MUSIC HATH CHARMS: EFFECTS OF VALENCE, AROUSAL, AND ABSORPTION ON THE REGULATION OF STRESS

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Abstract

The purpose of this study was to investigate the effects of valence and arousal dimensions of music on physiological and subjective recovery from stress, and how these effects might be moderated by trait absorption. In Experiment 1, 40 participants experienced stress after being told to prepare a speech, and then listened to peaceful music or white noise after the speech task was dismissed. Peaceful music promoted recovery better than white noise. In Experiment 2, 88 participants experienced stress using the same methodology, and then listened to happy, peaceful, sad or agitated music. Music with a positive valence promoted recovery better than music with a negative valence, and low arousal music was more effective than high arousal music. In both experiments, differences in recovery were largely driven by individuals who were high in absorption.

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Music hath charms: The effects of valence, arousal, and absorption on the regulation of stress

In the age of the iPod, music grows ever more portable and ubiquitous. We listen to music for many reasons, but one of the primary attractions is the emotional power it exerts. When Juslin and Laukka (2004) asked participants why they listen to music, the most common response was "to express, release, and influence emotions" (p. 232). Thayer, Newman and McClain (1994) asked participants to list what strategies they use to minimize a bad mood, to increase their level of energy, and to reduce tension. In each case, participants mentioned music. Despite this pervasive recognition that music is an effective means to alter mood, little research has looked at the factors involved in emotion regulation through music. In this study, we investigated whether musical characteristics, specifically the emotion conveyed by music, influence individuals' recovery from induced stress. In addition, we explored whether the effectiveness of music for emotion regulation is impacted by individual differences, including trait absorption.

EMOTION DIMENSIONS

Since its early days, psychology has attempted to describe the structure of emotion with regard to its underlying dimensions. On the basis of introspection, Wundt (1896, as cited by Lang, 1994) proposed that emotions have three dimensions: pleasure, tension and inhibition (arousal). Osgood, Suci and Tannenbaum (1957) confirmed similar dimensions by factor analysis, finding that valence (pleasant-unpleasant) accounted for the most variance, followed by arousal (calm-aroused). Russell (1980) used multi-dimensional scaling to develop a circumplex model in which affective states are arranged in a circular pattern around two axes represented by the dimensions of arousal and valence. The importance of valence and arousal as underlying dimensions of emotion conveyed by music has been supported by numerous studies (Bigand, Vieillard, Madurell, Marozeau, & Dacquet, 2005; Nyklicek, Thayer, & Van Doornen, 1997).

Physiological reactivity occurs as a result of the whole situational context, not the emotional stimulus alone (Lang, 1994). Consequently, when attempting to show an emotional impact as a result of music listening it is imperative to include a control condition that shares the same context, but is emotionally neutral. Traditionally, this has been accomplished by using white noise (Nyklicek et al., 1997; Sokhadze, 2007).

The present study employs a subset of the music excerpts used by Nyklicek et al. (1997) in order to represent the four quadrants of Russell's circumplex. If emotion regulation using music is influenced by the emotional content of the music, then we would expect to see differences in the extent of regulation (i.e., extent of recovery following induced stress) for music excerpts from the different quadrants. We would also expect to see a difference between the effects of music and white noise, which serves as an emotion-neutral control condition.

EMOTION REGULATION

Gross (1998) defined emotion regulation as "the processes by which individuals influence which emotions they have, when they have them, and how they experience and express these emotions" (p. 275). A large part of the literature has focused on person variables and emotion dysregulation in particular, which has been implicated in clinical disorders such as binge eating, alcohol abuse, and anxiety and mood disorders (Gross, 1998). However, emotion regulation can also be considered from the perspective of situational variables. One way to regulate our emotional response to a stimulus is to follow it with an emotional response to a subsequent stimulus. There has been little study regarding whether the valence of the subsequent emotional state impacts its effectiveness (Baron, 1976; Zillmann, 1978), and the evidence thus far has been mixed.

The effectiveness of emotion regulation through music may depend on the music's valence and arousal. Fredrickson, Mancuso, Branigan and Tugade (2000) proposed, in their "undoing" hypothesis, that positive emotions can assist with emotion regulation by counteracting the negative physiological concomitants of negative emotions. They induced stress with a speech task, and then showed participants one of four silent film clips, intended to induce contentment, amusement, neutrality or sadness. They found that the two film clips that conveyed positive valence provided the most beneficial effect on physiological indices of stress; participants recovered from the stress more quickly after watching the positive emotion clips.

Sokhadze (2007) tested the undoing hypothesis with music excerpts instead of film clips. He induced disgust by having participants view emotion-inducing images (from the International Affective Picture System; IAPS) and subsequently played either pleasant or sad music, or white noise. Sokhadze found a complete return to baseline for most physiological measures following both pleasant and sad music, but a poorer recovery following white noise. The undoing hypothesis was only partially supported; some physiological measures indicated a more favourable recovery following pleasant as opposed to sad music, but other physiological measures did not.

Roy, Peretz and Rainville (2008) studied music's capacity to soothe the pain resulting from administration of thermal stimulations. Participants who concurrently listened to music with a positive valence (rated by independent participants) reported reduced pain intensity and unpleasantness, compared to those who heard music with a negative valence, or no music.

In comparison to valence, there has been even less study regarding whether the arousal conveyed by the subsequent emotional stimulus may impact its effectiveness for emotion regulation. Bernardi, Porta & Sleight (2006) found that different styles of music (e.g., Raga, Classical, Techno) had differing abilities to induce a state of relaxation; music with a slower tempo (lower arousal) was more relaxing than music with a faster tempo (higher arousal), as indicated by the lower degree of physiological reactivity (e.g., less acceleration of heart rate). They suggested that music conveying low arousal leads to more relaxation than music conveying high arousal.

In the present study, we induced stress with a speech task as did Fredrickson et al. (2000), rather than inducing disgust as did Sokhadze (2007). We presented music excerpts conveying a wider range of emotions than either Fredrickson et al. (2000) or Sokhadze (2007), in order to examine all combinations of valence and arousal and test their independent contributions to emotion regulation.

PHYSIOLOGICAL MEASURES OF EMOTION

Stress triggers changes in endocrine, cardiovascular, respiratory, gastrointestinal, and renal systems. Endocrinologically, stress triggers adrenaline and cortisol secretion. In the autonomic nervous system (ANS), blood vessels dilate to allow rapid muscle movement and constrict elsewhere in the body, resulting in measurable changes in blood pressure. Stress-related stimulation of sweat glands is detected by measuring the galvanic skin response (GSR). Acceleration of the heart rate (HR) can be discerned in measurements of the pulse. Heart rate variability (HRV) refers to fluctuations in the intervals between heartbeats. Variability in the heart rate is considered healthy, and acute stress lowers this variability. HRV can be computed as a ratio comparing the low frequency (LF; around 1 Hz) portion of the heart rate, to the high frequency (HF; 0.15-0.4 Hz) portion. The HF component, which is thought to be an index of vagal activity, is sometimes analyzed separately, and is also referred to as respiratory sinus arrhythmia (RSA), since respiration occurs in the same frequency band. As with HRV, RSA is lower in response to stress.

Some of the same physiological measures that can be used to detect stress have also been used to understand the emotional response to music – e.g., GSR (Baumgartner, Esslen, & Jäncke, 2006; Khalfa, Peretz, Blondin, & Manon, 2002; Krumhansl, 1997; Rickard, 2004; Sokhadze, 2007), HR (Baumgartner et al., 2006; Bernardi et al., 2006; Knight & Rickard, 2001; Krumhansl, 1997; Nyklicek et al., 1997; Rickard, 2004; Sokhadze, 2007; Witvliet & Vrana, 2007), HRV (Sokhadze, 2007), and RSA (Krumhansl, 1997; Nyklicek et al., 1997).

The valence and arousal characteristics of music affect these measures in a listener. GSR has demonstrated a consistent positive correlation with arousal; Khalfa et al. (2002) found that participants had a higher GSR when they listened to a fearful or happy (high arousal) music excerpt than they did when they listened to a sad or peaceful (low arousal) music excerpt. Listeners who heard non-musical sound clips in a study by Bradley and Lang (2000) showed the greatest increases in GSR for sounds that were high in arousal.

In the visual domain, HR has demonstrated a modest, positive correlation with the valence of International Affective Picture System's (IAPS) emotional pictures (Lang, 1995). However, Bradley and Lang (2000) were only able to confirm a similar response to auditory stimuli (non-musical sounds) when they were highly arousing. On the other hand, Krumhansl (1997) found that HR was faster during happy music than during sad music, and Witvliet and Vrana (2007) found higher HR in response to high arousal music and music with a positive valence.

Results from measurement of HRV and RSA have been less consistent. Sokhadze (2007) found a significant increase in the HF component of HRV as a result of inducing disgust, but no significant differences in recovery between conditions (pleasant music, sad music, white noise). Similarly, Krumhansl (1997) found no differences in RSA between music listening conditions (sad, fearful and happy excerpts). On the other hand, Nyklicek, et al. (1997) found significant differences in RSA between music listening conditions, specifically larger decreases in RSA in response to high arousal music.

Other studies have found that the characteristics of the music are unimportant to the emotion response, and that situational and personal factors, such as preference, may be more salient. In a within-subjects study of the effects of music on the frequency of agitated behaviours in older adults with Alzheimer's disease, Gerdner (2000) found that individualized, preferred music (selected with assistance from the family of the patient) significantly reduced agitation, while relaxing, classical music did not. Similarly, in a study of surgeons who habitually listen to music in the operating room, Allen and Blascovich (1994) found that those who listened to self-selected music demonstrated better performance on a stressful, non-surgical task than those who listened to experimenter-selected, relaxing, classical music. In another study, Allen and colleagues (2001) assigned ophthalmic surgery patients to listen to self-selected music, or not, during preoperative, surgical and postoperative periods. Participants who listened to music experienced accelerated recovery of blood pressure and lower levels of perceived stress compared to those who did not listen to music, regardless of the type of music they chose to listen to.

In the present study, we used GSR, HR and the HF component of HRV as physiological measures. They should indicate a stress response after we present the speech task (i.e., increases in galvanic skin response and heart rate and a decrease in HRV), followed by a reversal during recovery when the music is playing. Differences between music conditions should be manifested by differences in the rate of recovery of the physiological measures.

EMOTIONAL RESPONSES

Lang's tri-partite theory (Lang, 1968; Lang, 1984) postulates the existence of three emotional response systems: physiological, behavioural and cognitive. Despite being components of the same emotional response, there is often a discordance between these systems, especially between subjective self-report judgments and physiological changes (Mandler & Kremen, 1958). There is a general consensus that the absence of a particular type of response does not allow one to conclude that an emotion has not occurred (Lundqvist, Carlsson, Hilmersson, & Juslin, 2009).

Studies of emotional response to music have shown a similar discordance. Khalfa et al. (2002) found that skin conductance response measurements did not agree with participants' subjective judgments of the emotion conveyed by music excerpts. Similarly, Nyklicek et al. (1997) found only modest correlations between cardiorespiratory measures and subjective reports of the emotion expressed by music excerpts. Subjective variables yielded better discrimination between emotions than did physiological variables. Burns, Labbé, Williams and McCall (1999) randomly assigned participants to sit in silence or listen to different types of music. They reported significant differences in self-reported feelings of relaxation between listening conditions, but no significant differences in physiological measures (skin temperature, muscle tension and heart rate).

These findings speak to the importance of gathering multiple types of emotional responses. The current study examines physiological and self-report measures.

INDIVIDUAL DIFFERENCES

Emotional responses to music are driven by more than just the characteristics of the music; individual differences such as musical background and trait absorption can moderate the emotional response to music (Kreutz, Ott, Teichmann, Osawa, & Vaitl, 2008). Tellegen and Atkinson (1974) defined absorption as "a disposition for having episodes of 'total' attention that fully engage one's representational resources" (p. 268). This trait appears to have biological foundations; Ott, Reuter, Hennig and Vaitl (2005) found a relationship between trait absorption, as measured by the Tellegen Absorption Scale, and particular genotypes. Kreutz et al. (2008) found that high absorbers generally reported stronger emotions in response to music than did low absorbers. Nagy and Szabo (2004) found that high absorbers reported a stronger liking for all types of music presented in their study.

This influence of absorption on emotional response may be relevant to understanding the regulation of emotion through music. Specifically, being more absorbed by the music might lead to an enhancement in the effectiveness of music to regulate the emotions. The study by Roy et al. (2008) concerning the use of music as a pain analgesic provides some suggestive evidence. They found that the effectiveness of pleasant music to regulate pain was enhanced in listeners who reported the strongest emotional response to the music. These listeners are likely to be those who are high in trait absorption.

Some evidence indicates that individuals with music training have different physiological responses to music than untrained individuals. VanderArk and Ely (1992; 1993) found that music majors had higher levels of cortisol and higher GSR after listening to music than did biology majors. After inducing stress with a blindfolded pencil-maze task, Peretti and Swenson (1974) played music for participants. Music majors showed a lower GSR than non-music majors, suggesting that they had recovered better following the stressful task.

However, many studies have not found any differences between highly musically trained and untrained participants. In a music listening task, Kreutz et al. (2008) found that musically trained individuals rated the excerpts higher in arousal, but did not differ from less musically trained individuals with respect to ratings of intensity or specificity of discrete emotions (happy, sad, angry, fearful or peaceful). Knight and Rickard (2001) played music for one group of participants while they prepared to make a speech. There were no interactions between condition (music or the silence control condition) and extent of music training on physiological responses. Rickard (2004) studied physiological responses to relaxing, arousing and emotionally powerful music. There were no correlations between degree of musical training and any of the physiological response measures.

Personality traits have been linked to differences in emotion regulation styles (Gross, 1999). Individuals who are high in conscientiousness are able to control impulses, and thus are able to deploy their attention away from an emotionally negative stimulus, in a way that assists with emotion regulation. Individuals high in neuroticism are less skilled at emotion regulation, and lack the attentional resources necessary for attentional deployment. Those who are high in openness are often high in cognition and thus tend to use cognitive techniques such as attentional deployment.

Rickard (2004) found correlations between personality traits and physiological measures of emotional response to music. Extraversion showed a positive correlation with HR and number of chills, while agreeableness showed a positive correlation with skin conductance.

Kokkonen and Pulkkinen (2001) hypothesized that extraversion would be positively correlated and neuroticism negatively correlated with attempts to regulate emotions, and that the relationship would be mediated by a person's current mood and their evaluation of their mood. They found the expected negative correlation between neuroticism and the usage of each of three emotion regulation strategies (repair, maintenance and dampening) for men only. Path analysis models included agreeableness, neuroticism, extraversion and openness to experience for men, and neuroticism and conscientiousness for women.

In a series of studies, Furnham and colleagues (Furnham & Bradley, 1997; Furnham & Allass, 1999; Furnham & Strbac, 2002) investigated the effects of music on task performance for individuals high and low in extraversion. Over a variety of tasks, the performance of introverts tended to be more negatively affected by the presence of music than that of extraverts.

In the present study, our main aim was to examine the impact of the valence and arousal dimensions of music on recovery following stress, but we did look at potential moderators: degree of absorption and the big 5 personality traits, and extent of music experience. Given that we had predictions for the effects of absorption, the main results sections report this variable. However, the remaining moderators were highly exploratory and relevant analyses are presented within the appendices only.

CURRENT STUDY

The aim of the current study was to explore the effects of music following induced stress. Due to the discordance often found between different emotion response systems (Lang, 1968; Lang, 1984; Mandler & Kremen, 1958), we gathered both physiological and self-report evidence of stress and recovery. We expected to find that music is more effective than white noise in promoting recovery from stress. This is the first study that we are aware of to examine music from all four quadrants of Russell's circumplex model following a stress induction. This allows us to examine the effects of valence and arousal independently. We hypothesized that recovery would be better after listening to music with a positive valence compared to a negative valence and after listening to music low in arousal compared to high in arousal. Finally, we expected that individuals who were more drawn into the music would see an exaggerated effect. In other words, we anticipated that individuals who were high in absorption would benefit more strongly from music with positive valence and low arousal than would individuals low in absorption. We had no specific hypotheses concerning the predictive ability of the big five personality traits, music preferences or music experience; these were included as exploratory variables.

Pretest Study

The goal of the pretest study was to select appropriate music excerpts from each quadrant of Russell's circumplex model, thus representing different valence and arousal characteristics. Nyklicek et al. (1997) were able to discriminate between happy, sad, peaceful and agitated musical excerpts on the basis of autonomic response patterns. We tracked down 11 of these musical pieces (two from the "happy" quadrant, and three from each of the remaining quadrants). In Phase 1 of the pretest study we presented 30-second excerpts to eight musically-trained lab members and asked for ratings of valence and arousal on a 7-point scale (where 0 is neutral). Two excerpts representing each emotion were then selected for Phase 2 so as to maximize differences in valence and arousal dimensions across the four quadrants.

In Phase 2, 46 undergraduate participants rated the eight excerpts from Phase 1 on familiarity (from "I've never heard this song before" to "I am very familiar with this song") as well as on valence and arousal. For all of the eight excerpts, participants and lab members agreed on the quadrant that best represented the music. One excerpt was chosen from each quadrant, minimizing the familiarity while maximizing the differences on the valence and arousal dimensions. The excerpts used in this study were: Strauss' Unter Donner und Blitz (Thunder and Lightning) polka ("happy"; positive valence, high arousal), Bizet's Intermezzo from the Carmen Suite ("peaceful"; positive valence, low arousal), Grieg's Aase's Death from the Peer Gynt Suite ("sad"; negative valence, low arousal), and the adagio from Shostakovich's 8th Symphony ("agitated"; negative valence, high arousal).

Experiment 1

In Experiment 1, participants were given a speech task, which induced stress, causing a peak of physiological reactivity. They subsequently listened to either peaceful music or white noise, during which they started recovery towards their individual baseline. We measured this recovery using a cognitive appraisal (Subjective Units of Discomfort; SUD), as well as physiological indicators: galvanic skin response (GSR), heart rate (HR) and heart rate variability (HRV), specifically the high frequency (HF) component.

The goal of Experiment 1 was to determine if individuals who listened to peaceful music after a stress induction would recover more completely than those that instead listened to white noise. We expected that participants who were high in absorption would be more drawn into the music than those who were low in absorption, and thus exhibit more of a difference between peaceful music and white noise conditions.

Method

PARTICIPANTS

Forty-one students were recruited from Ryerson University. Due to problems with the equipment, data was dropped for one participant, leaving 40 participants (57% female). Twenty of these participants listened to peaceful music and 20 listened to white noise. On average, the participants were 23.8 years of age (*SD*=3), had 2.1 years of individual music training (*SD*=3.6), and 1.3 years of group training (*SD*=1.8). Students received either course credit or financial compensation.

MATERIALS

Music Stimuli

The amplitude of a musical waveform can be measured using the root mean square (RMS) method, which provides a measure of acoustic intensity (Johnson, 2003). A two-minute long white noise clip was generated as a control. The RMS of the peaceful music clip from the pretest was equalized with that of the noise clip to equate perceived loudness. A one second fade-in and a one second fade-out were added to both clips in order to avoid a startle effect.

Questionnaires

Participants appraised their level of stress by providing a Subjective Unit of Discomfort score (SUD; Kaplan, 1995) at three points in time during the study. Participants were instructed to provide a value between 0, representing a state of extreme relaxation, and 100, representing a state of extreme anxiety (see Appendix I).

We assessed the mood of the participants at the beginning and end of the study using the short version of the Profile of Mood States (POMS; McNair, Lorr, & Droppleman, 1971). Participants judged to what extent they were feeling each of 30 mood states on a 5-point Likert scale ranging from "not at all" to "extremely". The POMS questionnaire provides an overall general mood disturbance score, as well as six factor scores: tension-anxiety, anger-hostility, fatigue-inertia, depression-dejection, vigor-activity, and confusion-bewilderment.

After hearing the music intervention, participants were asked how familiar they were with the music they had heard and how much they had enjoyed it. Familiarity was assessed using a 4-point Likert scale ranging from "I've never heard this song before" to

“I am very familiar with this song”. Liking was measured on a 4-point Likert scale ranging from “not at all” to “liked”.

We used the Single-Item Measures of Personality (SIMP; Woods & Hampson, 2005) to assess the big-five personality traits. The participant read two statements representative of each of the five traits and indicated, on a 9-point scale, the extent to which they felt they matched one description more than the other (see Appendix II).

Participants reported their music preferences by completing the Short Test of Music Preferences (STOMP; Rentfrow & Gosling, 2003). They rated 14 genres on a 7-point Likert scale ranging from “strongly dislike” to “strongly like” (see Appendix III). This instrument has four dimensions of music preference: reflective and complex (which includes classical music), intense and rebellious, upbeat and conventional, and energetic and rhythmic.

In order to evaluate to what degree participants were open to absorbing experiences, we administered the Tellegen Absorption Scale (TAS; Tellegen & Atkinson, 1974). Participants indicated how often they tend to experience different events on a 4-point Likert scale ranging from “never” to “always” (e.g., “When I listen to music I can get so caught up in it that I don't notice anything else.”) (see Appendix IV). The means and standard deviations for Experiment 1 (M=86; SD=15.5) and Experiment 2 (M=84.5; SD=15.7) were both similar to those reported by Glisky, Tataryn, Tobias, Kihlstrom & McConkey (1991) (M=84; SD=18).

We rated each participant’s music experience by evaluating the total years of individual lessons and group lessons (see Appendix V) and weighting the former twice as much as the latter.

Equipment

Galvanic skin response (GSR) and heart rate (HR) were measured using a Biopac MP100 system. Two TSD203 Ag-Agcl electrodes were attached to the distal phalanges of the index and ring fingers of the non-dominant hand by Velcro straps, and connected to the GSR100C electrodermal activity amplifier module to monitor the galvanic skin response. Isotonic conductant gel was applied to the electrodes and to the fingertips on the non-dominant hand. One TSD200 photoplethysmogram transducer was attached by a Velcro strap to the distal phalange of the middle finger of the non-dominant hand. This transducer was connected to the PPG100C photoplethysmogram amplifier module to measure capillary expansion through an infrared sensor, and thus indirectly measure the heart rate.

The video and music stimuli were presented to each participant using supra-aural headphones connected to a MacBook Pro laptop. The Biopac system was connected to a separate, data collection machine (Mac mini). Physiological data was analyzed with AcqKnowledge software, version 3.9.2 for Mac (BIOPAC Systems, 2007) (GSR and HR) and Kubios HRV, version 2.0 for Windows (Kubios HRV, 2008) (HF component of HRV).

PROCEDURE

Participants were brought into a quiet room and provided consent. Isotonic conductant gel was placed on their index and ring fingers, and while it was soaking into their skin, they completed the POMS questionnaire. The physiological monitors were then attached to their fingers, and they were instructed to stay as still as possible. Participants provided an initial, baseline SUD score, and then watched a short video clip, 2 minutes and 17 seconds in length, from BBC news. This news report discusses illegal music downloading and shows the police arresting a man accused of hosting an illegal music downloading website. Following the video clip, the experimenter asked the participant to relax for three minutes, in order to provide a window for baseline physiological measures.

The experimenter returned to the room with a video camera mounted on a tripod and informed the participant that they would be required to make a short speech on the topic of music piracy. They were asked to defend free access (i.e., defend music downloading) and were told that their speech would be recorded and shown to music industry executives as well as to other students. They were given one minute to collect their thoughts and prepare while a timer counted down the seconds on the computer screen in front of them. The experimenter informed them that there was a chance they would not be required to make the speech, and that a computer would randomly determine whether or not they would make the speech. No participant was required to make a speech; these instructions justified the experimenter returning with the news that the participant had not been chosen to make the speech.

After leaving the room for one minute to allow the participant to prepare for the speech, the experimenter returned and asked the participant for a second SUD score. The participant was then informed that they would not be required to deliver a speech. They were asked to listen to a sound clip (either music or white noise). Instructions were given to "close your eyes and let yourself be absorbed by what you hear". Following the sound clip, participants provided a final SUD score before the physiological monitors were detached. A second POMS questionnaire was completed, to allow us to compare the mood state immediately preceding and immediately following the intervention. This was followed by questions about familiarity and liking of the sound clip, the personality questionnaire (SIMP), the musical preference questionnaire (STOMP), the absorption questionnaire (TAS) and the music experience questionnaire. Participants were asked, as a manipulation check, if they had believed the speech task, and then they were fully debriefed.

DATA PREPARATION

Data analysis focused on three time windows of interest. After the video ends, there is an adaptation period of 200 seconds. The *baseline window* occurs in the last 10 seconds of the adaptation period. The *stress window* occurs in the final 10 seconds during which the participant was preparing for the speech. Finally, the *recovery window* occurs in the last 10 seconds of the sound clip presentation. Analyses of physiological measures were performed on averages taken over the duration of each window.

We normalized the physiological measures for each participant, taking into account the values from the beginning of the baseline window until the end of the recovery window. To take into account the individual differences in reactivity to the stress induction, we adopted a ratio approach comparing the degree of recovery to the degree of stress induction:

$$\text{GSR \% return to baseline} = \frac{GSR_{stress} - GSR_{recovery}}{GSR_{stress} - GSR_{baseline}} \quad X\ 100 \qquad [1]$$

The same ratio approach was used to determine percentage return to baseline for HR, HRV and SUD. A 100% return to baseline for the HR, for example, means that the participant had the same HR after listening to the sound clip as they did at the beginning of the study. The higher the percentage return to baseline, the greater the degree of recovery. Rickard (2004) used a similar ratio measure to look at physiological arousal evoked by intense emotions resulting from exposure to music and film.

We omitted participants from the SUD analyses when this ratio resulted in a "divide by zero" condition; if the participant reported the same SUD score during the stress window as they reported during the baseline window, then the denominator of the ratio resulted in a zero.

Median splits were used to categorize individuals as either high or low in trait absorption, high or low on each of the big-five personality traits, high or low in preference for musical genres or categories, and high or low in music experience.

Study of stress regulation is contingent on successfully inducing stress. We considered the stress induction successful when the physiological measure during the stress window was higher than in the baseline window. Similarly, examining recovery from stress is contingent on the participant believing that the stress has been removed and consequently recovering in a reasonable time. We removed individuals whose GSR or HR was lower during the stress window than during the baseline window (no induction), and individuals whose GSR or HR was higher during the recovery window than during the stress window (no recovery).

Any participant whose return to baseline was more than 1000% or more than 2.5 standard deviations from the mean for a particular condition was classified as an outlier and excluded from further analysis. Heart rate data was deemed problematic when visual inspection of the photoplethysmograph (PPG) signal revealed no discernible peaks in the waveform and/or lack of periodicity. Since the HRV is computed from the heart rate data, participants with problematic heart rates were also excluded from the HRV analysis.

We used a band pass filter on the HR data, keeping the part of the signal that was between .5 Hz and 3 Hz, and then used a custom script in Matlab to detect the peaks. Careful visual inspection confirmed that all peaks were properly detected. A file with inter-beat intervals was computed and used as the input to the Kubios software (Kubios HRV, 2008). We chose a frequency measure of HRV, which involved a Fourier transformation of the inter-beat interval data. The Task Force of the European Society of Cardiology and the North American Society of Pacing Electrophysiology recommend a recording of at least 10 times the wavelength (Electrophysiology, 1996). This means that a one-minute epoch is acceptable for analyzing the HF component, but a minimum 2 minute recording epoch is needed to properly analyze the LF component. Our time course only allowed analysis of 1 minute time windows, thus we analyzed only the HF component, and not the LF component or the LF/HF ratio.

Davis and Thaut (1989) found stronger physiological responses to preferred music. Due to the positive relationship between familiarity and liking (Szpunar, Schellenberg, & Pliner, 2004; Witvliet & Vrana, 2007), we omitted data for one participant from all analyses because they indicated that they were very familiar with the music clip that they listened to.

We removed one outlier, and five additional participants whose SUD percentage return to baseline resulted in a "divide by zero" condition, resulting in a total of seven unique participants that were removed from SUD analyses.

Two outliers were removed from HR analyses, and two participants were excluded because their HR was deemed problematic. Seven participants were excluded because we could not induce stress-related increases in HR, and six participants because they did not show recovery in HR. A total of 14 unique participants were excluded from HR analyses. Analyses which include the individuals that did not show recovery in HR can be found in Appendix IX.

Thirteen outliers were removed from HRV-HF analyses, and two participants were excluded because their HR was deemed problematic. Seven participants were excluded because we could not induce stress-related increases in HR, and six participants because they did not show recovery in HR. A total of 20 unique participants were excluded from HRV-HF analyses.

Results

MANIPULATION CHECK

In a post-study manipulation check, the majority of participants claimed to have believed that they would have to give a speech. Those who were skeptical prepared to make a speech "just in case"; no participants unequivocally believed that there would be no speech. The physiological reactivity should provide definitive confirmation that we were successful in inducing stress.

We conducted a repeated measures ANOVA for each dependent variable, comparing the baseline window measurement to the stress window measurement in order to determine whether we were successful at inducing stress. We confirmed a significant increase from the baseline values for SUD, GSR and HR: $F(1,31)=38.39$,

$F(1,37)=506.90$, $F(1,24)=66.25$, p's$<.001$ respectively. However, there was no significant change in HRV, $F(1,18)=0.96$, $p>.3$.

We ran a one-way ANOVA to test for any pre-existing differences in mood across conditions. No significant differences were found between conditions for the POMS aggregate mood disturbance score.

SUBJECTIVE EXPERIENCE

SUD

A 2 (music vs. white noise) x 2 (high vs. low absorption) ANOVA found no significant main effects or interactions. Specifically there was no significant difference in the percentage return to baseline of the SUD scores for those who listened to peaceful music (M=128) compared to those who listened to white noise (M=118.3) (see Table 1 for means and Table 3 for the ANOVA).

Variable	Music	White Noise
SUD	128 (19.8)	118.3 (19.1)
GSR	94.7 (8.9)	58.5 (8.6)
HR	105.7 (14.2)	109.1 (12.9)
HRV-HF	233.2 (99.4)	216 (89.7)

Table 1. Means for percentage return to baseline of all dependent variables in Experiment 1, broken down by condition. Standard error shown in brackets.

Variable	High Absorption	Low Absorption
SUD	104.5 (20.4)	141.8 (18.6)
GSR	88.7 (8.9)	64.5 (8.6)
HR	118.8 (14.2)	96 (12.9)
HRV-HF	338 (99.4)	111.3 (89.7)

Table 2. Means for percentage return to baseline of all dependent variables in Experiment 1, broken down by degree of absorption. Standard error shown in brackets.

Source	df	SS	MS	F	Sig.
Between	1	49.51	49.51		
Condition	1	0.08	0.08	0.12	0.73
Absorption	1	1.14	1.14	1.83	0.19
Condition*Absorption	1	0.02	0.02	0.03	0.86
Error	29	18	0.62		
Total	33	68.75			

Table 3. ANOVA results for SUD percentage return to baseline in Experiment 1.

Mood State

We ran repeated-measures ANOVA's to determine if there were any changes in mood, from before the study until after the intervention. There were significant decreases in depression (M=1.42 to .79), fatigue (M=4.54 to 3.49) and vigour (M=7.26 to 5.56), $F(1,34)$=5.44, 5.34 and 10.51 respectively, p's<.05, but these did not differ across conditions.

PHYSIOLOGICAL MEASURES

GSR

Individuals showed a sharp increase in GSR when they were informed about the speech task. After the stressor was removed, GSR levels gradually decreased towards the baseline levels. The overall pattern can be seen for both conditions in Figure 1.

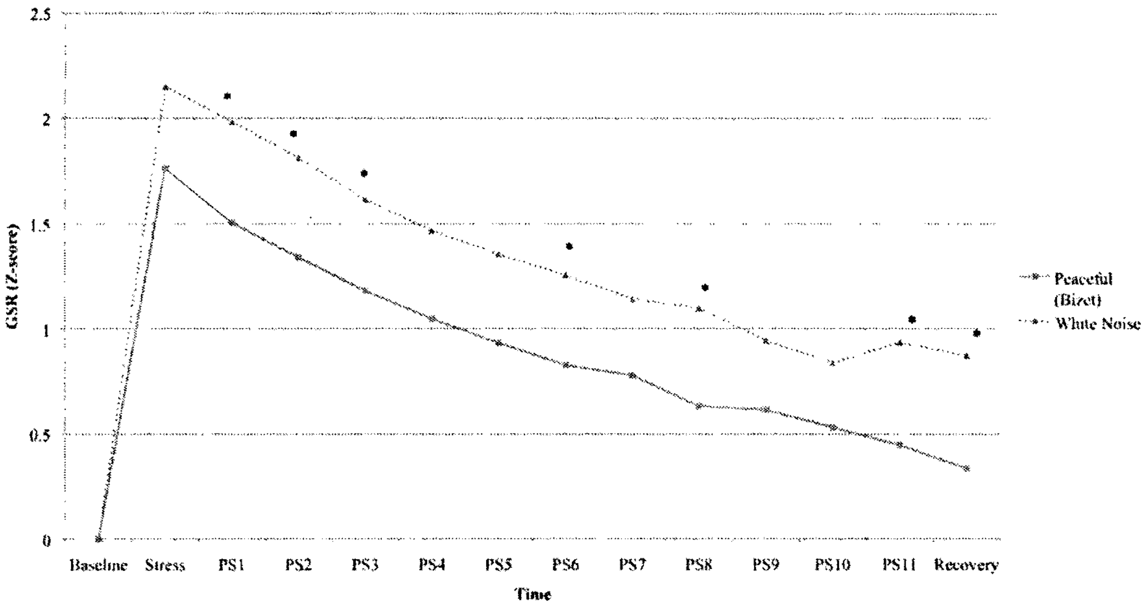

Figure 1. Time series graph of GSR recovery in Experiment 1. Normalized galvanic skin response (GSR) activity during the baseline window, stress window, recovery window, and every 10 seconds post-stress between the stress and recovery windows (PS1 to PS11). Significant differences between the noise and peaceful music conditions are marked with an asterisk.

A 2 (music vs. white noise) x 2 (high vs. low absorbers) ANOVA revealed a significant effect of condition on GSR percentage return to baseline. Participants recovered more completely when they listened to music (M=94.7), as compared to white noise (M=58.5), $F(1,35)=8.53$, $p<.01$ (see Table 1 for means, and Table 4 for the

ANOVA). This main effect was driven by the significant interaction between condition and trait absorption, $F(1,35)=7.21$, $p<.05$. High absorbers recovered more completely when they listened to peaceful music (M=123.4) as compared to white noise (M=54.0), whereas low absorbers recovered about the same for peaceful music (M=65.9) and white noise (M=63.0) (see Figure 2). We ran a planned contrast to test our a priori hypothesis that high absorbers would recover more completely after listening to music rather than white noise. The contrast was significant, $t(35)=3.91$, $p<.01$. The same contrast was not significant for low absorbers, $t(35)<1$.

Source	df	SS	MS	F	Sig.
Between	1	22.82	22.82		
Condition	1	1.27	1.27	8.53	0.01
Absorption	1	0.57	0.57	3.82	0.06
Condition*Absorption	1	1.08	1.08	7.21	0.01
Error	35	5.23	0.15		
Total	39	30.97			

Table 4. ANOVA results for GSR percentage return to baseline in Experiment 1.

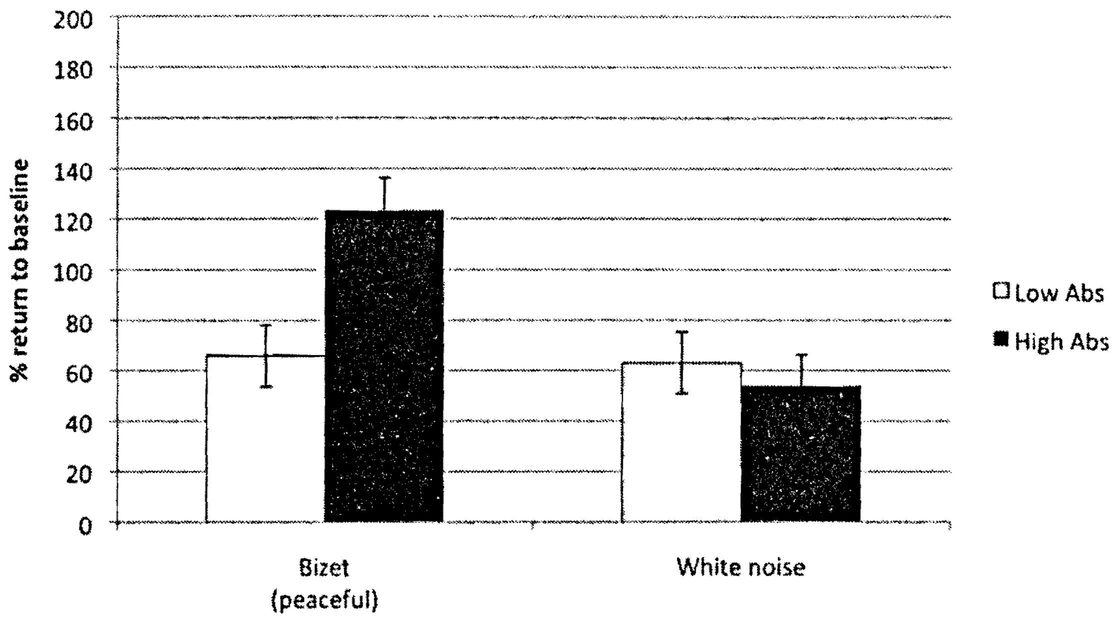

Figure 2. GSR percentage return to baseline for high absorbers vs. low absorbers in the Bizet (peaceful) and white noise conditions.

HR

Individuals showed a sharp decrease in HR during the first 20 seconds after the stressor was removed, to a point below the baseline, and then gradually increased towards baseline. The overall pattern can be seen for both conditions in Figure 3.

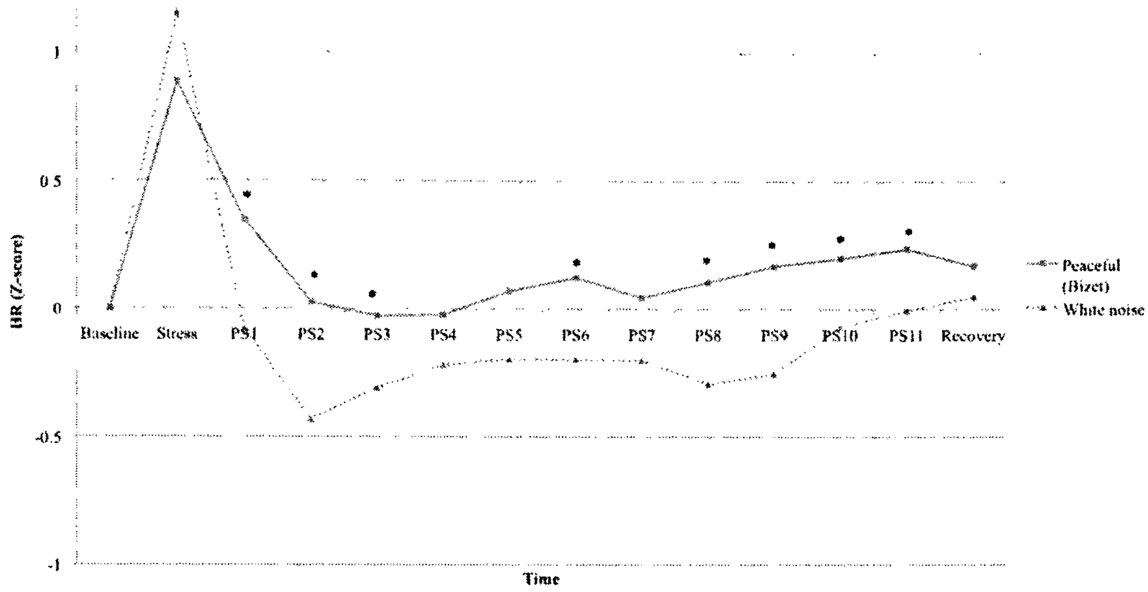

Figure 3. Time series graph of HR recovery in Experiment 1. Normalized heart rate (HR) activity during the baseline window, stress window, recovery window, and every 10 seconds post-stress between the stress and recovery windows (PS1 to PS11). Significant differences between the noise and peaceful music conditions are marked with an asterisk.

Condition was not a significant predictor for the percentage return to baseline of the heart rate, likely due to the large variability (see Table 5 for the ANOVA).

Source	df	SS	MS	F	Sig.
Between	1	29.36	29.36		
Condition	1	0.01	0.01	0.03	0.86
Absorption	1	0.33	0.33	1.4	0.25
Condition*Absorption	1	0.3	0.3	1.28	0.27
Error	22	5.16	0.24		
Total	26	35.16			

Table 5. ANOVA results for HR percentage return to baseline in Experiment 1.

We chose to use a percentage return to baseline measure in our analyses, but one alternative, employed by Fredrickson et al. (2000), is to measure the time elapsed before a complete and stable return to baseline. Because the GSR does not fully recover in either condition, it did not make sense to statistically analyze the elapsed time. However, the HR does return to baseline, and shows an earlier stable return to baseline in the peaceful music condition than in the white noise condition (see Figure 3). In the peaceful music condition, the normalized HR returns to within 0.2 standard deviations of the baseline for a minimum of two time windows (i.e., 20 seconds) starting at time 2 (20 seconds after the music begins). On the other hand the white noise does not return to within 0.2 SD's of baseline until time 4 (40 seconds after the music begins).

HRV-HF

A 2 (music vs. white noise) x 2 (high vs. low absorbers) ANOVA revealed no significant main effects or interactions (see Tables 1 and 2 for the means, and Table 6 for the ANOVA).

Source	df	SS	MS	F	Sig.
Between	1	98.85	98.85		
Condition	1	0.14	0.14	0.02	0.9
Absorption	1	25.17	25.17	2.87	0.11
Condition*Absorption	1	10.63	10.63	1.21	0.29
Error	16	140.5	8.78		
Total	20	275.29			

Table 6. ANOVA results for HRV-HF percentage return to baseline in Experiment 1.

GENERAL

Exploratory analyses using personality traits as predictors for the subjective and physiological measures can be found in Appendix VI. Similarly, exploratory analyses using music preferences as predictors can be found in Appendix VII.

Correlation matrices between trait absorption, personality traits and the subjective and physiological measures can be found in Appendix VIII.

Discussion

We found that participants recovered more fully physiologically, as indexed by their GSR, when they listened to peaceful music as opposed to white noise. Low absorbers recovered about the same regardless of what they listened to, whereas high absorbers recovered more fully when they listened to peaceful music. Although we found no significant differences with respect to HR percentage return to baseline or the HRV-HF percentage return to baseline, we did find that the normalized HR exhibited an earlier stable return to baseline in the peaceful music condition.

There was no difference in subjective recovery between peaceful music and white noise conditions. This evidence of discordance between the physiological and self-report measures is anticipated by Lang's tri-partite theory.

Experiment 1 confirmed that peaceful music is more effective than white noise in helping individuals recover from stress. In order to more fully investigate the ability of music to help individuals regulate stress, we next examined the effectiveness of music drawn from each quadrant of Russell's circumplex model.

Experiment 2

The goal of Experiment 2 was to determine if the valence and arousal dimensions of music were related to the degree of recovery following stress induction. To this end, we used music excerpts from each quadrant of Russell's circumplex model. We expected more benefits from excerpts with positive valence compared to negative valence and from excerpts with low arousal compared to high arousal. Additionally, we wanted to further explore the effects of trait absorption on the degree of recovery. We hypothesized that high absorbers would show larger effects of valence and arousal than would low absorbers.

Method

PARTICIPANTS

Seventy-one students were recruited from Ryerson University. Data was dropped for three participants due to problems with the equipment. Twenty participants listened to agitated music, 24 listened to sad music, and 24 listened to happy music. In addition, the 20 participants from Experiment 1 who listened to peaceful music were included as a fourth music condition. Overall, the 88 students (74% female) had an average age of 22.7 (*SD*=2.94), an average of 2.3 years of individual music training (*SD*=3.3) and 1 year of group training (*SD*=1.6). Students received either course credit or financial compensation.

MATERIALS

Music Stimuli

Four, two-minute long music clips were created from the excerpts identified in the pretest study. As in Experiment 1, the root mean square of the music clips were equalized, and a one second fade-in and fade-out were applied.

DATA PREPARATION

Data analysis was the same as in Experiment 1, focusing on the same three time windows of interest and using the same percentage return to baseline measure. We did the same median splits, and omitted data from all analyses for five participants who indicated that they were very familiar with the music clip that they listened to.

We removed four outliers from the SUD analyses, and removed 10 participants because the SUD percentage return to baseline resulted in a "divide by zero" condition. Two participants were excluded because we could not induce stress-related increases in GSR, and six participants did not show recovery in their GSR. A total of 23 unique participants were removed from SUD analyses.

Three outliers were removed from GSR analyses. Two participants were excluded because we could not induce stress-related increases in GSR, and six participants did not show recovery in GSR. Fifteen unique participants were excluded from GSR analyses.

Eleven outliers were removed from HR analyses, and 10 participants were excluded because their HR was deemed problematic. Twenty-three participants were excluded because we could not induce stress-related increases in HR, and 16 participants did not show recovery in HR. A total of 42 unique participants were excluded from HR analyses.

Thirty-six outliers were removed from HRV-HF analyses, and 10 participants were excluded because their HR was deemed problematic. Twenty-three participants were excluded because we could not induce stress-related increases in HR, and 16 participants did not show recovery in HR. A total of 53 unique participants were excluded from HRV-HF analyses.

Analyses which include individuals that did not show recovery in GSR or HR can be found in Appendix IX.

Results

MANIPULATION CHECK

We conducted a repeated measures ANOVA for each dependent variable, comparing the baseline window to the stress window in order to determine whether we were successful at inducing stress. We confirmed a significant increase from the baseline values for the SUD score, GSR and HR: $F(1,61)=78.52$, $F(1,69)=609.74$, $F(1,42)=125.86$, $p's<.001$ respectively. However, there was no significant change in the HRV-HF, $F(1,31)=0.69$, $p>.4$.

We ran a one-way ANOVA to test for any pre-existing differences in mood across conditions. No significant differences were found between conditions for the POMS aggregate mood disturbance score.

SUD

A 2 (positive vs. negative valence) x 2 (high vs. low arousal) x 2 (high vs. low absorbers) ANOVA revealed significant main effects of both valence and arousal. Participants recovered better when the music had a positive valence (M=103.7) as compared to a negative valence (M=69.9), $F(1,57)$= 6.66, p<.05 (see Table 8 for the means and Table 10 for the ANOVA). Recovery was also better when music was low in arousal (M=110.8) instead of high (M=62.8), $F(1,57)$=13.4, p<.01 (see Table 7 for the means and Table 10 for the ANOVA).

Variable	High Arousal	Low Arousal
SUD	62.8 (9.2)	110.8 (9.3)
GSR	99.2 (11.7)	95.5 (11)
HR	104.3 (24.4)	155.8 (20.9)
HRV-HF	153.5 (70)	126.7 (59.9)

Table 7. Means for percentage return to baseline of all dependent variables in Experiment 2, broken down by degree of absorption. Standard error shown in brackets.

Variable	Positive Valence	Negative Valence
SUD	103.7 (9.1)	69.9 (9.4)
GSR	102.6 (11.4)	92.1 (11.3)
HR	117.3 (22.1)	142.8 (23.3)
HRV-HF	130.6 (67.4)	149.6 (62.9)

Table 8. Means for percentage return to baseline of all dependent variables in Experiment 2, broken down by valence. Standard error shown in brackets.

Variable	High Absorption	Low Absorption
SUD	85.6 (9.9)	88 (8.6)
GSR	116.5 (11.9)	78.2 (10.7)
HR	149.7 (24.4)	110.4 (20.9)
HRV-HF	251.3 (67.4)	28.9 (62.9)

Table 9. Means for percentage return to baseline of all dependent variables in Experiment 2, broken down by arousal. Standard error shown in brackets.

Source	df	SS	MS	F	Sig.
Between	1	47.69	47.69		
Valence	1	1.81	1.81	6.66	0.01
Arousal	1	3.64	3.64	13.4	0.01
Absorption	1	0.01	0.01	0.03	0.86
Valence*Arousal	1	0.01	0.01	0.01	0.96
Valence*Absorption	1	0.04	0.04	0.15	0.7
Arousal*Absorption	1	0.27	0.27	1	0.32
Valence*Arousal*Absorption	1	0.78	0.78	2.87	0.1
Error	57	15.47	0.27		
Total	65	69.72			

Table 10. ANOVA results for SUD percentage return to baseline in Experiment 2.

A follow-up one-way ANOVA revealed a significant main effect of music condition on SUD percentage return to baseline, $F(3,61)=6.79, p<.01$. Pairwise comparisons using a Bonferroni adjustment revealed that participants recovered significantly better when they listened to peaceful music (M=130) as compared to happy music (M=78.3) or to agitated music (M=48.3).

Mood State

We ran repeated-measures ANOVA's to determine if there were any changes in mood, from before the study until after the intervention. There were significant decreases in depression (M=1.45 to 0.95), fatigue (M=4.49 to 3.8) and vigour (M=6.83 to 5.14), $F(1,61)$=5.96, 5.08 and 29.27 respectively, p's<.05. These three decreases were found, with similar magnitudes, in Experiment 1, suggesting that the changes may be due to the context of the study, rather than attributable to the music, especially seeing as there were no interactions with the valence or arousal characteristics of the music.

Interestingly, there was a significant valence by arousal by time interaction for confusion, $F(1,61)=10.09$, $p<.01$. There was an increase in confusion from the beginning of the study until after the music intervention for the agitated music condition (M=2.19 to 2.75), and a decrease in confusion during the same period for the other three conditions. This suggests that the emotional content of the music influenced the mood state of the listeners.

PHYSIOLOGICAL MEASURES

GSR

As in Experiment 1, individuals showed a sharp increase in GSR in response to stress, followed by a gradual decrease as the music played during the recovery phase. This overall trend can be seen for all music conditions in Figure 4.

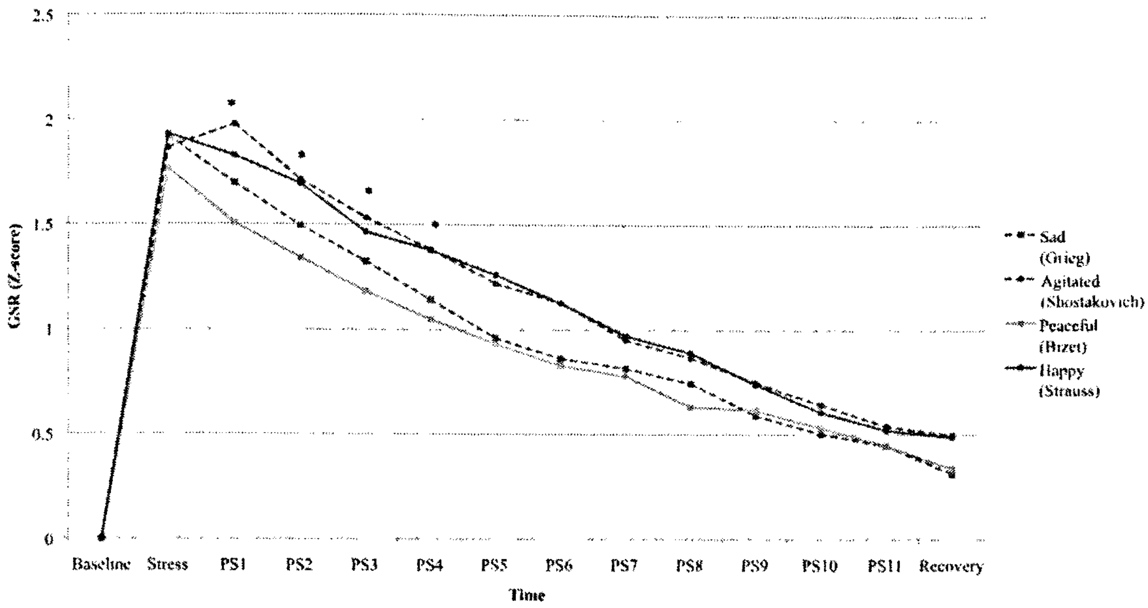

Figure 4. Time series graph of GSR recovery in Experiment 2. Normalized galvanic skin response (GSR) activity during the baseline window, stress window, recovery window, and every 10 seconds post-stress between the stress and recovery windows (PS1 to PS11). Significant differences between the four music conditions are marked with an asterisk.

A 2 (positive vs. negative valence) x 2 (high vs. low arousal) x 2 (high vs. low absorbers) ANOVA revealed that neither valence nor arousal was a significant predictor of the GSR percentage return to baseline (see Table 11 for the ANOVA).

Source	df	SS	MS	F	Sig.
Between	1	67.49	67.49		
Valence	1	0.2	0.2	0.43	0.51
Arousal	1	0.03	0.03	0.06	0.82
Absorption	1	2.61	2.61	5.72	0.02
Valence*Arousal	1	0.26	0.26	0.58	0.45
Valence*Absorption	1	1.89	1.89	4.14	0.05
Arousal*Absorption	1	0.03	0.03	0.08	0.79
Valence*Arousal*Absorption	1	0.14	0.14	0.32	0.58
Error	65	29.64	0.46		
Total	73	102.29			

Table 11. ANOVA results for GSR percentage return to baseline in Experiment 2.

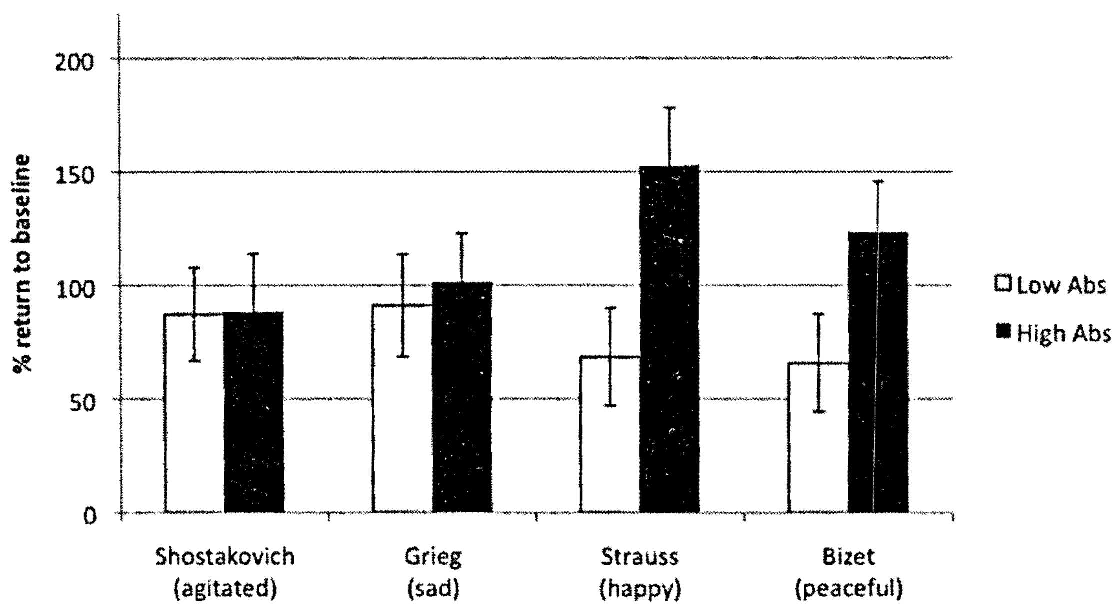

Figure 5. GSR percentage return to baseline for high absorbers vs. low absorbers in the four music conditions.

There was a main effect of absorption, $F(1,65)=5.72$, $p<.05$. This main effect was driven by a significant interaction between valence and absorption, $F(1,65)=4.14$, $p<.05$ (see Figure 5). High absorbers recovered more fully for music with a positive valence ($M=138.1$) than for music with a negative valence ($M=94.9$). On the other hand, low absorbers showed a similar degree of recovery regardless of whether the music had a positive ($M=67.2$) or negative ($M=89.2$) valence.

The planned contrast to test our a priori hypothesis that high absorbers would recover more completely after listening to music with a positive valence than a negative valence was significant, $t(69)=1.75$, $p<.05$. The same contrast for low absorbers was not significant, $t(69)=1.05$, $p>.2$. We also hypothesized an interaction between arousal and absorption, but this was not significant (see Table 11 for the ANOVA).

HR

As in Experiment 1, individuals showed a sharp decrease in HR during the first 20 seconds of the music, to a point below the baseline, and then gradually increased towards the baseline level. This overall trend can be seen for all music conditions in Figure 6.

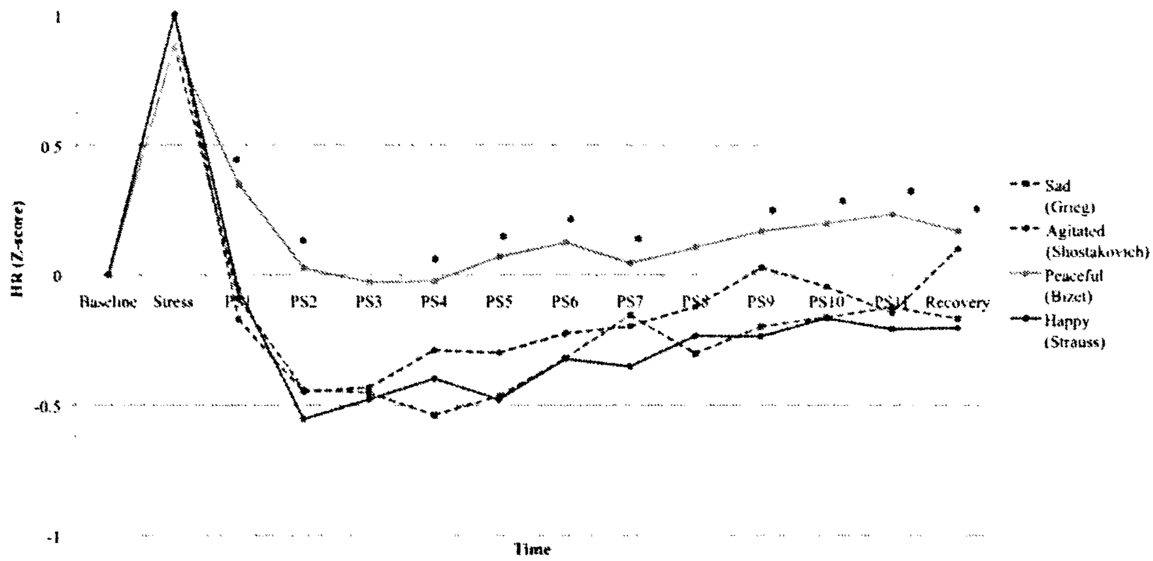

Figure 6. Time series graph of HR recovery in Experiment 2. Normalized heart rate (HR) activity during the baseline window, stress window, recovery window, and every 10 seconds post-stress between the stress and recovery windows (PS1 to PS11). Significant differences between the four music conditions are marked with an asterisk.

With respect to predicting the percentage return to baseline for the HR, there were no main effects for valence, arousal or absorption, and no interactions (see Table 12 for the ANOVA). There was a significant interaction between valence and arousal, $F(1,38)=5.42$, $p<.05$. Pairwise comparisons with a Bonferroni adjustment showed that when the music had a negative valence, individuals recovered better when the music was also low in arousal (M=205.9) instead of high in arousal (M=79.7), but when the music had a positive valence, there was no difference in recovery between low arousal (M=105.7) and high arousal (M=128.9) music.

Source	df	SS	MS	F	Sig.
Between	1	72.12			
Valence	1	0.69	0.69	0.63	0.43
Arousal	1	2.83	2.83	2.58	0.12
Absorption	1	1.65	1.65	1.5	0.23
Valence*Arousal	1	5.95	5.95	5.42	0.03*
Valence*Absorption	1	0.59	0.59	0.54	0.47
Arousal*Absorption	1	2.32	2.32	2.11	0.16
Valence*Arousal*Absorption	1	0.34	0.34	0.31	0.58
Error	38	41.76	1.1		
Total	46	128.25			

Table 12. ANOVA results for HR percentage return to baseline in Experiment 2.

As in Experiment 1, examination of the time series graph shows that the HR shows an earlier stable return to baseline in the peaceful music condition than in any other condition (see Figure 6). In the peaceful music condition, the normalized HR returns to within 0.2 SD's of the baseline for a minimum of two time windows (i.e., 20 seconds) starting at time 2 (20 seconds after the music begins). The agitated music does not return to within 0.2 SD's of baseline until time 8 (80 seconds after the music begins), and no other music condition reaches this mark during the length of the study.

HRV-HF

A 2 (positive vs. negative valence) x 2 (high vs. low arousal) x 2 (high vs. low absorbers) ANOVA found no main effect for valence or arousal, but did reveal a main effect of absorption, $F(1,27)=5.8$, $p<.05$ (see Table 13 for the ANOVA). Individuals recovered better when they were high (*M*=251.3) rather than low (*M*=28.9) in absorption (see Table 7 for the means).

Source	df	SS	MS	F	Sig.
Between	1	64.97	64.97		
Valence	1	0.3	0.3	0.04	0.84
Arousal	1	0.6	0.6	0.09	0.77
Absorption	1	40.92	40.92	5.82	0.02*
Valence*Arousal	1	44.59	44.59	6.34	0.02*
Valence*Absorption	1	0.61	0.61	0.09	0.77
Arousal*Absorption	1	1.09	1.09	0.16	0.7
Valence*Arousal*Absorption	1	38.26	38.26	5.44	0.03*
Error	27	189.78	7.03		
Total	35	381.12			

Table 13. ANOVA results for HRV-HF percentage return to baseline in Experiment 2.

There was a significant interaction between valence and arousal, $F(1,27)=6.34$, $p<.05$. When the music had a negative valence, individuals recovered better when the music was also high in arousal (*M*=279.1) instead of low in arousal (*M*=20.1). However, when the music had a positive valence, there was no difference between recovery based on whether the music was high (*M*=27.9) or low (*M*=233.2) in arousal.

There was also a valence*arousal*absorption interaction (see Table 13 for the ANOVA). When individuals were high in absorption and listened to music with a negative valence, they recovered better when the music was high in arousal (*M*=529.5) rather than low (*M*=19.2). However, when individuals high in absorption listened to music with a positive valence, they recovered better when the music was low in arousal (*M*=420) rather than high (*M*=36.2). These differences were not significant for low absorbers.

There is a large amount of variability in the HRV-HF data, and the cell sizes are quite small (sometimes less than 5), so these findings should be judged with caution.

GENERAL

Exploratory analyses using personality traits as predictors for the subjective and physiological measures can be found in Appendix VI. Similarly, exploratory analyses using music preferences as predictors can be found in Appendix VII.

Correlation matrices between trait absorption, personality traits and the subjective and physiological measures can be found in Appendix VIII.

DISCUSSION

Participants' subjective reports indicated that the type of music they listened to affected how well they recovered from induced stress. With respect to Russell's circumplex model of emotion, participants recovered more completely for music with a positive valence as opposed to a negative valence, and for music that was low in arousal as opposed to high in arousal. According to their SUD percentage return to baseline, peaceful music (positive valence, low arousal) resulted in the most extensive recovery, whereas agitated music (negative valence, high arousal) resulted in the least extensive recovery.

Judging by GSR and HR percentage return to baseline, participants as a whole were unaffected by the type of music. However, when we looked at the subset of participants who were high in absorption, we found support for our prediction that recovery would be better after listening to music with a positive valence compared to music with a negative valence. The predicted difference concerning high and low arousal music was not found for either high or low absorbers.

Although we found no overall differences with respect to HR percentage return to baseline, we did find that the normalized HR exhibited an earlier stable return to baseline in the peaceful music condition than in any other music condition.

General Discussion

The central aim of the current study was to explore the effects of the valence and arousal dimensions of music on recovery from induced stress. We found that peaceful music was more effective than white noise, music with a positive valence was more effective than music with a negative valence, and low arousal music was more effective than high arousal music. We also found that these differences in recovery tended to be driven by individuals who were high in absorption. Results revealed the expected discordance between physiological and self-report measures.

In Experiment 1, we tested whether peaceful music was more effective than white noise in promoting recovery from stress. Physiological results indicated that participants recovered more completely after listening to peaceful music as compared to white noise. The GSR percentage return to baseline was significantly higher and the normalized HR exhibited an earlier stable return to baseline in the peaceful music condition. The subjective appraisal of the degree of recovery did not differ depending on condition; participants felt that they recovered just as well when they listened to white noise as they did when they listened to peaceful music.

In Experiment 2 we varied the valence and arousal dimensions of music in order to assess their independent contributions to stress regulation. We expected that recovery would be better for participants who listened to music positive in valence rather than negative in valence, and low in arousal rather than high in arousal. Participants' subjective reports did in fact indicate that they had recovered significantly better when they listened to music with a positive valence or music low in arousal. Physiologically, participants showed no overall difference due to either valence or arousal, however, normalized HR exhibited an earlier stable return to baseline in the peaceful music condition compared to any other condition.

Our secondary hypothesis in both experiments was that high absorbers would show larger differences in recovery than low absorbers (i.e., improved recovery for peaceful music more than white noise, music with a positive valence more than music with a negative valence, and music low in arousal more than music high in arousal). In both experiments we found supportive evidence in GSR percentage return to baseline. Absorption interacted with condition in Experiment 1; high absorbers recovered more in the music condition than in the white noise condition, whereas low absorbers recovered about the same in both conditions. In Experiment 2 we found an interaction between absorption and valence, such that high absorbers recovered significantly better when the music had a positive valence compared to a negative valence, but the recovery for low absorbers was not affected by valence.

This study is the first to compare the effectiveness of music representing each of the four quadrants of Russell's circumplex model in promoting recovery following stress. By selecting excerpts from each quadrant, we were able to test the effects of valence and arousal independently. We are also not aware of another study looking at the individual difference of trait absorption in predicting improvements in recovery following stress. The interactions involving absorption that were observed in the current study suggest that it would be a worthwhile trait dimension to consider in future studies of emotion regulation, regardless of whether or not they involve music.

EFFECT OF VALENCE

Sokhadze (2007) induced disgust and then looked at physiological recovery following music, comparing the effectiveness of pleasant and sad music to white noise. He found that both music conditions resulted in improved recovery compared to the white noise, but he did not find differences between the pleasant and sad music conditions (i.e., an effect of valence). We also found no overall difference in physiological recovery depending on valence, although we did find the expected effect of valence on GSR percentage return to baseline amongst high absorbers. It would be interesting to investigate whether absorption plays a role in recovery following induction of disgust as it does following induction of stress. We also found a main effect of valence on the self-reported recovery. Sokhadze included ratings of nervousness, depression and stress, but only following the music intervention and a post-music rest period, at which point any differences in cognitive appraisal may have dissipated. We asked for a SUD score before the stress was induced and after the music played, and were therefore able to compute a change score, which may be a more sensitive measure.

METHODOLOGY

We hypothesized that music would be more effective than white noise, and that peaceful music (positive valence, low arousal) would be most effective in promoting recovery. Our results were largely consistent with these hypotheses. However, when comparing peaceful music and white noise, we saw improved overall physiological recovery, but no overall difference in subjective reports of recovery. When comparing music from different quadrants, we saw improved subjective reports of recovery, but no overall differences in physiological recovery. This discordance between subjective and physiological measures is predicted by Lang's tripartite theory (Lang, 1968; Lang, 1984). One important factor that may be involved is the different decay rates for different emotional response systems. Zillmann's (1978) excitation transfer theory proposes that the cognitive appraisal of an emotion decays more quickly than the physiological reactivity. We could test this by asking for the self-report at an earlier time, before the feeling of stress decays; a higher level of self-reported stress at an earlier time would support Zillmann's theory. However, self-report of stress might be especially prone to self-presentation issues since individuals may not like to admit that they were feeling anxious as a result of the task. Alternatively, we could play the music for a longer period of time, allowing the physiological measures to fully recover. We anticipated that individuals would recover fully before our two-minute music excerpts had finished, since Fredrickson et al. (2000) observed full recovery in less than one minute following a similar stress induction, albeit using different measures.

We used the SUD instrument for obtaining a self-reported level of anxiety at the beginning of the study, after the stress induction, and after listening to the audio stimulus. When asked for a SUD score after the stress induction, the participants were given the option of saying they felt "the same as before", in an attempt to avoid demand characteristics. However, the instructions for the SUD score refer to anxiety and ask individuals to think about how anxious they are feeling (see Appendix I). This would undoubtedly prompt the participants to be thinking about anxiety, and in particular to think about the speech task as being stressful. The use of a speech task is extremely common for inducing stress; the Trier Social Stress Test, which uses a speech task, is cited nearly 550 times (Kirschbaum, Pirke, Hellhammer, 1993). We therefore assume that our participants would experience some anxiety as a result of the task, even without being primed to think about anxiety. Any delay between the stress induction and the start of the audio stimulus allows for dissipation of stress, both physiologically and cognitively, so it was important to use an extremely fast measure such as the SUD instrument, with its single question. It is possible that their self-reports after the stress induction would be higher than if some less obvious measure had been used, but this would be true of all participants and should affect our measure of relative recovery equally amongst participants.

White noise is often used as a control condition because it has a loudness and frequency range that is comparable to music (Nyklicek et al., 1997; Sokhadze, 2007), but is emotionally neutral. Sokhadze (2007) used white noise as a control condition, and found that music was significantly better in facilitating autonomic recovery than white noise. However, others have used silence as a control condition. Chafin (2004) found that music, more than silence, improved physiological recovery after stress. Although silence may be more ecological (since individuals may not normally have access to music when experiencing stress), we believe that in the context of comparing music excerpts that vary on arousal and valence characteristics, white noise is a more suitable control. Unlike silence, white noise, simply by virtue of being an auditory stimulus, will provide some degree of physiological arousal, without providing any emotional arousal.

In the present study, we instructed participants to close their eyes, and let themselves be absorbed by what they were hearing. Lenton and Martin (1991) found that musical mood induction procedures were effective because of the instructions, and that the music itself was incidental to the effectiveness. In their silence condition (participants were told that there was "subliminal" music), the instructions were as effective as they had been in the music and instructions condition. A follow-up to the current study should look at the impact that instructions have when participants listen to music when recovering from stress. It would be informative to compare the current results against those obtained in a condition where no instructions are given about how to make use of the music.

MEDIATION

Undoubtedly variables other than emotion conveyed by music and individual differences in absorption may have contributed to the differences in recovery from stress found in the current study. We looked at several variables as possible mediators. Enhanced physiological responses have been found for preferred, self-selected music (Davis & Thaut, 1989) and for music presented repeatedly (Iwanaga, Ikeda, & Iwaki, 1996), suggesting both degree of liking and degree of familiarity as possible mediators. Our decision to use classical music excerpts was partly driven by the expectation that most undergraduates would not be familiar with the pieces we selected. In the pilot study, we selected the excerpts that were the least familiar to our listeners. Nonetheless, five participants in our study indicated that they were very familiar with the piece of music that they heard, and we removed them from our analyses to avoid the possible confound. Analyzing the remainder of the participants, we found no correlation between degree of liking and the extent of recovery on any measure (SUD, GSR, HR, HF).

Research suggests that physiological responses to music may be mediated by music training. Peretti and Swenson (1974) found that after an anxiety-inducing cognitive task, music majors recovered more completely physiologically than non-music majors.

On the other hand, many studies have found no significant differences in subjective emotional responses to music that could be attributed to the amount of music training (Knight & Rickard, 2001; Rickard, 2004; Kreutz et al., 2008). The sample in the present study was musically untrained, with a mean of less than 3 years of individual and group training. We found no significant differences between musically trained and untrained participants on any of the subjective or physiological recovery measures. However, due to the general lack of training, our sample was not normally distributed, and it is not safe to speculate on the generalizability of the results to musically trained individuals.

Past research has found mixed evidence for respiratory entrainment, or synchronization with the rhythm of heard music. Gomez and Danuser (2007) found correlations between musical features and respiration; they found accelerated respiration in response to music that was fast, accentuated and staccato. Etzel, Johnsen, Dickerson, Tranel and Adolphs (2006) found that much of the difference in respiratory response to music clips conveying different emotions (happiness, sadness, fear) could be attributed to tempo differences and explained by entrainment. Khalfa, Roy, Rainville, Dalla Bella and Peretz (2008) found evidence for tempo entrainment in a control condition that varied on tempo only (i.e., without pitch or temporal variations), but did not find any difference in respiration rates between unaltered sad and happy music. We did not measure respiration, but it has a close relationship to cardiovascular function (Scherer & Zentner, 2001), and thus respiratory entrainment might manifest itself in changes in cardiovascular measures. If our participants experienced respiratory entrainment, then when they listened to fast music (high arousal), their HR should be different than in response to slower music (low arousal). We cannot rule out the possibility that some respiratory entrainment is occurring, but it cannot fully explain the pattern of physiological measures in the present study given that we saw no difference in HR as a function of arousal. Furthermore, respiratory entrainment cannot explain the differences we found that are attributable to valence.

UNDERLYING MECHANISM

The goal of the current study was to look at the effects of musical characteristics and individual differences on music-assisted recovery from stress. Although we did not investigate the mechanism by which music can promote recovery, our results may assist in weighing some possible explanations and point the direction for future study.

Associations between relaxation and certain musical characteristics may account for part of our emotional response. Researchers have long studied correlations between structural components of music and the conveyed emotions. Peaceful music, for example, is usually represented by a slow tempo, major key, simple harmony, soft dynamics, and a flowing, regular rhythm (Rigg, 1964). Listeners seem to be aware of this on some level, because over 100 studies show that listeners tend to agree on the emotion conveyed by a particular piece of music (Juslin & Laukka, 2004). Clearly participants in the present study would associate relaxation with certain kinds of music; it is possible that their subjective reports of post-stress recovery are based on these beliefs. Whether or not individuals have more fine-tuned beliefs, about whether sad music or happy music would be better for regulating stress, for instance, is unknown. Associations are undoubtedly part of the explanation behind high subjective reports of recovery for peaceful music.

Music may be assisting with recovery from stress by inducing an emotion in the listener that replaces the previous emotion (i.e., stress). Although most researchers agree that listeners can perceive emotion in music, there has been a long-standing question about whether music can actually induce emotions. Juslin and Laukka (2004) argue that induction of emotion is supported by converging evidence, showing changes in behavioural, physiological and self-report measures as a result of music listening, though usually not all three in the same study. We found that participants who heard agitated music were more confused after listening to the music, thus implying that music is capable of changing our mood state. On the other hand, we found no overall differences between music conditions in either GSR or HR recovery, which is not supportive of emotion replacement.

Distraction may be the most parsimonious explanation for the effects of music on recovery from stress; participants may regulate their emotions by shifting their attention to the music, and thus away from the stress. The evidence from this study prohibits us from making a blanket statement about the ability of music to distract, given the differing results for different music excerpts, but perhaps the music excerpts differ in the degree to which they are distracting. Erber and Tesser (1992) found that a demanding cognitive task was more distracting and more effective than a simple cognitive task in attenuating feelings of induced sadness. If distraction is indeed the active mechanism, further work is needed to determine the factors contributing to the differing degrees of distraction evidenced by our musical excerpts.

We found that absorption was a strong predictor of recovery following stress. If the advantage of music following stress lies in a shift in the emotions that one is feeling, then the openness to being deeply affected by stimuli that is characteristic of high absorbers (Kreutz et al., 2008) might be responsible for the improved recovery shown by high absorbers. Tellegen and Atkinson (1974) described high absorbers as demonstrating "a heightened sense of the reality of the attentional object, imperviousness to distracting events" (p. 268). If distraction is the underlying mechanism, this means that high absorbers may show improved recovery because they are better able to shift their attention to the music and away from the stressful event. Nagy and Szabo (2002) found that high absorbers reported listening to music as a main activity, whereas low absorbers more often listened to music in the background. Perhaps the low absorbers in our study did not benefit from the music because they don't habitually pay as much attention to music, and therefore it does not function as a salient distraction.

GENERALIZABILITY

Further research will need to assess the generalizability of these findings. Young adults generally consider music to be an important part of their lives (North, Hargreaves, & O'Neill, 2000). It remains to be seen if middle aged and older adults would exhibit the same patterns of emotion regulation in response to music. Our study was limited to one classical music exemplar from each quadrant of Russell's circumplex. A design that incorporates multiple exemplars from each quadrant, perhaps even incorporating different musical genres, would contribute greatly to the generalizability of our findings.

No known present or past culture has lacked music. Emotional responses are partly based on enculturation, but there may also be universal characteristics common to emotional communication that transcend cultural differences, such as tempo, timbre and complexity. Balkwill and Thompson (1999) showed that Western individuals with no previous knowledge of northern Indian music were able to perceive joy, sadness and anger in Indian ragas that were intended to convey these emotions. We therefore expect that emotion regulation using music would be effective using music from any culture that conveys the appropriate emotions.

Another question concerns the generalizability of the findings to different types of stressors. There are physiological stressors (e.g., heat, hunger) and psychological ones. With respect to the latter, Lazarus (1993) distinguished between harm, threat and challenge, which have different antecedent conditions and different consequences. Frankenhaeuser (1982) showed that psychological arousal caused by a challenge is primarily related to catecholamine secretion, whereas arousal caused by distress is primarily related to cortisol secretion. Our speech task may involve differing degrees of effort and distress to different participants depending on their individual cognitive appraisals, whereas a future study using a physiological stressor might produce a more uniform response.

SUMMARY

This study suggests that music can be used to effectively regulate the physiological and subjective response to stress. By using excerpts from each of the four quadrants of Russell's circumplex, we were able to systematically study the independent contributions of the valence and arousal characteristics of music. We also found that trait absorption is an important individual difference, predicting degree of recovery from stress. Individuals are intuitively drawn to music to help them regulate their emotions. Much more work is needed, but this study begins to provide a systematic outlook on the effectiveness of music for regulation of stress.

Appendix I: Subjective Units of Discomfort (SUD) Instructions

We would like you to indicate the amount of anxiety you are experiencing right now. To do this we will use the SUD score. The SUD score provides a way to communicate how comfortable you are feeling. First, think of a time (or times) in your life when you are most nervous or anxious or uptight. Assign this the number 100. Now think of the time (or times) in your life when you are perfectly calm and relaxed--free from all tension and anxiety. Call this 0. Now you have a scale from 0 to 100 on which you can rate how anxious or relaxed you are at any time. High ratings (such as 92) on this scale indicate relatively greater anxiety or tension: low ratings (such as 13) indicate relatively more feelings of relaxation. On this scale please indicate your 0-100 SUD score for how you feel at this moment.

Appendix II: Single Item Measure of Personality

Below are five pairs of descriptions. Circle one point on each scale to indicate how much you think each description sounds like you. For example:

If a pair of descriptions describe you equally well, then mark the centre of the scale

Description 1 1-----2-----3-----4-----**X**-----6-----7-----8-----9 Description 2

If you are slightly more like description 1 than description 2, then mark the scale slightly closer to description 1

Description 1 1-----2-----3-----**X**-----5-----6-----7-----8-----9 Description 2

If description 2 is exactly right and description 1 is not like you at all, then mark the scale right next to description 2

Description 1 1-----2-----3-----4------5-----6-----7-----8-----**X** Description 2

How much does each description sound like you?
Generally, I come across as:

someone who is talkative, outgoing, is comfortable around people, but could be noisy and attention seeking	1--2--3--4--5--6--7--8--9	someone who is a reserved, private person, doesn't like to draw attention to themselves and can be shy around strangers
someone who is forthright, tends to be critical and find fault with others and doesn't suffer fools gladly	1--2--3--4--5--6--7--8--9	someone who is generally trusting and forgiving, is interested in people, but can be taken for granted and finds it difficult to say no
someone who is sensitive and excitable, and can be tense	1--2--3--4--5--6--7--8--9	someone who is relaxed, unemotional, rarely gets irritated and seldom feels blue
someone who likes to plan things, likes to tidy up, pays attention to details, but can be rigid or inflexible	1--2--3--4--5--6--7--8--9	someone who doesn't necessarily work to a schedule, tends to be flexible, but disorganized and often forgets to put things back in their proper place

someone who is a practical person who is not interested in abstract ideas, prefers work that is routine and has few artistic interests	1--2--3--4--5--6--7--8--9	someone who spends time reflecting on things, has an active imagination and likes to think up new ways of doing things, but may lack pragmatism

Appendix III: Short Test of Musical Preferences

For the following items, please indicate your basic preference level for the genres listed using the scale provided.

1------------2------------3------------4------------5------------6------------7		
Strongly dislike	neither like nor dislike	Strongly like

1. _____ Classical
2. _____ Blues
3. _____ Country
4. _____ Dance/Electronica
5. _____ Folk
6. _____ Rap/hip-hop
7. _____ Soul/funk
8. _____ Religious
9. _____ Alternative
10. _____ Jazz
11. _____ Rock
12. _____ Pop
13. _____ Heavy Metal
14. _____ Soundtracks/theme songs

Appendix IV: Tellegen Absorption Scale

This questionnaire consists of questions about experiences that you may have had in your life. We are interested in how often you have these experiences. It is important, however, that your answers show how often these experiences happen to you when you are not under the influence of alcohol or drugs.

1----------------2-----------------3-----------------4
Never   Always

1. ____ Sometimes I feel and experience things as I did when I was a child.
2. ____ I can be greatly moved by eloquent or poetic language.
3. ____ While watching a movie, a TV show, or a play, I may become so involved that I may forget about myself and my surroundings and experience the story as if it were real and as if I were taking part in it.
4. ____ If I stare at a picture and then look away from it, I can sometimes "see" an image of the picture almost as if I were still looking at it.
5. ____ Sometimes I feel as if my mind could envelop the whole world.
6. ____ I like to watch cloud shapes change in the sky.
7. ____ If I wish I can imagine (or daydream) some things so vividly that they hold my attention as a good movie or story does.
8. ____ I think I really know what some people mean when they talk about mystical experiences.
9. ____ I sometimes "step outside" my usual self and experience an entirely different state of being.
10. ____ Textures -- such as wool, sand, wood -- sometimes remind me of colors or music.
11. ____ Sometimes I experience things as if they were doubly real.
12. ____ When I listen to music I can get so caught up in it that I don't notice anything else.
13. ____ If I wish I can imagine that my body is so heavy that I could not move it if I wanted to.
14. ____ I can often somehow sense the presence of another person before I actually see or hear her/him.
15. ____ The crackle and flames of a wood fire stimulate my imagination
16. ____ It is sometimes possible for me to be completely immersed in nature or in art and to feel as if my whole state of consciousness has somehow been temporarily altered.
17. ____ Different colors have distinctive and special meanings for me.
18. ____ I am able to wander off into my thoughts while doing a routine task and actually forget that I am doing the task, and then find a few minutes later that I have completed it.
19. ____ I can sometimes recollect certain past experiences in my life with such clarity and vividness that it is like living them again or almost so.
20. ____ Things that might seem meaningless to others often make sense to me.

21. ____ While acting in a play I think I could really feel the emotions of the character and "become" her/him for the time being, forgetting both myself and the audience.
22. ____ My thoughts often don't occur as words but as visual images.
23. ____ I often take delight in small things (like the five-pointed star shape that appears when you cut an apple across the core or the colors in soap bubbles).
24. ____ When listening to organ music or other powerful music I sometimes feel as if I am being lifted into the air.
25. ____ Sometimes I can change noise into music by the way I listen to it.
26. ____ Some of my most vivid memories are called up by scents and smells.
27. ____ Some music reminds me of pictures or changing color patterns.
28. ____ I often know what someone is going to say before he or she says it.
29. ____ I often have "physical memories"; for example, after I have been swimming I may still feel as if I am in the water.
30. ____ The sound of a voice can be so fascinating to me that I can just go on listening to it.
31. ____ At times I somehow feel the presence of someone who is not physically there.
32. ____ Sometimes thoughts and images come to me without the slightest effort on my part.
33. ____ I find that different odors have different colors.
34. ____ I can be deeply moved by a sunset.

Appendix V: Music Questionnaire

Name: ______________________ Age: _____ Gender: Male / Female
Are you Right or Left Handed? Right / Left Is English your first language? Yes / No

I. Formal music training:

1. Have you ever taken music lessons (ANY type of lessons count, e.g., high school band class)? Yes / No
* If **YES**, please continue to #2; If **NO**, please proceed to #4

2. Please indicate your *instrument/voice training*, using a different line for each different instrument or voice:

Instrument/Voice	Individual (years)	Group (years)	RC Grade*	Age at time of lessons
1)				
2)				
3)				
4)				

*If not Royal Conservatory training, what method of training?____________________

3. Please indicate your *music theory training* (if any):

Type (e.g., composition)	Individual (years)	Group (years)	RC Grade*	Age at time of lessons
1)				
2)				
3)				

*If not Royal Conservatory training, what method of training? ___________________

II. Informal music training/current music involvement:

4. Have you ever taught yourself to play an instrument (i.e., without formal lessons on that instrument)?

Instrument	How long played?
1)	
2)	

5. Are you currently active musically (i.e., within the last year)? Yes / No

If 'Yes': ___ Recreational (indicate activity): ______________________________
___ Formal lessons (indicate activity): ______________________________

6. Do you listen to music (circle one)? Yes / No

If 'Yes', how often (e.g., everyday for about 3 hours)? ____________________
If 'Yes', what type (e.g., classical, rock)? ____________________

7. What is your favorite type of music? ____________________

8. Is music important to you? Yes / No If 'Yes', how? ____________________

9. Do you consider yourself musical? Yes / No / Somewhat

10. Do you have normal hearing? Yes / No

Appendix VI: Results using personality traits as predictors

Experiment 1

We tested each of the big five personality traits as a predictor for each dependent variable using 2 (music vs. white noise) x 2 (high vs. low in personality trait) ANOVA's, with alpha levels corrected using a Bonferroni adjustment for multiple tests.

SUBJECTIVE EXPERIENCE

SUD

Emotional stability was revealed as a significant predictor, $F(1,29)=10.4, p<.01$ respectively. Participants reported recovering more fully when they were high in emotional stability (M=168.2) instead of low (M=90.5).

PHYSIOLOGICAL MEASURES

GSR

There was a main effect of conscientiousness, $F(1,35)=5.2, p<.05$. Participants recovered more fully when they were high in conscientiousness (M=83.8) rather than low (M=49.2).

There was also a main effect of emotional stability, $F(1,35)=7.82, p<.01$. Individuals recovered more completely when they were low in emotional stability (M=89.5) rather than high (M=53.3).

HR

There were no main effects for the personality traits on heart rate recovery, nor were there interactions between the personality traits and condition.

HRV (HF)

These findings should be judged with caution; because of the variability in the HF data, and the number of outliers, some of the cell sizes in this analysis are extremely small (e.g., two cells had n=2).

There was a significant interaction between openness and condition, $F(1,16)=5.92$, $p<.05$. Pairwise comparisons with a Bonferroni adjustment showed that individuals who were low in openness recovered significantly better when they listened to music (M=689.1) rather than to white noise (M=122). However, individuals high in openness recovered about the same, regardless of whether they listened to music (M=76.3) or white noise (M=232.5).

Experiment 2

Each of the big five personality traits was tested as a predictor for each dependent variable using a 2 (valence) x 2 (arousal) x 2 (high vs. low in personality trait) ANOVA.

SUBJECTIVE EXPERIENCE

SUD

There was a significant interaction between emotional stability and valence, $F(1,57)=4.09$, $p<.05$. Individuals who were high in emotional stability recovered significantly better when they listened to music with a positive valence (M=118) instead of a negative valence (M=49.8). However, individuals who were low in emotional stability recovered about the same, regardless of whether they listened to music with a positive (M=96.1) or negative (M=80.8) valence.

PHYSIOLOGICAL MEASURES

GSR

Conscientiousness was found as a significant predictor, $F(1,65)=4.91, p<.05$. Participants recovered more completely when they were high in conscientiousness (M=104) rather than low (M=57.1).

There was also a significant effect of agreeableness, $F(1,65)=4.6, p<.05$. This main effect was driven by significant interactions between valence and agreeableness, and between arousal and agreeableness, $F(1,65)=4.32$, $F(1,65)=5.1$ respectively, p's<.05. Individuals who were low in agreeableness recovered more completely when they listened to music with a positive valence (M=160.5) instead of a negative valence (M=90.7), or music that was high in arousal (M=159.4) instead of low (M=91.8). However, recovery for individuals high in agreeableness did not differ based on valence (M=75.9 for positive valence; M=89.4 for negative valence) or arousal (M=71.1 for high arousal; M=94.1 for low arousal).

HR

There were no main effects, nor any interactions with valence, arousal.

HF of HRV

These findings should be judged with caution; because of the variability in the HF data, and the number of outliers, some of the cell sizes in this analysis are extremely small (e.g., two cells had n=1 and two cells had n=2).

There was a significant interaction between openness and valence, $F(1,27)=4.64$, $p<.05$. Individuals who were low in openness recovered better when they listened to music with a positive valence (M=342.8) instead of a negative valence (M=-72.3). However, individuals who were high in openness recovered about the same, regardless of whether they listened to music with a positive (M=55.4) or negative (M=172.7) valence.

Appendix VII: Results using music preferences as predictors

Experiment 1

We tested preferences for classical and, more generally, reflective music as predictors for each dependent variable using 2 (music vs. white noise) x 2 (high vs. low in preference) ANOVA's, with alpha levels corrected using a Bonferroni adjustment for multiple tests.

SUBJECTIVE EXPERIENCE

SUD

There were no main effects, nor any interactions with condition.

PHYSIOLOGICAL MEASURES

GSR

There were no main effects, nor any interactions with condition.

HR

There was a significant interaction between condition and preference for classical music, $F(1,31)=4.41$, $p<.05$. Pairwise comparisons with a Bonferroni adjustment showed that those who preferred classical music recovered more completely for the music condition ($M=177.9$) than for the white noise condition ($M=-11.8$), while those who did not enjoy classical music recovered about the same for the music ($M=72.3$) as they did for the white noise ($M=70.1$).

Similarly, there was an interaction between condition and preference for reflective music (a broader category that includes classical music), $F(1,31)=4.41$, $p<.05$. Pairwise comparisons with a Bonferroni adjustment revealed that those who preferred reflective music recovered more completely for the music condition ($M=231.3$) than for the white noise condition ($M=5.6$), whereas those who did not enjoy reflective music recovered about the same for the music ($M=80.9$) as they did for the white noise ($M=66.8$).

HRV (HF)

There were no main effects, nor any interactions with condition.

Experiment 2

We tested preferences for classical and, more generally, reflective music as predictors for each dependent variable using a 2 (valence) x 2 (arousal) x 2 (high vs. low in preference) ANOVA.

SUBJECTIVE EXPERIENCE

SUD

There were no main effects nor any interactions with valence or arousal.

PHYSIOLOGICAL MEASURES

GSR

There were no main effects nor any interactions with valence or arousal.

HR

There were no main effects nor any interactions with valence or arousal.

HF of HRV

There was a significant interaction between valence and preference for reflective music, $F(1,27)=5.59$, $p<.05$. Pairwise comparisons with a Bonferroni adjustment showed that those who preferred reflective music recovered more completely for music with a positive valence (M=242.3) instead of a negative valence (M=-48), while those who did not enjoy reflective music recovered about the same for the music with a positive (M=43.9) or negative (M=224) valence.

Appendix VIII: Correlational Matrices

Experiment 1

	GSR	HR	HRV-HF	Abs	E	A	N	C	O
SUD	r=-0.11 p=.52	r=.02 p=.92	r=.01 p=.99	r=-.32 p=.06	r=-.28 p=.10	r=.02 p=.91	r=.28 p=.11	r=.02 p=.90	r=.20 p=.26
GSR		r=-.02 p=.90	r=.18 p=.34	r=.31 p=.05	r=-.07 p=.67	r=-.06 p=.72	r=-.34 p=.03*	r=.38 p=.02*	r=-.05 p=.75
HR			r=-.02 p=.91	r=.03 p=.83	r=-.25 p=.12	r=-.11 p=.50	r=.13 p=.43	r=-.06 p=.70	r=.13 p=.44
HRV-HF				r=.21 p=.27	r=-.20 p=.31	r=-.08 p=.69	r=-.21 p=.28	r=-.10 p=.61	r=.02 p=.92
Abs					r=.25 p=.11	r=-.04 p=.83	r=-.13 p=.44	r=.06 p=.71	r=.28 p=.08
E						r=.01 p=.96	r=-.07 p=.65	r=-.05 p=.75	r=.14 p=.41
A							r=.21 p=.13	r=-.15 p=.35	r=-.20 p=.21
N								r=-.18 p=.26	r=.01 p=.94
C									r=-.07 p=.68

NOTE: Abs=Absorption; E=Extraversion; A=Agreeableness; N=Emotional Stability; C=Conscientiousness; O=Openness

Experiment 2

	GSR	HR	HRV-HF	Abs	E	A	N	C	O
SUD	r=.01 p=.94	r=.04 p=.73	r=-.06 p=.71	r=-.17 p=.15	r=-.12 p=.31	r=.11 p=.33	r=-.13 p=.26	r=-.07 p=.54	r=.14 p=.22
GSR	1	r=.49 p=.01*	r=.06 p=.69	r=.03 p=.79	r=-.23 p=.04*	r=-.28 p=.01*	r=-.14 p=.21	r=.09 p=.42	r=-.04 p=.74
HR		1	r=-.03 p=.83	r=-.02 p=.87	r=-.09 p=.43	r=-.17 p=.11	r=-.07 p=.54	r=-.01 p=.91	r=-.04 p=.71
HRV-HF			1	r=.21 p=.13	r=-.14 p=.33	r=.01 p=.98	r=-.11 p=.45	r=-.05 p=.75	r=.07 p=.62
Abs				1	r=.17 p=.12	r=-.05 p=.67	r=-.02 p=.83	r=-.25 p=.82	r=.32 p=.01*
E					1	r=.07 p=.51	r=.12 p=.26	r=.14 p=.20	r=.06 p=.58
A						1	r=-.04 p=.73	r=-.12 p=.28	r=-.04 p=.73
N							1	r=-.21 p=.05*	r=.20 p=.07
C								1	r=-.23 p=.03*

NOTE: Abs=Absorption; E=Extraversion; A=Agreeableness; N=Emotional Stability; C=Conscientiousness; O=Openness

Appendix IX: Results including individuals who did not demonstrate physiological recovery

Experiment 1

SUBJECTIVE EXPERIENCE

SUD

No differences; no individuals were excluded for these analyses.

PHYSIOLOGICAL MEASURES

GSR

No differences; no individuals were excluded for these analyses.

HR

Condition was still not a significant predictor for the percentage return to baseline of the heart rate, $F(1,25)=.143, p>.7$.

HRV (HF)

There were still no significant main effects or interactions.

Experiment 2

SUBJECTIVE EXPERIENCE

SUD

The significant main effect of arousal is still present, $F(1,60)=15.14$, $p<.001$. Participants recovered better when the music was low in arousal ($M=110.8$) as compared to high ($M=55.8$).

The significant main effect of valence is now not quite significant, $F(1,60)=3.58$, $p<.07$. Recovery was better, though not significantly so, when music had a positive valence ($M=96.6$) instead of negative ($M=69.9$).

A follow-up one-way ANOVA continued to reveal a significant main effect of music condition on SUD percentage return to baseline, $F(3,64)=6.5$, $p<.001$. Pairwise comparisons using a Bonferroni adjustment revealed that participants recovered significantly better when they listened to peaceful music ($M=130$) as compared to happy music ($M=65.3$) or to agitated music ($M=48.3$).

PHYSIOLOGICAL MEASURES

GSR

The main effect of absorption was still present, $F(1,71)=5.15$, $p<.05$. However, the interaction between valence and absorption is no longer significant, $F(1,71)=.49$, $p>.4$.

HR

As in the original analyses, there were no main effects for valence, arousal or absorption, and no interactions. The interaction between valence and arousal is not significant, $F(1,42)=1.78$, $p>.1$.

HF of HRV

The main effect of absorption is still present, $F(1,29)=5.72$, $p<.05$. Individuals recovered better when they were high ($M=236.7$) rather than low ($M=27.9$) in absorption.

The interaction between valence and arousal is still significant, $F(1,29)=6.27$, $p<.05$. When the music had a negative valence, individuals recovered better when the music was also high in arousal ($M=279.1$) instead of low in arousal ($M=20.1$). However, when the music had a positive valence, there was no difference between recovery based on whether the music was high ($M=25.9$) or low ($M=204.1$) in arousal.

There is a significant interaction between valence, arousal and absorption that was not found in the original analyses, $F(1,29)=5.22$, $p<.05$.

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