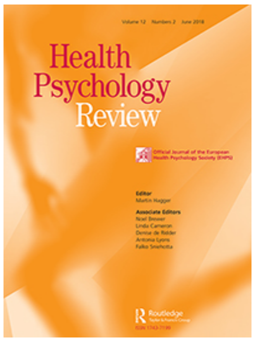


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# Effects of Music Interventions on Stress-Related Outcomes: A Systematic Review and Two Meta-Analyses

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## Abstract

Music interventions are used for stress reduction in a variety of settings because of the positive effects of music listening on both physiological arousal (e.g., heart rate, blood pressure, and hormonal levels) and psychological stress experiences (e.g., restlessness, anxiety, and nervousness). To summarize the growing body of empirical research, two multilevel meta-analyses of 104 RC, containing 327 effect sizes and 9,617 participants, were performed to assess the strength of the effects of music interventions on both physiological and psychological stress-related outcomes, and to test the potential moderators of the intervention effects. Results showed that music interventions had an overall significant effect on stress reduction in both physiological ($d$ = .380) and psychological ($d$ = .545) outcomes. Further, moderator analyses showed that the type of outcome assessment moderated the effects of music interventions on stress-related outcomes. Larger effects were found on heart rate ($d$ = .456), compared to blood pressure ($d$ = .343) and hormone levels ($d$ =.349). Implications for stress-reducing music interventions are discussed.

**Keywords:** music interventions, music therapy, arousal, stress, state anxiety, multilevel meta-analysis.

## Introduction

Stress is believed to be one of the major factors negatively affecting our health. High stress levels have shown to be strongly associated with many physical and emotional problems, such as cardiovascular disease, chronic pain, anxiety disorders, depression, burnout, and addictions (American Psychological Association [APA], 2017; 2015; Australian Psychological Society [APA], 2015; Casey, 2017; Howe, Chang, & Johnson, 2013; McEwen & Gianaros, 2010). Furthermore, there is a strong relationship between these stress-related health problems and higher absenteeism at work (UK Health and Safety Executive, 2016). To cope with stressors, millions of people around the world use tranquilizing medication, which is associated with numerous contraindications and negative side effects (e.g., Bandelow et al., 2015; Olfson, King, & Schoenbaum, 2015; Puetz, Youngstedt & Herring, 2015). Because of the difficulty of reducing or preventing stress without any professional support and the great demand for nonpharmacological stress reduction interventions, the relevance of the development of cost-effective interventions for stress reduction is high (APA, 2015; Casey, 2017; Holahan, Moos, Holahan, Brennan, & Schutte, 2005; Howe et al., 2013; McEwen & Gianaros, 2010; World Health Organization [WHO], 2010).

Music listening and music making have been associated with a broad range of positive outcomes in the domains of health and well-being (Juslin & Västfjäll, 2008; Koelsch, 2012, 2015; Thaut & Hoemberg, 2014; Zatorre, 2015). The most widely studied effects of music are the calming and stress reducing effects (Chanda & Levitin, 2013; Gillen, Biley, & Allen, 2008; Juslin & Västfjäll, 2008; Koelsch, 2015). For decades, music has been used as an intervention for stress reduction, such as music activities (like singing or music making), music listening for a certain patient group ("music as medicine"), and live music therapy offered by music therapists (Bradt, Dileo, & Shim, 2013; Gold et al., 2011).

In order to integrate the available knowledge on the effects of music interventions on stress, the present study is a systematic review and meta-analysis of experimental studies testing the effects of music interventions on both physiological and psychological stress-related outcomes in clinical, medical and work- or study-related settings.

**The Stress System**

The *stress system* can be considered as a highly important and preserved system in human beings. In physiology and medicine, the general definition of *stress* is introduced by Selye (1956): *"Stress is a general activation reaction to a stimulus that could mean both a challenge (in a positive way) and a threat (in a negative sense)"* (p. 32). Aldwin (2007) emphasized the negative part and defined stress as the quality of an experience, produced through a person-environment transaction that, through either overarousal or underarousal, results in psychological or physiological distress (Aldwin, 2007; Riley & Park, 2015). The responses to stress can be categorized as *physiological arousal* and *emotional responses* (e.g. Aldwin, 2007; Li & Goldsmith, 2012; Pelletier, 2004). Together, the underlying systems of these responses regulate stress and affect each other during stress (e.g., Linnemann, Strahler, & Nater, 2017; McEwen & Gianaros, 2010).

The physiological response to stress implies the activation of the hypothalamic-pituitary adrenal (HPA) axis and, because of a release of adrenalin and noradrenalin, increased activity of the sympathetic nervous system resulting in increased physiological arousal, such as heartrate, blood pressure, and cardiac output (Bally, Campbell, Chesnick, & Tranmer, 2003; McCance & Huether, 2006; Pfaff, Martin, & Ribeiro, 2007). In a parallel process, involving the hypothalamus and the adrenal glands, cortisol is released. The emotional response to stress can be described as emotional states of subjective worry, such as state anxiety, restlessness or nervousness (Akin & Iskender, 2011; Cohen, Kamarck, & Mermelstein, 1983; Pittman & Kridli, 2011; Pritchard 2009). *State anxiety* has been defined as an emotional response to an individual‟s perception of a stressful experience (e.g., Hook, Songwatha, & Petpichetchian, 2008; Koelsch et al., 2011b; Ming et al., 2016; Zhang et al., 2014). Therefore, state anxiety was operationalized for several decades as one of the psychological stress-related outcomes (Koelsch et al., 2011b; Lazarus, 1966; Pelletier, 2004). It is assumed that both the physiological and the emotional responses of stress may be reduced by music (Bradt & Dileo, 2014; Dileo & Bradt, 2007; Pelletier, 2004).

**Effects of Music on Stress**

Recent neuroscientific studies provide insights into how music interventions may lead to stress reduction and increased well-being. Firstly, music seems to be able to decrease *physiological arousal,* which is increased during stress. Music listening, and music making/singing, have been associated with decreases of physiological arousal, shown by reduction of cortisol levels or decrease in heart rate and blood pressure (Hodges, 2011; Koelsch et al., 2016; Kreutz, Murcia, & Bongard, 2012; Leardi, Pietroletti, Angeloni, Necozione, Ranalletta, & Del Gusto, 2007; Linnemann, Ditzen, Strahler, Doerr, & Nater, 2015; Nilsson, 2009; Sokhadze, 2007). These three outcomes have been identified in neurobiology as distinct stress biomarkers (Cacioppo, Tassinary, & Berntson, 2007; Pfaff et al., 2007).

Music may also affect stress-related *emotional states*, such as subjective worry, anxiety, restlessness or nervousness (Akin & Iskender, 2011; Cohen, Kamarck, & Mermelstein, 1983; Pittman & Kridli, 2011; Pritchard, 2009). This is because music can modulate activity in brain structures that are known to be crucially involved in emotional processes. Recent neuroimaging studies on music and emotion showed that music may strongly influence the *amygdala*, a part of the limbic system, which is a section of the brain that plays a crucial role in the regulation of emotional processes by releasing endorphins. These neurotransmitters play an important role in enhancing a sense of well-being (Blood & Zatorre, 2001; Hodges, 2011; Koelsch, 2015; Koelsch, Siebel, & Fritz, 2011a; Levitin, 2009; Moore, 2013; Peretz, 2009; Thaut & Wheeler, 2010; Trainor & Schmidt, 2003; Uhlig, Jaschke, & Scherder, 2013; Zatorre, 2015).

The systematic review of Moore (2013) on the neurological effects of music on emotional processes indicated that musical improvisation and music listening could deactivate the amygdala, which may decrease the intensity of stress-related emotional states and psychophysiological arousal. This in turn has been shown to evoke feelings of pleasure and happiness (Blood & Zatorre, 2001; Koelsch, Offermanns, & Franzke, 2010; Koelsch et al., 2016; Limb & Braun, 2008). The (cognitive) behavioural framework is consistent with this and takes into account that music can serve as a distractor, diverting attention from a stressful event to something more pleasant, which reduces stress levels (Sendelbach, Halm, Doran, Miller, & Gaillard, 2006; Vaajoki, Kankkunen, Pietila, & Vehviläinen-Julkunen, 2011).

Many studies on the effects of music considered *state anxiety* to be a stress-related emotional state, examining relationships between state anxiety outcomes and physiological stress-related outcomes (e.g., Hook et al., 2008; Koelsch et al., 2011b; Ming et al., 2016; Zhang et al., 2014). Although the terms *state anxiety* and *stress* are used interchangeably in the psychology literature, different self-reporting questionnaires are used. It is therefore necessary to examine whether music has the same effects on stress and state anxiety.

**Music Interventions**

Music interventions can be regarded as purposeful musical exercises or methods in which music listening, music making, or singing is central. In both literature and practice there is a distinction between music interventions offered by a music therapist and music interventions offered by other healthcare professionals or without any support. First, music interventions can be defined as purposeful music activities if they concern listening to prerecorded music offered by medical or healthcare professionals, if the intervention is self-administered by the patient ("music as medicine"), or if it concerns music making or singing without the involvement of a music therapist or a therapeutic context (American Music Therapy Association, 2019). Second, music interventions as a part of *music therapy* are offered by trained music therapists and are characterized by the presence of a therapeutic process and the use of personal music experiences (Bradt & Dileo, 2014; Bradt et al., 2013; Dileo, 2006; Gold et al., 2011; Kamioka et al., 2014). Music interventions in the practice of music therapy may concern music listening or music playing, but may also include composing, songwriting, or interacting with music (Leubner & Hinterberger, 2017).

It is assumed that specific characteristics of the music may have an impact on the stress-reducing effects of music interventions (e.g., Bradt & Dileo, 2014; Bradt, Dileo & Potvin, 2013b; Pittmann & Kridli, 2011). *Music tempo* can be considered as one of the most important moderators of music-related arousal and relaxation. Music with a slow tempo (60-80 beats per minute), for example meditative music, has often been associated with reductions in heart rate, resulting in greater relaxation (e.g. Bernardi, Porta, & Sleight, 2006; Bringman, Giesecke, Thörne, & Bringman, 2009; Chlan, 2000; Hilz et al., 2014; Nomura, Yoshimura, & Kurosawa, 2003). The use of *instrumental music*, instead of *music with lyrics*, would often lead to greater effects of music interventions on stress reduction. Several studies reported that music containing lyrics may be more distracting and activating instead of calming (Good et al., 2000; Halpern & Savary, 1985). However, Koelsch (2011) reported that the use of music with lyrics may reinforce the positive effects of music interventions on stress reduction through the possible comforting effects of the lyrics. Another component of music interventions for stress reduction is the way the music is played (live music or prerecorded music). Music therapy consists mainly of live music interventions, which are assumed be more effective than "music as medicine" interventions because music therapists individualize their interventions to meet patients" specific needs (Bradt et al., 2014; Dileo, 1999; 2005). Notably, some studies measured differences in stress responses between participants receiving live music and those receiving prerecorded music, with live music appearing to be the most stress-reducing (e.g., Arnon, 2006; Bailey, 1983; Baker, 2001).

Many studies examining the effects of music interventions on stress-related outcomes in specific patient groups or settings have been published, such as cancer patients (Bradt, Dileo, Grocke & Magill, 2011), coronary heart disease patients (Bradt, Dileo, & Potvin, 2013), and patients undergoing endoscopic procedures (Rudin, Kiss, Wetz, & Sottile, 2007). Several studies reported positive effects of music-listening on stress-related outcomes. In medical settings, listening to tranquilizing music before, during, and after medical procedures has been reported to correlate with lower cortisol levels, associated with the reduction of stress and/or anxiety (e.g., Chanda & Levitin, 2013; Kamioka et al., 2014; Koelsch et al., 2016; Linnemann et al., 2015; Nilsson, 2008). However, the strength of the effect differs both within and between studies, and the particular impact of potential moderators – such as patient/client, setting, measurement and intervention characteristics – is largely unknown.

**Rationale for the Present Study**

The present study consists of two multilevel meta-analyses on the effects of music interventions on both physiological stress-related arousal (e.g., blood pressure, heart rate, hormone levels) and psychological stress-related experiences (e.g., state anxiety, restlessness or nervousness) in various populations and settings, and is a replication of the meta-analysis by Pelletier (2004), who reviewed 22 quantitative studies examining the effects of music interventions on stress reduction. Pelletier‟s (2004) meta-analysis showed that music alone and music-assisted relaxation significantly reduced stress-related arousal, with an overall medium-to-large effect size of $d = .67$, moderated by study characteristics, such as age, type of stress, musical preference and type of intervention. An important difference with the present study is that Pelletier included only studies in which the intervention consisted of listening to prerecorded music, often combined with relaxation techniques, whereas studies with live music interventions were excluded. Besides, studies examining *music therapy* for stress reduction were not included. The quality of the included studies was not assessed. Therefore, it is not clear whether the methodology of the studies did influence Pelletier‟s overall effects. In addition, we assume that the study quality of comparable studies has increased over the last 15 years.

In the last decade, music interventions were increasingly developed and used to reduce stress in a variety of settings (Chanda & Levitin, 2013; Heiderscheit, Chlan, & Donley, 2011; Koelsch, 2015; Uhlig et al., 2013), and to support physical and psychological health by creating an environment that stimulates relaxation and stress reduction (Bradt & Dileo, 2014; Kamioka et al., 2014; Koelsch & Stegemann, 2012; Nilsson, 2008). Therefore, it is timely to replicate the meta-analysis by Pelletier (2004) by using new multilevel meta-analytic techniques that enable moderator analyses of both within and between study differences in outcomes, thus preventing loss of information and increasing statistical power (Assink & Wibbelink, 2016).

The present meta-analytic study includes all *randomized controlled trials* (RCTs) on the effects of music interventions on stress-related outcomes in adults, who are not suffering from dementia, that have been published. The first aim of this study is to examine whether, and the degree to which, music interventions are effective in reducing stress. The second aim is to examine possible moderator effects of study, sample and intervention characteristics, which may influence the strength of the effects of music interventions on stress-related outcomes. The results of this meta-analysis may be used to increase the effects of music interventions on stress by examining the conditions under which music interventions have the largest effects on both physiological and psychosocial dimensions of coping and stress.

## Methods

### Inclusion Criteria

For the current meta-analysis, multiple inclusion criteria were applied. Firstly, only RCTs that examined the effect of music interventions on the experience of stress and/or (state) anxiety were included. Outcome measures related to quality of life (QoL) or pain were excluded, because these outcomes can be a response to stress, but are not measuring the primary stress-related outcome measures, upon which the present study is focused. The physiological effects of stress had to be measured by heart rate, blood pressure and hormone levels. Psychological effects of stress had to be measured by self-report instruments aiming at "stress" or "state anxiety". Secondly, studies including participants younger than 18 years of age or examining people with dementia were excluded. Although many studies reported cognitive and emotional benefits in dementia patients when they were singing or when they were listening to familiar songs (Särkämo et al., 2008, 2014), such findings are not directly related to "stress reduction". Moreover, the regular stress measurement instruments, which are also used in the included RCTs of the present study, are not used in studies in which people with dementia are being examined.

### Selection of Studies

We conducted a computer-based search of the psychological and medical electronic literature databases, including Medline, Academic Search Complete, Cochrane Library, Web of

Science, Wiley Online Library, SpringerLink, PubMed, PiCarta, Academic Search Premier, ScienceDirect, PsychINFO and Google Scholar. Pelletier‟s meta-analysis (2004) can be seen as the starting point of current meta-analysis because Pelletier also included all kinds of settings and patient groups. All RCTs available until November 2017 that were in line with the inclusion criteria were included in this meta-analysis. The electronic databases were searched using the following English search string: (music*) AND (stress* OR anxiety* OR arousal) AND (“randomized controlled trial” OR “randomised controlled trial” OR RCT). Furthermore, reference sections of review- and meta-analytic articles about the effect of music interventions on stress-related outcomes were inspected for qualifying studies. The initial search resulted in 2679 studies. Finally, 104 studies met all the inclusion criteria (Figure 1). An overview of the included studies and their main characteristics are presented in Table 1 (See Appendix A).

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Insert Figure 1
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**Coding and Moderators**

The included studies were coded by the first author using a coding sheet according to the guidelines of Lipsey and Wilson (2001). *Stress* can be considered as the dependent variable and was coded into *physiological* or *psychological* stress-related outcomes, resulting in two meta-analyses. For each meta-analysis, various factors with a potential moderating effect on the relation between music interventions and stress were identified. These moderators were divided into outcome-, study-, sample-, and intervention characteristics.

Regarding the stress-related outcomes, three different physiological outcome measures were coded: *heart rate, blood pressure* and *hormone levels*. These are three different biomarkers and each biomarker must be measured differently (Cacioppo, Tassinary, & Berntson, 2007; Pfaff, et al., 2007). Regarding the psychological stress-related outcomes, it was coded whether the outcomes were assessed by means of questionnaires measuring *stress* or *state anxiety*. For measuring stress, the self-report questionnaires Perceived Stress Scale (PSS; Cohen, Kamarck, & Mermelstein, 1983) and the Visual Analogue Scale Stress (VAS-S) are widely used and 19% of the included studies measuring psychological stress-related outcomes have applied them. State anxiety is measured in multiple studies by the state version of the Spielberger State-Trait Anxiety Inventory (STAI-S; Spielberger et al., 1983), and is used in 59% of the included studies assessing psychological stress-related outcomes ($k$ = 76). Notably, despite the positive psychometric features of the STAI-S, the measures have been criticized for their inability to adequately discriminate between the symptoms of anxiety and depression (Caci, Bayle, Dossios, Robert, & Boyer, 2003; Grös, Antony, Simms, & McCabe; 2007).

We coded whether the study quality was *strong, moderate* or *weak* with the „Quality Assessment Tool for Quantitative Studies" (Effective Public Health Practice Project [EPHPP], 2009). This tool assesses the quality of a study by providing a comprehensive and structured assessment of the concept of study quality (Armijo-Olivo, Stiles, Hagen, Biondo, & Cummings, 2012). The EPHPP has been reported to have content and construct validity (Jackson & Waters, 2005; Thomas, Ciliska, Dobbins, & Micucci, 2004). Low-quality studies negatively affect the internal (causal conclusion) validity, which can lead to a biased estimation of the overall effect estimate (Higgins & Green, 2011; Zeng et al., 2015). Regarding the setting in which the study was conducted, we coded whether the study was conducted in a *polyclinic medical setting*, *pre-, during or after medical surgery*, or whether it was a so-called *nonmedical setting* (e.g., work-related settings, research among students at universities or musical activities to improve health in chronical patients). Further, we coded whether the study was conducted in a *Western* country (European countries, Australia, USA, Canada, New Zealand) or in a non-Western country (mainly Asiatic countries). The cultural environment has been shown to influence the way people respond to and cope with stress (Lonner, 2007; Tweed, White, & Lehman, 2004), which could influence the effect of music on stress. The type of control condition was coded as care as usual (CAU) or another intervention. Different control conditions can lead to different effect sizes and recognizing this is crucial for drawing accurate conclusions about treatment efficacy (Finney, 2000; Karlsson & Bergmark, 2015).

Several sample characteristics were also coded, such as the percentage of men in each study. There are indications men and women tend to react differently to stress, both psychologically and physiologically, leading to substantiated gender differences in measured stress levels (Galanakis, Stalikas, Kallia, Karagianni, & Karela, 2009; Kajantie & Phillips, 2006; Verma, Balhara, & Gupta, 2011). We also coded the average age of the samples per study because research on occupational stress shows the existence of several significant differences in stress levels between different ages (Galanakis et al., 2009).

Finally, we coded six music intervention characteristics. First, according to Bradt and Dileo (2014), we coded whether the music intervention was offered in the context of *music therapy* by a trained music therapist, or whether the music intervention was offered by a healthcare professional, the researcher, or by the patient himself, as a *music activity* (Dileo, 2006; Dileo & Bradt, 2007; Kamioka et al., 2014; Leubner & Hinterberger, 2017). Second, we coded whether the music intervention involved *live music* or *prerecorded musi*c, because differences in effects on stress-related outcomes were found (e.g., Arnon, 2006; Bailey, 1983; Baker, 2001). Third, regarding the selection of music, it was coded whether the music was self-selected by the participants and based on *own preference* (bringing their own music) or whether the music was *pre-selected* by the researcher or the (music) therapist. Some researchers have advised to allow participants choose the music themselves, because this may have a greater stress reducing impact (Brannon & Fiest, 2007; Juslin, Liljeström, Västfjäll, Barradas, & Silva, 2008), but this does not always mean that participants could bring their own music. On the other hand, the pre-selected music (by the researchers) is mostly based on the musical characteristics related to classical and soothing music, which are assumed to positively affect relaxation and stress reduction (Burns et al., 2002; Labbé, Schmidt, Babin, & Pharr, 2007). Fourth, we coded whether the music intervention concerned the music tempo of 60–80 bpm, or whether no specific music tempo was mentioned in the study. Fifth, it was coded whether the music contained lyrics or whether the music was purely instrumental. Lastly, we coded the number of music intervention sessions. The number of interventions is positively correlated to improvements in many outcomes including the regulation of stress and anxiety (Cassileth, Vickers, & Magill, 2003; Gold, Solli, Krüger, & Lie, 2009; Robb, Burns, & Carpenter, 2011).

**Calculation and Analyses**

Data analysis was performed by the first and second author. The effect sizes were transformed into Cohen's *d* by use of Wilson‟s (2013) calculator and Lipsey and Wilson‟s (2001) formulae. Negative effect sizes indicate that music interventions had a negative effect on stress-related outcomes. Most *d*-values were calculated based on reported means and standard deviations. To correct for pretreatment differences, pretest effects were subtracted from posttest effects. The effect size was coded as zero when a study mentioned that an effect was not significant without providing any statistics (Lipsey & Wilson, 2001). For both meta-analyses, the continuous moderators (age of the participants, gender of the participants, duration of the music intervention and frequency of the music intervention) were centred on their means. For categorical variables, dichotomous dummy variables were created. Extreme outliers in effect sizes were identified using box plots (Tabachnik & Fidell, 2013), and were winsorized (i.e., replaced by the highest or lowest acceptable score falling within the normal range) for both meta-analyses. Standard errors were estimated using Lipsey and Wilson‟s (2001) formulae.

In almost all the studies it was possible to calculate more than one effect size as most studies reported on multiple stress-related outcome variables, multiple scales or measurement instruments. It is possible that the effect sizes from the same study are more alike than effect sizes from other studies. The assumption of independent effect sizes underlying traditional meta-analytic methods was therefore violated (Hox, 2002; Lipsey & Wilson, 2001). In line with recently conducted meta-analyses, we applied a multilevel approach in both meta-analyses in order to deal with the interdependency of effect sizes (Assink et al., 2015; Cheung, 2014; Houben, van den Noortgate, & Kuppens, 2015; Spruit, Assink, van Vugt, van der Put, & Stams, 2016; ter Beek et al., 2018).

A three-level meta-analytic model was used to calculate the combined effect sizes and to perform the moderator analyses. Three sources of variance were modelled, including the sampling variance for each effect sizes (level-one), the variance between effect sizes within studies (level-two), and the variance between studies (level-three) (Assink & Wibbelink, 2016). The meta-analysis was conducted in R (version 3.4.3) with the metafor package, employing a multilevel random effects model (Houben et al., 2015; van den Bussche, van den Noortgate, & Reynvoet, 2009; Viechtbauer, 2010). This model is adequate and often used for multilevel meta-analyses and is, in general, superior to the fixed-effects approaches used in traditional meta-analyses (Van den Noortgate & Onghena, 2003). We used likelihood ratio tests to compare the deviance scores of the full model and the models without variance parameters on level two or three to determine if the level-two and -three variances were significant, indicating heterogeneity of effect sizes. A heterogeneous effect size distribution indicates that the effect sizes cannot be treated as estimates of a common overall effect size. In that case, we conducted moderator analyses, because the differences among effect sizes may be explained by outcome, study, sample, and/or intervention characteristics.

**Publication Bias**

A common problem in conducting a meta-analysis is that studies with nonsignificant or negative results are less likely to be published than studies with positive and significant results. The studies included in this meta-analysis may therefore not be an adequate representation of all studies that have been conducted. This phenomenon is called the "file drawer problem" (Rosenthal, 1995).

In order to check the presence of publication bias in the current meta-analysis, a trim and fill procedure was performed (Duval & Tweedie, 2000a, 2000b) by testing the asymmetry of the funnel plot according to Egger's method (Egger, Davey Smith, Schneider, & Minder, 1997). In case of publication bias, the funnel plot of the distribution of effect sizes is asymmetric, resulting in a significant Egger's test. If Egger‟s method indicates publication bias, a trim and fill procedure is required. We tested if effect sizes were missing on the left side of the distribution, since publication bias would only be likely to occur in the case of nonsignificant or unfavourable (i.e., negative) results. In case of left-sided funnel plot asymmetry, we imputed estimations of effect sizes of missing studies through trim and fill analyses, and subsequently computed an overall effect size that would take the influence of publication bias into account (Duval & Tweedie, 2000b), providing an estimate of the degree to which publication bias might have affected the overall mean effect size.

## Results

This meta-analytic review included 104 RCTs (all non-overlapping samples) with a total of *N* = 9.617 participants of whom *n* = 4.838 participated in a music intervention group or music therapy group, and *n* = 4.779 constituting the comparison group. Table 1 shows an overview of the most important characteristics of the included studies (see Appendix A). Table 2 shows the overall effects of music interventions on both physiological stress-related outcomes and psychological stress-related outcomes.

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Insert Table 2

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### Effect of Music Interventions on Physiological Stress-Related Outcomes

The meta-analysis on the effect of music interventions on physiological stress-related outcomes contained 61 independent studies (*s*), from which 197 effect sizes (*k*) were denied, and a total sample of *N* = 3.188 participants, of which *n* = 1.624 participants in the music intervention groups, and *n* = 1.564 participants in the comparison groups.

**Overall effect on physiological stress-related outcomes.** A significant small-to-medium effect ($d = 0.380$, $p = < .001$) of music interventions on physiological stress-related outcomes (heart rate, blood pressure, stress-related hormones) was found, indicating that music interventions reduced physiological stress symptoms. According to the trim-and-fill plot, the presence of publication bias was unlikely, as there were no imputed effect sizes on the left side of the funnel (see Figure 2, Appendix B). The likelihood ratio test showed that significant variance was present at the between-study level (level 3) and the within studies level (level 2). In cases of heterogeneous effect size distributions, moderator analyses are advised to assess whether the variance between the effect sizes can be explained by moderators. Therefore, we conducted moderator analyses on type of outcome, study, sample, and music intervention characteristics to examine the effect of music intervention on physiological stress-related outcomes.

**Results of moderator analyses on physiological stress-related outcomes.** The moderator analyses of the physiological stress-related outcomes were justified by significant overall heterogeneity for all moderator variables, including the variables with missing values. The results of these moderator analyses are presented in Table 3.

***Outcome characteristics.*** We found a significant moderating effect ($p = < .05$) on the different types of physiological stress-related outcomes (heart rate, blood pressure or stress-related hormones). The strongest effects of music interventions on the physiological stress-related outcomes were measured by heart rate ($d = 0.456$) compared to blood pressure ($d = 0.343$) and hormone levels ($d = 0.349$).

***Study characteristics.*** No significant moderating effects of study characteristics were found. More specifically, the type of setting (nonmedical settings, pre- or postmedical surgery or during medical procedures), the continent where the study was conducted (Western or non-Western countries), and the quality of the study (weak, moderate or strong) showed no significant moderating effects. The continent where the study had been carried out showed a trend ($p = 0.089$), indicating that non-Western studies yielded larger effects on physiological stress-related outcomes than studies conducted in Western countries.

***Sample characteristics.*** The age and gender of the samples did not have a moderating effect on the physiological stress symptoms.

***Intervention characteristics.*** No significant moderating effect was found in the type of intervention (music therapy or music intervention), type of control condition (CAU or another intervention), music induction (prerecorded music or live music), music style (predetermined relaxing music or patient preferred music), music tempo (60-80 beats per minute or another tempo), or the use of music with lyrics in contrast to the use of purely instrumental music.

**Effect of Music Interventions on Psychological Stress-Related Outcomes**

The meta-analysis on the effect of music interventions on physiological stress-related outcomes contained 79 independent studies (*s*), from which 130 effect sizes (*k*) were denied, and a total sample of $N = 6.800$ participants, of which $n = 3.373$ participants in the music intervention groups and $n = 3.427$ participants in the comparison groups.

**Overall effect on psychological stress-related outcomes.** A significant medium-to-large effect ($d = 0.545$, $p = < .001$) of music interventions on psychological stress-related outcomes was found, indicating that music interventions reduced psychological stress-related symptoms (state anxiety, nervousness, restlessness, and feelings of worry). The trim-and-fill plot did not show lack of effect sizes on the left side of the funnel (see Figure 3, Appendix B), therefore publication bias was unlikely. The likelihood ratio test showed that significant variance was present at the between (level 3) and within (level 2) study level. Moderator analyses on type of outcome, study, sample, and music intervention characteristics were conducted to examine the effect of music intervention on psychological stress-related outcomes.

**Results of moderator analyses on psychological stress-related outcomes.** The moderator analyses of the psychological stress-related outcomes were justified by significant overall heterogeneity for all moderator variables, including the variables with missing values. The results of these moderator analyses are presented in Table 4.

***Outcome characteristic***. The type of psychological outcome (stress- or state anxiety) did not moderate the effect of music interventions on psychological stress-related outcomes.

***Study characteristics.*** No significant moderating effects were found in the study characteristics. More specifically, the continent where the study was conducted, type of setting, and quality of the study, did not moderate the effect of the music intervention on physiological stress-related outcomes.

***Sample characteristics.*** No moderating effects of the age and gender composition of the samples were found.

***Intervention characteristics.*** We found no significant moderating effects of the intervention characteristics, which included the type of intervention (music therapy or music intervention), music induction (prerecorded music or live music), music style (predetermined relaxing music or self-selected music by the patient), and the use of music with lyrics in contrast to the use of purely instrumental music. The music tempo showed a trend ($p$ = .064), indicating that music with 60–80 bpm yielded larger effects than music with another or unspecified tempo. Another trend concerned the type of control condition ($p$ = .097). If a non-established intervention aimed at stress reduction was used as a control condition, effects were somewhat larger than if the control condition concerned CAU (i.e., regular medical care). Finally, the number of interventions showed a trend ($p$ = .078) indicating that one single session generated larger effects than two or more sessions.

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Insert Table 3 and Table 4

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## Discussion

### Overall Effects

By conducting two separate multilevel meta-analyses, the current study aimed to assess the strength of the effect of music interventions on both physiological and psychological stress-related outcomes. Furthermore, the study aimed to examine which outcome, study, sample or intervention characteristics moderated the strength of the effect on physiological and psychological stress-related outcomes. Overall, we found a significant small-to-medium effect of music interventions on physiological stress-related outcomes ($d$ = .380) and a medium effect of music interventions on psychological stress-related outcomes ($d$ = .545), indicating that music intervention groups benefited more than the comparison groups. We conclude that music interventions are effective in reducing physiological and psychological stress-related symptoms in different kinds of settings (mental healthcare, polyclinic medical settings, during medical surgery and in daily life situations). There were no indications of publication bias.

The overall findings of the current study are consistent with findings of previous meta-analyses (Bradt & Dileo, 2014; Bradt et al., 2013a; Bradt et al., 2013b; Bradt et al., 2011; Gillen et al., 2008; Kim et al., 2015; Pelletier, 2004; Rubin et al., 2007). There is a growing body of evidence that music interventions yield positive, moderate effects on stress reduction. Considering the demands of today‟s society, the need for stress reduction interventions are large. Millions of people around the world use tranquilizing medications, such as tricyclic antidepressants and benzodiazepines, to cope with life stressors or anxiety (e.g., Bandelow et al., 2015; Olfson, King, & Schoenbaum, 2015; Puetz, Youngstedt, & Herring, 2015). Not only do these types of medications have considerable negative side effects, including substance dependence and abuse, research also indicates that the effects of pharmacological treatment on stress-related problems are not much larger than the effects of music interventions found in the current meta-analytic study (Olfson et al., 2015). Besides, a common argument for starting pharmacological treatment instead of psychological treatment for stress reduction is that its effects occur immediately or faster (Bandelow et al., 2015; Fedoroff & Taylor, 2001). However, the results of this meta-analysis were based on mainly short-term music interventions, most of the time on a single occasion, having a direct stress reducing effect in various contexts. The current study therefore indicates the relevance of brief music interventions for stress reduction in all kinds of settings. Also, our search revealed that the effects of long-term music interventions have been seldom examined.

**Psychological Effects of Music**

Results of our meta-analysis show a medium effect of music interventions on psychological stress-related outcomes, including emotional states of subjective worry, state anxiety, restlessness and nervousness. Music not only reduces *physiological arousal*, but also affects *emotional states*. This may be attributed to the effect of music on brain areas, such as the amygdala, which are responsible for emotional processes. A related explanation for the positive effects of music interventions on psychological stress-related outcomes concerns the positive influence of listening to pleasant music on *emotional valence*, which can be explained by the degree of attraction that an individual feels towards a specific object or event (Jäncke, 2008; Juslin & Västfjäll, 2008). Music experienced as pleasant increases the intensity of emotional valence (the felt happiness), which has a stress-reducing effect (Jiang, Rickson, & Jiang, 2016; Rohner & Miller, 1980; Sandstrom & Russo, 2010; Witvliet & Vrana, 2007). An increased dopamine activity in the mesolimbic reward brain system has been shown to be associated with these feelings of happiness in response to high-valence music (e.g. Blood & Zatorre, 2001; Salimpoor et al., 2013; Salimpoor, Benovoy, Larcher, Dagher, & Zatorre, 2011; Zatorre, 2015).

Another explanation for the positive effect of music interventions on psychological stress-related outcomes may be that listening to music can provide "distraction" from stress-increasing thoughts or feelings (Bernatzky, Presch, Anderson, & Panksepp, 2011; Chanda & Levitin, 2013). Indeed, the beneficial property of music to distract people from aversive states has been supported by short-term music interventions for acute stress reduction (Fancourt, Ockelford, & Belai, 2014; Linnemann et al., 2015). These findings are therefore in line with the current meta-analysis, which primarily included studies involving short-term music interventions.

Music listening in the presence of others may strengthen the stress-reducing effect of the music intervention, which is believed to be caused by increased emotional well-being (Juslin et al., 2008), and increased feelings of social cohesion (Boer & Abubakar, 2014; Linnemann, Strahler, & Nater, 2016; Pearce, Launay, & Dunbar, 2015). There is also empirical evidence showing that people synchronize in movement (auditory-motor synchronization) with each other when engaging in music therapy group interventions, which evokes positive feelings of togetherness and bonding, and decreases stress levels (Linnemann et al., 2016; Tarr, Launay, & Dunbar, 2014). Group music-making or singing together may result in social bonding, which may be explained by the release of the neurotransmitters *endorphin* and *oxytocin* (e.g., Dunbar, Kaskatis, MacDonald, & Barra, 2012; Freeman, 2000; Tarr et al., 2014; Weinstein, Launay, Pearce, Dunbar, & Stewart, 2016). These neurotransmitters play a role in the defensive response to stress (Amir, Brown, & Amit, 1980; Dief, Sivukhina, & Jirikowski, 2018; Myint, Jayakumar, Hoe, Kanthimathi, & Lam, 2017). It should be noted that nearly all studies included in our meta-analysis examined participants listening to music alone (e.g., by using headphones), because most studies examined "music as medicine" instead of music therapy, which is applied by a music therapist, and can be delivered both in a group and individual format.

**Effect Moderating Variables**

Results indicate that moderating variables may explain differences in the strength of the effect sizes. Significant stronger moderating effects were found in studies in which physiological arousal, as a result of stress, was measured by heart rate, compared to studies in which physiological arousal was measured by blood pressure or stress-related hormone levels. These results are consistent with the large body of knowledge concerning the immediate effects of psychological stress on the sympathetic responses in the autonomic nervous system, meaning increases of heart rate and decreases of heart rate variability (Chandola, Heraclides, & Kumari, 2010; Föhr et al., 2017). The results are also in line with the assumption that music with a slow steady rhythm provides stress reduction by altering inherent body rhythms, such as heart rate (Thaut & Hoemberg, 2014; Thaut, Kenyon, Schauer, & McIntosh, 1999).

None of the other possible moderators of interventions effects proved to be significant, but results showed some noteworthy trends of the intervention characteristics. First, the *music tempo* seemed to influence the strength of the effect of music interventions on the psychological stress-related outcomes. Larger effect sizes were found in music with a tempo of 60–80 bpm, where tempo represents slow and soothing music. This corresponds with previous research, which suggests that music with a slow tempo can be considered to be one of the most significant determinants of audio-related effects on stress reduction (Bernardi et al., 2006; Björkman et al., 2013; Iwanaga, Kobayashi, & Kawasaki, 2005; Jiang et al., 2016; Nilsson, 2008; Steelman, 1991; White & Shaw, 1991). Second, the frequency of the music intervention sessions did moderate the effect of music interventions on the psychological stress-related outcomes, indicating that only one session is needed for achieving effects on stress reduction. This is in line with previous research, which implies that music has an immediate positive effect on stress reduction (e.g., Koelsch, 2015; Zatorre, 2015). However, Leubner, and Hinterberger‟s (2017) review of the effectiveness of music interventions on depression showed that more than one session yielded larger effects (at least, within the first 6 weeks of treatment).

Contrary to our expectations, we did not find a significant moderating effect of some intervention characteristics. Firstly, type of intervention did not moderate the effects on physiological stress-related outcomes. Studies in which *music therapy* is offered (by a trained therapist) did not yield significantly larger effect sizes than studies in which music interventions were offered as so-called purposeful *music activities* (by the researcher, healthcare professionals or self-administered by the patient). However, Dileo (2005) stated that music therapy is more effective than “music as medicine” interventions and attributed this difference to the fact that music therapists individualize their interventions to meet patients‟ specific needs (Bradt et al., 2014; Dileo, 1999; 2005). A possible explanation for different findings of Dileo‟s review (2005) compared to the current meta-analytic review is that, in the past 14 years, the number of RCTs examining the effects of “music as medicine” interventions has grown substantially, and with that, both the associated research methods and intervention protocols were improved. However, experimental research on the effects of *music therapy* is still in its infancy, while considerable diversity is evident in the interventions that have been examined so far. Secondly, results show that the way the music was selected did not influence the effect of music interventions on stress-related outcomes, while many previous studies report that self-selected music is the most effective in terms of stress reduction (e.g. Brannon & Fiest, 2007; Jiang et al., 2016; Jiang, Zhou, Rickson, & Jiang, 2013; Juslin et al., 2008). A possible explanation is that the term “self-selected music” is used differently in studies included in this meta-analytic review. The term “self-selected music” was both used when the patient brings their own favourite music *and* when the patient could choose the music from a pre-selected list of musical styles (e.g. Bradt et al., 2014; Cepeda, Carr, Lau, & Alvarez, 2006; Helsing, Västfjäll, Bjälkebring, Juslin, & Hartig, 2016; Lee, Chung, Chan, & Chan, 2005; Nilsson, 2008). Notably, where self-selected music also means that patients have to choose their music from a preselected list, the researcher can preselect only music with specific characteristics (nonlyrical music with a tempo of 60–80 bpm and a sound intensity level of 60 dB) which contributes to a stronger effect on physiological stress-related outcomes (Bernardi et al., 2006; Björkman et al., 2013; Dileo, 2007; Gan, Lim, & Haw, 2015; Good et al., 2000). Besides, previous research shows that listening to soothing music, pre-selected by the researcher, lowers the stress-levels significantly in contrast to energetic up-tempo music (Iwanaga et al., 2005; Jiang et al., 2013; Sandstrom & Russo, 2010). This differs from the findings of many studies, which attribute these positive effects to the ability of participants to self-select music (Brannon & Fiest, 2007; Juslin et al., 2008). However, this often means that the participants can choose one of the researcher‟s pre-selected playlists instead of actually bringing their own music. Because of the uncertainty about what the effect actually causes, in the present study we coded "own preference" when patients could bring their own music, and 'selection by researcher/therapist' when patients had to choose the music what was pre-selected by the researcher or therapist.

Results showed no moderating effect for the settings in which the music intervention was conducted (nonmedical, surgery, polyclinic procedures), which might indicate that the effects of music interventions do not depend on the type of setting. This is in line with the assumption that stress is a general activation response to any stimulus that could mean both a threat and a challenge, resulting in heightened arousal of the autonomic nervous system (Pfaff et al., 2007; Selye, 1976; 1973). Also, neurological evidence provides insight in to the positive effects of music on the stress response with respect to arousal regulation, and these effects appear to be independent of context or setting (e.g. Casey, 2017; Koelsch, 2015; Koelsch et al., 2016; Linnemann et al., 2015; Thaut & Hoemberg, 2014).

**Limitations of the Present Study**

The current study has some limitations that need to be mentioned. Firstly, we operationalized the concept of stress in terms of physiological and psychological outcomes, which resulted in two meta-analyses. Because the moderator analyses were performed on both psychological and physiological data, the impression can be that it concerns two independent outcomes, while the outcomes always affect and strengthen each other during stress. This is because the underlying systems of the physiological and psychological responses are both, and mostly at the same time, responsible for the experience of stress (e.g., Linnemann et al., 2017; McEwen & Gianaros, 2010). Secondly, some categories of relevant variables included in the moderator analyses contained only a few effect sizes, which reduces statistical power and sets limits to the generalizability of the study findings. This especially may be the case for the moderators *music induction* (prerecorded music vs. live music) and *music style* (relaxation vs.

own choice) in the meta-analysis of the physiological stress-related outcomes and the moderators *music tempo* (60–80 bpm vs. another tempo), and the *frequency* of the intervention (a single session vs. more than one session) in the meta-analysis of the psychological stress-related outcomes.

**Implications for Research and Practice**

Despite the limitations, this study has important implications for future research and the practical use of music interventions in stress reduction. First and foremost, this meta-analytic study indicates that music interventions can be effective in the reduction of stress. Many people suffer from stress-related symptoms, both in their daily lives and in specific settings (e.g., medical settings, mental health care settings, work-related settings). Considering the fact that music interventions are very easy and inexpensive to integrate in both daily lives and in medical settings, it is important to recognize the effects of music interventions. Another implication is that future research should focus on the specific characteristics of the music intervention on stress reduction, for example, the music tempo, the style of the music, the use of live music or prerecorded music, the way the music is selected, or the frequency of the music intervention sessions.

The vast body of neurological evidence regarding the influence of music on arousal, stress and emotional processes is still growing, but the specific practical implications have not yet been sufficiently investigated. In included RCTs, music interventions are still considered like one and the same, while the specific characteristics of music show different effects, such as the music tempo (60–80 bpm). To identify the most effective music intervention for stress reduction, it is important that the possible moderators of the music interventions be better tested. Therefore, it is recommended for future trials to describe all aspects of the music intervention, with both the specific characteristics involved in these two meta-analyses as well as the musical characteristics, such as timbre, melodic and harmonic aspects, and rhythmic accentuation. These characteristics were not reported in the included RCTs, but can nonetheless moderate the effects of music interventions on stress reduction (e.g. Leubner & Hinterberger, 2017; Moore, 2014; Thaut & Hoemberg, 2014). There are many RCTs examining the effect of *music as medicine interventions*, but there is definitely a lack of RCTs examining the effect of *music therapy interventions* on stress-related outcomes, and it is therefore impossible to establish at this time whether these interventions are more effective than the "music as medicine" interventions. Although the use of prerecorded music may be preferred by researchers as a standardized stimulus, it is recommended to also develop specific *music therapy* protocols that will adhere to the research standards of RCTs.

The relationship between the frequency/duration of the music intervention and the effects on stress reduction is unclear. Future research should examine this topic, because apart from the musical characteristics, such as the music style and music tempo, these general characteristics of the music intervention may also moderate the effects on stress reduction. It seems that the influence of the music selection method on the effects of the music intervention is interpreted differently. In new trials, we strongly recommend reporting clearly if the researcher/therapist did choose the music of the intervention, or if the participants had to choose one of the researchers‟ or therapists‟ pre-selected music playlists, or if the participants brought their own music. Finally, it is recommended to compare the effects of music (therapy) interventions on stress-related outcomes with pharmacological treatment, but also with other experiential interventions, such as yoga or mindfulness.

**Summary**

The current meta-analytic review provides high-level evidence that music interventions can be effective in reducing stress and provides justifications for the increasing use of music interventions for stress reduction in both medical and mental health care practice. Considering the low costs and lack of side effects of music interventions, the moderate tranquilizing effects of music are very significant for the prevention and treatment of stress-related problems. However, the development of music (therapy) intervention protocols are necessary to set up more robust research into the effects of music interventions, and to gain more insight into the effect moderating characteristics of music intervention for stress reduction.

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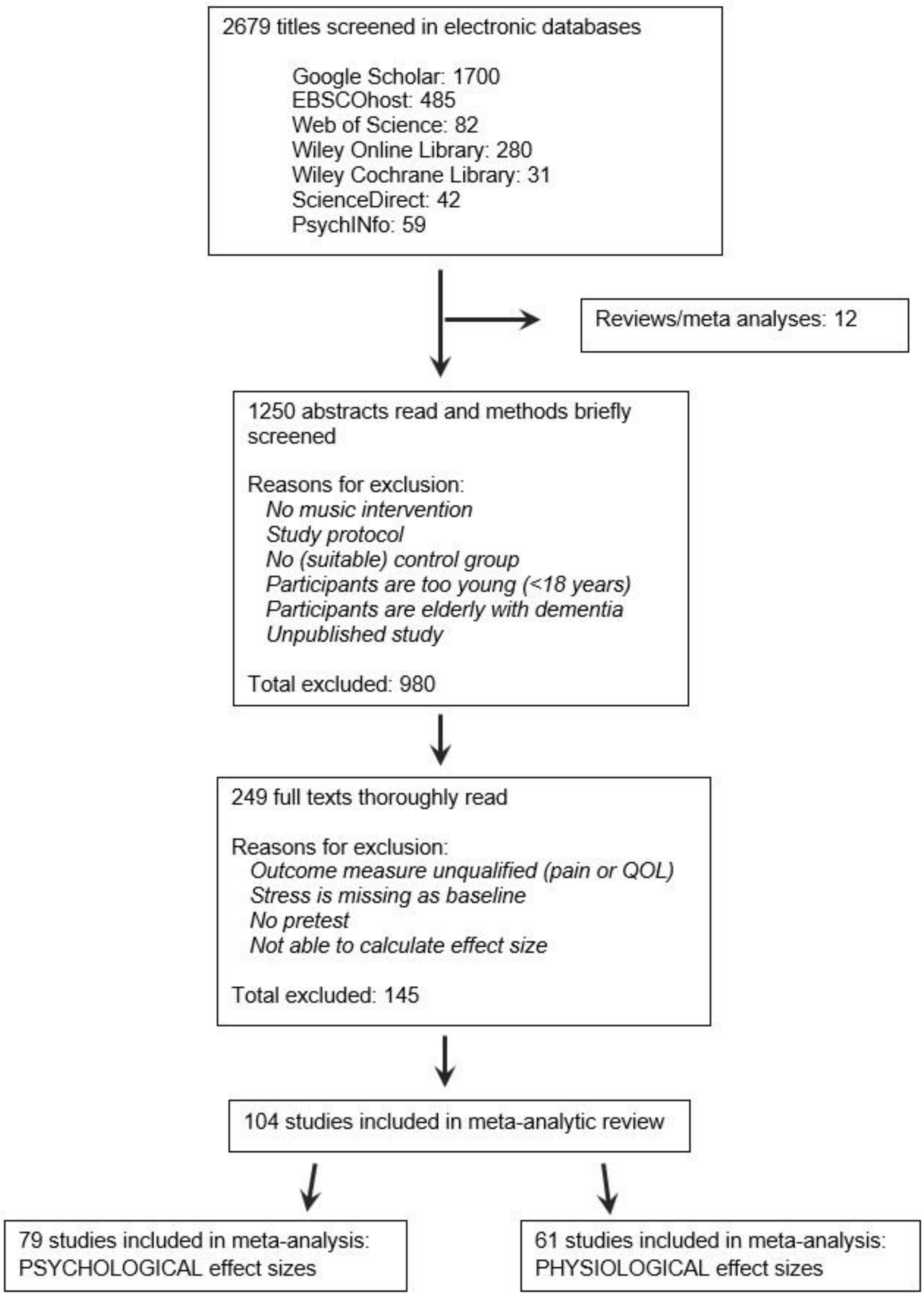


*Figure 1.* Flow chart of the search results.

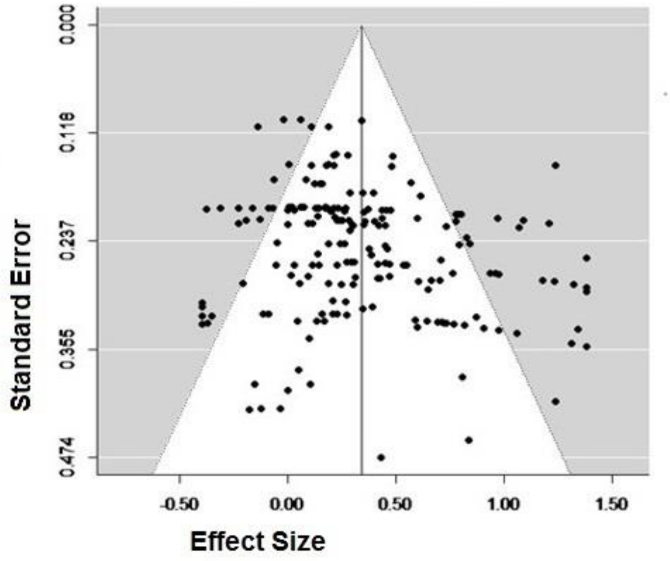


*Figure 2.* Trim–and–fill plot of the effects of music interventions on physiological stress–related outcomes.

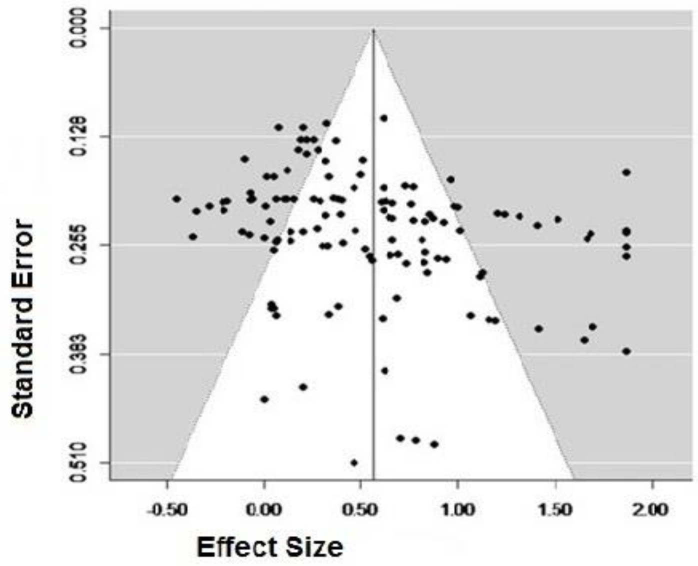


*Figure 3.* Trim–and–fill plot for the effects of music interventions on psychological stress–related outcomes.

Table 1.
*Characteristics of Included Studies*

| Authors | Year | *N* | Impact factor | Study quality | Type of measures | Type of outcome(s) | Physiological measure | Type setting | Intervention |
|---|---|---|---|---|---|---|---|---|---|
| Aba et al. | 2017 | 186 | 1.379 | Strong | psych | Anxiety | – | Med–proc | MA |
| Allen et al. | 2000 | 40 | 4.580 | Strong | phys | Stress | BP, HR | Surgery | MA |
| Ames et al. | 2017 | 41 | – | Strong | psych | Anxiety | – | Surgery | MA |
| Angioli et al. | 2014 | 372 | 1.283 | Moderate | phys, psych | Stress, Anxiety | BP, HR | Med–proc | MA |
| Bally et al. | 2003 | 107 | 1.326 | Strong | psych | Anxiety | – | Med–proc | MA |
| Bauer et al. | 2010 | 80 | 2.050 | Strong | psych | Stress | – | Med–proc | MT |
| Beck et al. | 2015 | 20 | 0.800 | Weak | phys, psych | Stress | Horm | Non–med | MT |
| Bekiroglu et al. | 2013 | 60 | 1.935 | Moderate | phys | Stress | BP | Med–proc | MA |
| Bringman et al. | 2009 | 326 | 2.322 | Moderate | phys, psych | Stress, Anxiety | BP, HR | Surgery | MA |
| Buffum et al. | 2006 | 170 | 0.524 | Weak | phys, psych | Stress, Anxiety | BP, HR | Surgery | MA |
| Bulfone et al. | 2009 | 60 | 0.659 | Moderate | psych | Anxiety | – | Med–proc | MA |
| Camara et al. | 2008 | 203 | 1.170 | Weak | phys | Stress | BP, HR | Surgery | MA |
| Cassileth et al. | 2003 | 62 | 6.072 | Moderate | psych | Anxiety | – | Med–proc | MT |
| Chan et al. | 2006 | 43 | 1.197 | Weak | phys | Stress | BP, HR | Med–proc | MA |
| Chen et al. | 2012 | 73 | 1.754 | Strong | psych | Anxiety | – | Med–proc | MA |
| Cutshall et al. | 2011 | 100 | 1.243 | Weak | phys, psych | Stress | BP, HR | Surgery | MA |
| Chang et al. | 2015 | 76 | 1.426 | Weak | phys | Stress | BP, HR | Med–proc | MA |
| Chang Yu, Chen & | 2015 | 296 | 1.545 | Strong | psych | Stress | – | Med–proc | MA |
| Chen | 2008 | 236 | 1.255 | Strong | psych | Stress | – | Med–proc | MA |
| Chang et al. | 2017a | 21 | 1.296 | Strong | phys, psych | Stress, Anxiety | HR | Non–med | MA |
| De la Torre–Luque et | 2017b | 58 | 1.394 | Strong | phys, psych | Stress, Anxiety | HR | Non–med | MA |
| al. | 2012 | 26 | – | Moderate | phys, psych | Stress, Anxiety | BP, HR | Surgery | MA |
| De la Torre–Luque et | 2016 | 100 | 2.807 | Moderate | phys | Stress | BP, HR | Med–proc | MA |
| al. | 2012 | 200 | – | Strong | psych | Anxiety | – | Med–proc | MA |
| DeMarco et al. | 2016 | 100 | 2.698 | Moderate | psych | Anxiety | – | Med–proc | MT |
| Di Nasso et al. | 2017 | 99 | 3.140 | Moderate | phys | Stress | BP, HR | Med–proc | MA |
| Doğan & Şenturan | 2009 | 180 | 5.727 | Weak | psych | Anxiety | – | Med–proc | MA |
| Doro et al. | 1994 | 38 | 1.657 | Strong | phys, psych | Stress, Anxiety | BP, HR | Med–proc | MA |
| Drzymalski et al. | 2013 | 23 | 1.185 | Moderate | phys, psych | Stress, Anxiety | BP, HR | Med–proc | MT |
| El–Hassan et al. | 2017 | 92 | 0.801 | Strong | psych | Anxiety | – | Med–proc | MA |
| Elliott | 2016 | 120 | 1.998 | Moderate | phys, psych | Stress, Anxiety | BP, HR | Surgery | MA |
| Ghetti | 2013 | 75 | 2.232 | Weak | phys | Stress | Horm | Surgery | MA |
| Ghezeljeh et al. | 2015 | 35 | 1.555 | Moderate | psych | Stress | – | Med–proc | MA |
| Gomez–Urquiza et al. | 2015 | 60 | 1.900 | Strong | phys, psych | Stress, Anxiety | BP, HR | Non–med | MA |
| Graversen & Sommer | 1989 | 53 | 1.657 | Strong | phys | Stress | HR | Med–proc | MA |
| Groener et al. | 2001 | 101 | 1.326 | Strong | phys, psych | Stress, Anxiety | BP, HR | Med–proc | MA |
| Gupta & Gupta | 1996 | 16 | 1.000 | Strong | psych | Anxiety | – | Non–med | MT |
| Guzetta | 2017 | 100 | 2.270 | Strong | phys, psych | Stress, Anxiety | BP, HR | Med–proc | MA |
| Hamel | 2010 | 137 | 1.255 | Strong | phys, psych | Stress, Anxiety | BP, HR | Surgery | MA |
| Hammer | 2008 | 25 | 2.023 | Moderate | phys | Stress | HR | Non–med | MT |
| Hamidi & Ozturk | 2008 | 110 | – | Strong | psych | Anxiety | – | Surgery | MA |
| Han et al. | 2016 | 70 | 2.056 | Moderate | psych | Anxiety | – | Med–proc | MA |
| Horne–Thomson & | 2003 | 198 | 0.671 | Weak | psych | Anxiety | – | Med–proc | MA |
| Grocke | 2016 | 143 | – | Moderate | psych | Anxiety | – | Surgery | MA |
| Hook et al. | 2013 | 40 | 0.211 | Strong | phys | Stress | BP, HR, | Surgery | MA |
| Hsu et al. | 2012 | 119 | 0.662 | Strong | psych | Anxiety | Horm | Surgery | MA |
| Hayes et al. | 2015 | 34 | – | Moderate | phys | Stress | – | Surgery | MA |
| Jeppesen et al. | 2017 | 138 | 1.252 | Weak | psych | Anxiety | Horm | Med–proc | MA |
| Jiménez–Jiménez et | 2015 | 88 | 0.922 | Strong | phys, psych | Stress, Anxiety | – | Med–proc | MA |
| al. | 2012 | 60 | 1.264 | Strong | phys | Stress | BP, HR, | Surgery | MA |
| Johnson et al. | 2011 | 54 | 1.741 | Strong | phys, psych | Stress | Horm | Non–med | MA |
| Kar et al. | 2008 | 44 | 1.255 | Strong | phys, psych | Stress, Anxiety | BP, HR | Med–proc | MA |
| Ko et al. | 2013 | 60 | 1.814 | Strong | phys | Stress | BP, HR, | Non–med | MA |
| Kunikullaya et al. | 2014 | 80 | – | Moderate | phys | Stress | Horm | Non–med | MA |
| Kushnir et al. | 2007 | 60 | 5.596 | Moderate | phys | Stress | BP, HR | Med–proc | MA |
| Lai & Li | 2016 | 64 | 1.585 | Moderate | phys, psych | Stress | BP, HR | Non–med | MA |
| Lai et al. | 2012 | 140 | 1.427 | Strong | phys, psych | Stress, Anxiety | BP, HR | Surgery | MA |
| Lai et al. | 2017 | 85 | 2.344 | Strong | phys, psych | Stress, Anxiety | Horm | Med–proc | MA |
| Latha et al. | 2017 | 85 | 1.549 | Strong | phys, psych | Stress, Anxiety | BP | Surgery | MA |
| Leardi et al. | 2017 | 100 | 2.013 | Weak | phys, psych | Stress, Anxiety | HR, HRV | Surgery | MA |
| Lee et al. | 2011 | 98 | 1.384 | Strong | psych | Anxiety | BP, HR | Med–proc | MA |
| Lee et al. | 2012 | 88 | 1.604 | Moderate | phys, psych | Stress | BP, HR | Med–proc | MA |
| Lee, Lai, Sung et al. | 2004 | 118 | 2.253 | Moderate | psych | Anxiety | BP, HR | Med–proc | MA |
| Lee, Lee, Hsu et al. | 2012 | 150 | – | Moderate | psych | Stress, Anxiety | – | Surgery | MA |
| Lee, Wu, Lee et al. | 2007 | 68 | 0.800 | Weak | phys, psych | Stress, Anxiety | BP, HR | Surgery | MT |
| Lin et al. | 1991 | 38 | 4.580 | Weak | phys | Stress | – | Med–proc | MA |
| Lin et al. | 2016 | 197 | 3.640 | Strong | psych | Anxiety | – | Med–proc | MA |
| López–Cepero | 2016 | 42 | – | Strong | phys, psych | Stress, Anxiety | BP | Med–proc | MA |
| Andrada | 2011 | 172 | 1.384 | Weak | phys, psych | Anxiety | BP, HR | Surgery | MA |
| Mahdipour et al. | 2009 | 58 | 1.332 | Strong | phys | Stress | – | Surgery | MA |
| Mandel et al. | 2005 | 75 | 3.634 | Strong | phys | Stress, Anxiety | HR | Surgery | MA |
| Menegazzi et al. | 2012 | 97 | 1.182 | Moderate | psych | Anxiety | BP, HR | Med–proc | MA |
| Ming et al. | 2017 | 132 | 0.810 | Strong | phys, psych | Stress, Anxiety | BP, HR, | Med–proc | MA |
| Miyata et al. | 2008 | 60 | 1.748 | Weak | psych | Anxiety | Horm | Med–proc | MA |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Ni et al. | 2014 | 123 | 3.473 | Strong | psych | Stress | BP, HR, | Non–med | MA |
| Nilsson | 2013 | 62 | 0.769 | Strong | psych | Stress, Anxiety | Horm | Med–proc | MT |
| Nilsson et al. | 2014 | 70 | 0.824 | Moderate | phys | Stress | – | Med–proc | MA |
| O'Callaghan et al. | 2016 | 166 | 0.972 | Strong | psych | Anxiety | BP, HR | Med–proc | MA |
| Padam et al. | 2014 | 70 | 0.647 | Weak | psych | Anxiety | – | Non–med | MA |
| Pothoulaki et al. | 2006 | 86 | 2.172 | Moderate | phys, psych | Stress, Anxiety | – | Surgery | MA |
| Radstaak et al. | 2010 | 100 | 0.240 | Moderate | psych | Anxiety | – | Med–proc | MA |
| Romito et al. | 2011 | 233 | 0.849 | Moderate | psych | Stress, Anxiety | BP, HR | Med–proc | MA |
| Ripley et al. | 2014 | 141 | 3.570 | Moderate | psych | Anxiety | – | Med–proc | MA |
| Salehi et al. | 2008 | 80 | – | Weak | psych | Anxiety | – | Non–med | MT |
| Sanal & Gorsev | 2016 | 66 | 3.560 | Moderate | psych | Anxiety | – | Med–proc | MA |
| Sendelbach et al. | 2016 | 80 | 2.993 | Strong | psych | Anxiety | BP, HR | Med–proc | MA |
| Shabanloei et al. | 2010 | 56 | 0.622 | Weak | psych | Stress, Anxiety | – | Surgery | MA |
| Shin & Kim | 2013 | 28 | 1.917 | Moderate | phys | Stress | – | Surgery | MA |
| Simavli et al. | 2012 | 90 | 1.292 | Weak | phys | Stress | – | Surgery | MA |
| Smith | 2015 | 100 | 1.158 | Moderate | phys | Stress | – | Med–proc | MA |
| Solomon & Ridgeway | 2015 | 92 | 2.130 | Weak | psych | Anxiety | – | Med–proc | MA |
| Soo et al. | 2017 | 70 | 2.013 | Moderate | psych | Anxiety | – | Med–proc | MA |
| Stein et al. | 2006 | 200 | 2.651 | Moderate | phys | Stress | – | Med–proc | MA |
| Su et al. | 2004 | 29 | 0.930 | Moderate | phys | Stress | BP, HR, | Med–proc | MA |
| Tabrizi et al. | 2013 | 100 | 1.936 | Strong | psych | Anxiety | Horm | Surgery | MA |
| Tan et al. | 2004 | 61 | 5.836 | Strong | psych | Stress, Anxiety | BP, HR | Surgery | MA |
| Thoma et al. | 2015 | 60 | 1.395 | Strong | phys, psych | Stress, Anxiety | – | Surgery | MT |
| Toker & Kömürcü | 2016 | 84 | 2.649 | Strong | phys, psych | Stress | – | Med–proc | MT |
| Triller et al. | 1992 | 40 | 0.766 | Strong | phys, psych | Anxiety | BP, HR | Surgery | MA |
| Uedo et al. | 2016 | 91 | 2.275 | Strong | phys, psych | Stress, Anxiety | Horm | Surgery | MA |
| Vachiramon et al. | 2008 | 70 | 1.710 | Weak | phys | Stress | – | Med–proc | MA |
| Voss et al. | 2013 | 100 | 1.935 | Weak | phys | Stress | – | Med–proc | MA |
| Wang et al. | 2014 | 124 | 0.680 | Strong | psych | Anxiety | BP, HR | Med–proc | MA |
| Warth et al. | | | | | | | HRV | | |
| White | | | | | | | BP, HR | | |
| Wiwatwongwana et | | | | | | | BP, HR | | |
| al. | | | | | | | BP, HR | | |
| Yeo et al. | | | | | | | BP, HR, | | |
| Zengin et al. | | | | | | | Horm | | |
| Zhang et al. | | | | | | | – | | |

*Note:* psych = psychological stress–related outcomes; phys = physiological stress–related outcomes; BP = blood pressure; HR = heart rate; Horm = hormone levels;
HRV = heart rate variability; MA = music activity; MT = music therapy.

Table 2.
*Overall Effects of Music Interventions on Physiological and Psychological Stress–Related Outcomes*

| Outcome | *s* | *k* | Mean *d* | 95% CI | *p* | $\sigma^2_{level2}$ | $\sigma^2_{level3}$ | % Var. level 1 | % Var. level 2 | % Var. level 3 |
|---|---|---|---|---|---|---|---|---|---|---|
| Physiological outcomes | 61 | 197 | 0.380 | 0.296 – 0.465 | < .001*** | 0.024*** | 0.076*** | 32.44 | 16.09 | 51.47 |
| Psychological outcomes | 79 | 130 | 0.545 | 0.432 – 0.657 | < .001*** | 0.119*** | 0.128*** | 15.38 | 40.76 | 43.87 |

*Note. s* = number of studies; *k* = number of effect sizes; CI = confidence interval; Mean *d* = mean effect size (*d*); CI = confidence interval; % Var = percentage of variance explained; $\sigma^2_{level2}$ = variance between effect sizes within the same study; $\sigma^2_{level3}$= variance between studies.

Table 3.

*Moderator Effects of Music Interventions on Physiological Stress–Related Outcomes*

| Moderator variables | *s* | *k* | $\beta_0$ (mean *d*) | $t_0$ | $\beta_1$ | $t_1$ | *F*(df1, df2) |
|---|---|---|---|---|---|---|---|
| *Outcome characteristics* | 61 | 197 | | | | | *F*(2, 193) = 3.581$^{*}$ |
| Bloodpressure (RC) | 47 | 104 | 0.343 | 7.141$^{***}$ | | | |
| Hormones | 13 | 22 | 0.349 | 3.949$^{***}$ | 0.006 | 0.067 | |
| Heart rate | 53 | 70 | 0.456 | 8.944$^{***}$ | 0.113 | 2.617 | |
| *Study characteristics* | | | | | | | |
| Setting | 61 | 197 | | | | | *F*(2, 194) = 1.099 |
| Surgery (RC) | 27 | 110 | 0.393 | 6.370$^{***}$ | | | |
| Nonmedical | 10 | 20 | 0.523 | 4.299$^{***}$ | 0.130 | 0.953 | |
| Polyclinical procedures | 24 | 67 | 0.320 | 4.677$^{***}$ | − 0.073 | − 0.794 | |
| Continent | 61 | 197 | | | | | *F*(1, 195) = 2.914 |
| Western (RC) | 30 | 108 | 0.306 | 5.097$^{***}$ | | | |
| Non–Western | 31 | 89 | 0.450 | 7.659$^{***}$ | 0.143 | 1.707 | |
| Study quality | 61 | 197 | | | | | *F*(2, 194) = 0.586 |
| Strong (RC) | 28 | 92 | 0.405 | 6.413$^{***}$ | | | |
| Moderate | 20 | 52 | 0.313 | 4.052$^{***}$ | − 0.093 | − 0.928 | |
| Weak | 13 | 53 | 0.426 | 4.596$^{***}$ | 0.021 | 0.190 | |
| *Intervention characteristics* | | | | | | | |
| Type of music intervention | 61 | 197 | | | | | *F*(1, 195) = 0.094 |
| Music activity (RC) | 54 | 183 | 0.379 | 8.346$^{***}$ | | | |
| Music therapy | 7 | 14 | 0.423 | 2.931$^{**}$ | 0.046 | 0.307 | |
| Type of control condition | 61 | 197 | | | | | *F*(1, 195) = 2.784 |
| CAU (RC) | 46 | 130 | 0.417 | 8.641$^{***}$ | | | |
| Other intervention | 18 | 67 | 0.284 | 3.948$^{***}$ | − 0.133 | − 1.668 | |
| Music selection | 61 | 197 | | | | | *F*(1, 195) = 1.040 |
| Own preference (RC) | 24 | 90 | 0.329 | 4.985$^{***}$ | | | |
| Selection by researcher/therapist | 37 | 107 | 0.415 | 7.580$^{***}$ | 0.087 | 1.020 | |
| Music induction | 61 | 197 | | | | | *F*(1, 195) = 1.065 |
| Prerecorded music (RC) | 54 | 184 | 0.367 | 8.287$^{***}$ | | | |
| Live music | 7 | 13 | 0.525 | 3.571$^{***}$ | 0.159 | 1.032 | |
| Music style | 58 | 186 | | | | | *F*(1, 184) = 1.336 |
| Relaxation (RC) | 46 | 152 | 0.393 | 8.689$^{***}$ | | | |
| Own choice | 12 | 34 | 0.285 | 3.417$^{***}$ | − 0.109 | − 1.156 | |
| Music with lyrics | 61 | 197 | | | | | *F*(2, 194) = 0.560 |
| No (RC) | 47 | 143 | 0.372 | 7.488$^{***}$ | | | |
| Yes | 2 | 6 | 0.189 | 0.789 | − 0.183 | − 0.747 | |
| Both | 12 | 48 | 0.446 | 4.604$^{***}$ | 0.074 | 0.678 | |
| Music tempo | 61 | 197 | | | | | *F*(1, 195) = 0.304 |
| 60–80 beats p/m (RC) | 36 | 130 | 0.361 | 6.449$^{***}$ | | | |
| No specific tempo | 25 | 67 | 0.409 | 6.029$^{***}$ | 0.049 | 0.551 | |
| Frequency | 60 | 193 | | | | | *F*(1, 195) = 0.091 |
| One session (RC) | 49 | 146 | 0.375 | 8.003$^{***}$ | | | |
| More sessions | 11 | 47 | 0.402 | 4.845$^{***}$ | 0.027 | 0.301 | |
| Duration (continuous) | 49 | 161 | 0.318 | 8.215$^{***}$ | 0.003 | 1.479 | *F*(1, 159) = 2.187 |
| *Sample characteristics* | | | | | | | |
| Proportion of males (continuous) | 55 | 181 | 0.366 | 7.871$^{***}$ | −0.094 | − 0.549 | *F*(1, 179) = 0.301 |
| Age (continuous) | 55 | 182 | 0.386 | 8.228$^{***}$ | −0.001 | − 0.223 | *F*(1, 180) = 0.050 |

*Note. s* = number of independent studies; *k* = number of effect sizes; $\beta_0$ = intercept/mean effect size (d); $t_0$ = difference in mean *r* with zero; $\beta_1$ = estimated regression coefficient; $t_1$ = difference in mean r with reference category; *F*(df1, df2) = omnibus test; (RC) = reference category. * $p < .05$, ** $p < .01$,*** $p < .001$

Table 4.
*Moderator Effects of Music Interventions on Psychological Stress-Related Outcomes*

| Moderator variables | *s* | *k* | $\beta_0$ (mean *d*) | $t_0$ | $\beta_1$ | $t_1$ | *F*(df1, df2) |
|---|---|---|---|---|---|---|---|
| *Outcome characteristics* | 79 | 130 | | | | | *F*(1, 128) = 0.118 |
| State anxiety (RC) | 70 | 101 | 0.553 | 9.008*** | | | |
| Stress | 19 | 29 | 0.512 | 4.592*** | −0.041 | −0.344 | |
| *Study characteristics* | | | | | | | |
| Setting | 79 | 130 | | | | | *F*(2, 127) = 2.353 |
| Surgery (RC) | 23 | 51 | 0.669 | 6.808*** | | | |
| Nonmedical | 12 | 19 | 0.694 | 4.553*** | 0.025 | 0.137 | |
| Polyclinic procedures | 44 | 60 | 0.433 | 5.707*** | −0.236 | −1.897 | |
| Continent | 79 | 130 | | | | | *F*(1, 128) = 0.765 |
| Western (RC) | 40 | 70 | 0.496 | 6.206*** | | | |
| Non–Western | 39 | 60 | 0.596 | 7.318*** | 0.100 | 0.874 | |
| Study quality | 79 | 130 | | | | | *F*(2, 127) = 1.573 |
| Strong (RC) | 42 | 71 | 0.628 | 8.175*** | | | |
| Moderate | 21 | 28 | 0.387 | 3.423*** | −0.240 | −1.757 | |
| Weak | 16 | 31 | 0.518 | 4.142*** | −0.110 | −0.749 | |
| *Intervention characteristics* | | | | | | | |
| Type of music intervention | 79 | 130 | | | | | *F*(1, 128) = 0.013 |
| Music intervention (RC) | 67 | 110 | 0.548 | 8.838*** | | | |
| Music therapy | 12 | 20 | 0.529 | 3.539*** | −0.019 | −0.115 | |
| Type of control condition | 79 | 130 | | | | | *F*(1, 128) = 2.795 |
| Other intervention (RC) | 23 | 35 | 0.592 | 9.252*** | | | |
| Care as usual | 63 | 95 | 0.402 | 3.900*** | −0.190 | −1.672 | |
| Music selection | 79 | 130 | | | | | *F*(1, 128) = 0.953 |
| Own preference (RC) | 30 | 62 | 0.611 | 6.911*** | | | |
| Selection by researcher/therapist | 49 | 68 | 0.498 | 6.709*** | −0.113 | −0.976 | |
| Music induction | 79 | 130 | | | | | *F*(1, 128) = 0.385 |
| Prerecorded music (RC) | 66 | 109 | 0.560 | 8.991*** | | | |
| Live music | 13 | 21 | 0.464 | 3.269** | −0.096 | −0.621 | |
| Music style | 71 | 120 | | | | | *F*(1, 118) = 0.512 |
| Own preference (RC) | 34 | 47 | 0.521 | 5.655*** | | | |
| Relaxation | 37 | 73 | 0.609 | 7.296*** | 0.089 | 0.716 | |
| Music with lyrics | 79 | 130 | | | | | *F*(2, 127) = 0.872 |
| No (RC) | 52 | 81 | 0.556 | 7.891*** | | | |
| Yes | 5 | 8 | 0.264 | 1.186 | −0.292 | −1.257 | |
| Both | 22 | 41 | 0.581 | 5.471*** | 0.026 | 0.201 | |
| Music tempo | 79 | 130 | | | | | *F*(1, 128) = 3.132 |
| 60–80 beats p/m (RC) | 49 | 82 | 0.625 | 8.789*** | | | |
| No specific tempo | 30 | 48 | 0.413 | 4.578*** | −0.212 | −1.871 | |
| Frequency intervention | 79 | 130 | | | | | |
| One session (RC) | 61 | 90 | 0.601 | 9.316*** | | | *F*(1, 128) = 3.156 |
| More than one session | 18 | 40 | 0.379 | 3.487*** | −0.222 | −1.776 | |
| Duration (continuous) | 65 | 109 | 0.547 | 8.662*** | 0.001 | 0.547 | *F*(1, 107) = 0.299 |
| *Sample characteristics* | | | | | | | |
| Proportion of males (continuous) | 78 | 129 | 0.549 | 9.480*** | 0.017 | 0.061 | *F*(1, 127) = 0.004 |
| Age (continuous) | 73 | 123 | 0.537 | 9.023*** | 0.003 | 0.629 | *F*(1, 121) = 0.395 |

*Note*. *s* = number of independent studies; *k* = number of effect sizes; $\beta_0$= intercept/mean effect size (*d*); $t_0$ = difference in mean *d* with zero; β = estimated regression coefficient; $t_1$ = difference in mean *d* with reference category; *F*($df_1$, $df_2$) = omnibus test; (RC) = reference category. $^{*}p < .05$, $^{**}p < .01$, $^{***}p < .001$