Οι θεωρητικές επεξηγήσεις για την επίδραση της μουσικής στον πόνο ποικίλουν αλλά είναι

ανεπαρκώς ανεπτυγμένες και στερούνται βιο-φυσιολογικών τεκμηρίων. Καταλήγουμε στο συμπέρασμα ότι η μουσικά-προκληθείσα αναλγησία παραμένει ένα συνεχώς παρατηρήσιμο φαινόμενο. Για την περαιτέρω ανάπτυξη του πεδίου χρειάζεται να εφαρμοστούν πιο αυστηρές μεθοδολογικές πρακτικές και να δοθεί μεγαλύτερη προσοχή στην διερεύνηση των υποκείμενων βιο-φυσιολογικών μηχανισμών που αφορούν τις σχέσεις μεταξύ μουσικής και πόνου.

ΛΕΞΕΙΣ ΚΛΕΙΔΙΑ

μουσικές παρεμβάσεις, μουσικοθεραπεία, πόνος, διαχείριση πόνου, μουσικά-προκληθείσα αναλγησία [music-induced analgesia], εναλλακτικές θεραπείες