Music Hath Charms: The Effects of Valence and Arousal on Recovery Following an Acute Stressor

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Abstract

The purpose of this study was to investigate the effects of the valence and arousal dimensions of music over the time course of physiological (skin conductance level and heart rate) and subjective (Subjective Unit of Discomfort score) recovery from an acute stressor. Participants experienced stress after being told to prepare a speech, and were then exposed to happy, peaceful, sad, or agitated music. Music with a positive valence promoted both subjective and physiological recovery better than music with a negative valence, and low-arousal music was more effective than high-arousal music. Repeated measures analyses found that the emotion conveyed by the music affected skin conductance level recovery immediately following the stressor, whereas it affected heart rate recovery in a more sustained fashion. Follow-up tests found that positively valenced low-arousal (i.e., peaceful) music was more effective across the time course than an emotionally neutral control (white noise).

Keywords

arousal, emotion, music, stress, valence

Researchers have long been interested in understanding the ability of music to counteract acute stress (Chafin, Roy, Gerin & Christenfeld, 2004; Davis & Thaut, 1989). Given the inherent stress of medical settings, many researchers have looked at the ability of music to help patients feel more relaxed and to reduce perceived pain (Allen et al., 2001; Roy, Peretz, & Rainville, 2008). One important question to be addressed concerns the type of music to be employed. Some researchers have tested different musical genres; others have tested experimenter-selected against self-selected music; and many have simply assumed that peaceful music, characterized by low arousal and positive valence, is the most effective. In this study, we investigated whether musical characteristics, specifically the emotion conveyed by music, influence individuals' recovery from induced stress.

Valence and Arousal and Stress Recovery

Several studies have manipulated the valence of emotional stimuli to investigate the effects on recovery following stress. Fredrickson, Mancuso, Branigan, and Tugade (2000) 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 emotional valence provided the most beneficial effect on physiological indices of stress. Roy et al. (2008) studied the capacity of music to soothe the pain resulting from administration of thermal stimulations. Participants who concurrently listened to positively valenced music reported reduced pain intensity and unpleasantness, compared to those who heard negatively valenced music.

Little research has manipulated the arousal of the emotional stimuli presented following a stressor; it seems to be generally assumed that low arousal is the most effective. Bernardi, Porta, and Sleight (2006) found that music with a slower tempo was more relaxing than music with a faster tempo, as indicated by a 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.

Physiological Measures of Emotion Response

Stress triggers changes in endocrine, cardiovascular, respiratory, gastrointestinal, and renal systems. Stress-related stimulation of sweat glands is detected by measuring the skin conductance level (SCL) and acceleration of the heart rate

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(HR) can be discerned in measurements of the pulse. These measures have also been used to understand the emotional response to music (e.g., SCL: Baumgartner, Esslen, & Jäncke, 2006; Khalfa, Peretz, Blondin, & Manon, 2002; Krumhansl, 1997; Rickard, 2004; Sokhadze, 2007; HR: Baumgartner et al., 2006; Knight & Rickard, 2001; Krumhansl, 1997; Nyklicek, Thayer, & Van Doornen, 1997; Rickard, 2004; Sokhadze, 2007; Witvliet & Vrana, 2007).

The arousal and valence characteristics of music affect these physiological measures in a listener. High-arousal music has been associated with higher SCL (Khalfa et al., 2002) and faster HR (Witvliet & Vrana, 2007) than has low-arousal music. Positively valenced music has been associated with higher HR than has negatively valenced music (Krumhansl, 1997; Witvliet & Vrana, 2007).

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; Mandler & Kremen, 1958), we gathered both physiological and self-report evidence of stress and recovery. This is the first study that we are aware of that compares the effectiveness of music from all four quadrants of Russell's (1980) circumplex on recovery following stress; this allows us to examine the effects of valence and arousal independently. We hypothesized that recovery would be stronger after listening to music with a positive valence compared to music with a negative valence and after listening to music low in arousal compared to music high in arousal. We looked at differences in recovery across time, pinpointing the time windows during which SCL and HR recovery differed by valence and arousal.

Materials and Methods

Participants

Eighty-six students were recruited from Ryerson University for the main study. Due to problems with the equipment, data were dropped for three participants. Nineteen participants listened to peaceful music, 20 listened to agitated music, 22 listened to sad music, and 22 listened to happy music. Overall, the 83 students (74% female) had an average age of 21.9 ($SD = 4.8$), an average of 2.3 years of individual music training ($SD = 3.3$), and 1 year of group training ($SD = 1.6$). Twenty additional Ryerson University students (55% female) were recruited and assigned to the white-noise control condition. These had an average age of 21.9 ($SD = 4.0$), an average of 1.9 years of individual music training ($SD = 3.3$), and 1.6 years of group training ($SD = 2.1$). Students received either course credit or financial compensation.

Music Stimuli

A pretest study ($N = 54$) was used 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 and used ratings of valence, arousal, and familiarity from 8 musically trained lab members and 46 undergraduate participants to choose one excerpt 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), Bizet's "Intermezzo" from the *Carmen Suite* (peaceful), Grieg's "Aase's Death" from the *Peer Gynt Suite* (sad), and the adagio from Shostakovich's 8th Symphony (agitated). Valence and arousal ratings for each excerpt can be seen in Table 1.

Table 1. Valence and Arousal Ratings for Music Excerpts

	Valence	
Arousal	Negative	Positive
High	Agitated (Shostakovich) valence: −1.58 (1.35) arousal: 2.02 (0.91)	Happy (Strauss) valence: 2.20 (1.16) arousal: 2.55 (0.99)
Low	Sad (Grieg) valence: −1.56 (1.18) arousal: −1.3 (1.47)	Peaceful (Bizet) valence: 1.37 (1.25) arousal: −1.69 (0.95)

Ratings ranged from −3 to +3. Values are given as means (*SD*s).

Four 2-minute music clips were created, and the root mean square of the music clips were equalized with one another to produce equal sound intensity. A 1-second fade-in and a 1-second fade-out were added to all clips in order to avoid a startle effect. (Audio files available as supplementary material for this article; download at http://mmd.sagepub.com/supplemental.)

Questionnaires

Participants appraised their level of stress by providing a Subjective Unit of Discomfort (SUD) score (Kaplan, 1995) at three points in time during the study. Degree of liking for musical excerpts was assessed with the following question: "Rate how much you like the song you just heard" on a 4-point Likert-type scale ranging from *not at all* to *liked*. Degree of music training was assessed with a series of questions about years of individual and group training. We created an index of total music training by summing the number of years of individual and group training, giving individual training double the weight of the group training.

Equipment

SCL and 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 nondominant hand to monitor SCL. One TSD200 photoplethysmograph

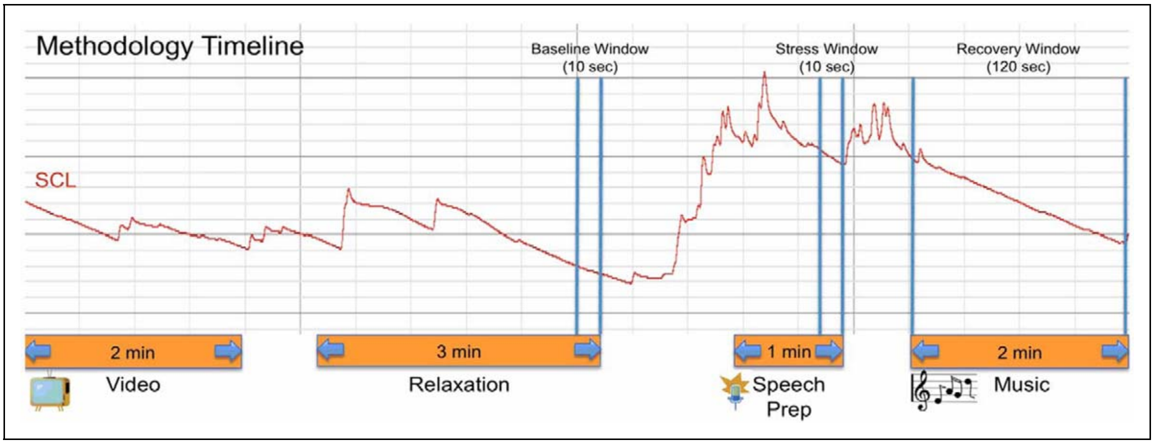

Figure 1. Timeline depicting the study methodology
The amount of time for each stage is marked at the bottom; intervals between stages indicate periods of communication between the experimenter and the participant. The analysis windows are marked with vertical lines: The baseline window is the last 10 seconds of the relaxation stage, the stress window is the last 10 seconds of the speech preparation stage, and the recovery window lasts throughout the 120 seconds when the music plays.

transducer was attached to the distal phalange of the middle finger of the nondominant hand to measure HR.

The video and music stimuli were presented to each participant using supra-aural headphones connected to a MacBook Pro laptop. Physiological data was processed with AcqKnowledge software, Version 3.9.2 for Mac (BIOPAC Systems, 2007).

Procedure

Participants were brought into a quiet room and provided consent. 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 news video clip. The experimenter asked the participant to relax for 3 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 he or she would be required to make a short speech about the video, which would be recorded and evaluated. Participants were given 1 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 only some participants would be required to make the speech and that a computer would randomly determine whether or not they would make the speech. However, 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.

The experimenter returned after 1 minute and asked the participant for a second SUD score. The participant was then informed that he or she would not be required to deliver a speech. The participant was asked to listen to a music clip and was instructed, "Close your eyes and let yourself be absorbed by what you hear." Following the music, the participant provided a final SUD score before the physiological monitors were detached. This was followed by questions about liking of the music and past musical training. The sequencing of events in the procedure is graphically illustrated in Figure 1. This experimental protocol was approved by the Ryerson University Research Ethics Board (REB-2007-240).

Results

We converted the subjective and physiological measures for each participant to standard z scores, taking into account the values from the beginning of the baseline window (the last 10 seconds of the adaptation period) until the end of the music.

Subjective Experience

We used the difference between the standardized SUD scores during the stress window (the final 10 seconds of time during which the participant was preparing for the speech) and the recovery window (the time during which the music was playing) as the dependent variable; a larger difference indicates greater recovery. We removed three outliers from SUD analyses; these were individuals for whom the dependent variable was more than 2.5 standard deviations from the mean for the particular music condition.

A 2 (positive vs. negative valence) $\times$ 2 (high vs. low arousal) ANOVA revealed a significant main effect of arousal, $F(1, 76) = 7.03$, $MSE = 0.61$, $p < .05$. Participants recovered better when the music was low in arousal ($n = 39$, $M = 1.51$) instead of high in arousal ($n = 41$, $M = 1.05$). Recovery was also marginally better when music had a positive valence ($n = 40$, $M = 1.44$) rather than a negative valence ($n = 40$, $M = 1.12$), $F(1, 76) = 2.01$, $MSE = 0.61$, $p < .10$. (Refer to Table 2 for the SUD scores for each quadrant.)

The correlation between liking and the SUD score difference was not significant. Neither was the correlation between musical training and the SUD score difference. These results

Table 2. Standardized Subjective Unit of Discomfort Score (post-stress induction) Minus Standardized Subjective Unit of Discomfort Score (post-music)

	Valence	
Arousal	Negative	Positive
High	Agitated (Shostakovich) 0.95 (0.82)	Happy (Strauss) 1.15 (0.93)
Low	Sad (Grieg) 1.30 (0.82)	Peaceful (Bizet) 1.73 (0.39)

Values are given as means (*SD*s).

suggest that self-reported recovery is not affected by liking for the music excerpt or by amount of music training.

Physiological Measures

One of the principle aims of this study was to understand how the time course of stress recovery is influenced by music. To more fully examine the time course of the physiological measures, the analyses for SCL and HR were done with repeated measures ANOVAs.

Skin Conductance Level

Figure 2 plots the standardized SCL values (*z* scores) from baseline through recovery. Values start low at baseline, reach a peak when the stressor is administered, and then gradually return to their starting point as the music plays; a lower standardized score during the music means greater recovery.

Two participants were excluded from the SCL analyses because we could not induce stress-related increases in SCL; study of recovery following stress is contingent on successfully inducing stress.

A 14 (time point) × 2 (positive vs. negative valence) × 2 (high vs. low arousal) repeated measures ANOVA was conducted on the standardized SCL values (*z* scores). The ANOVA revealed a main effect of time point, $F(13, 1{,}001) = 159.08$, $MSE = 0.14$, $p < .001$. The significant pairwise comparison between the baseline window ($M = -1.04$) and the stress window ($M = 0.74$), $p < .001$ (Bonferroni-corrected), validated the effectiveness of our stress induction procedure.

There were significant pairwise differences due to valence after 10 seconds of music, such that individuals had recovered more at that time when they listened to music with a positive valence ($n = 40$, $M = 0.54$) instead of music with a negative valence ($n = 41$, $M = 0.81$), $p < .01$. The differences after 20 and 30 seconds of music also trended in the same direction, $p < .10$. Due to the large number of comparisons (one per time point) and the lack of correction to control for increases in Type I error, these results concerning time course are best considered as exploratory. Nonetheless, an examination of Figure 2 clearly shows the sustained effect.

The effect of arousal was significant after 10 seconds of music, such that individuals had recovered more at that time when they listened to low-arousal music ($n = 40$, $M = 0.58$) instead of high-arousal music ($n = 41$, $M = 0.78$), $p < .05$. The difference after 20 seconds also trended in the same direction, $p < .10$.

We contend that it was the emotion conveyed by the music that contributed to the differences in physiological recovery across conditions. On the basis of the main effects of valence and arousal, it may be inferred that peaceful music is the most effective at promoting recovery.

Although the main purpose of this study was to investigate the effects of valence and arousal on physiological and subjective recovery, we tested whether peaceful music was different from an emotionally neutral control. We used white noise, equated with the intensity of the music, as our control condition (see Nyklicek et al., 1997; Sokhadze, 2007). Intensity-matched white noise provides a situational context that should be comparable to that of the music excerpts while remaining emotionally neutral (Nyklicek et al., 1997). A 14 (time point) × 2 (peaceful music vs. white noise) repeated measures ANOVA revealed a main effect of condition, $F(1, 37) = 5.81$, $MSE = 1.59$, $p < .05$; SCL recovery was better for those who listened to peaceful music ($n = 19$), as compared to white noise ($n = 20$). The recovery time course for white noise appears to be similar to that of the happy, sad, and agitated music conditions (see Figure 2).

There were no significant correlations between liking and SCL at any time point. The correlation between musical training and SCL was also not significant at any time point. These results suggest that SCL recovery is not affected by liking for the music excerpt or by amount of music training.

Heart Rate

Figure 3 plots the standardized HR values (*z* scores) from baseline through recovery. Values start low at the baseline and reach a peak when the stressor is administered. We see a classic triphasic cardiac defense response—that is, rapid acceleration, rapid deceleration, and mild acceleration (see, e.g., Sánchez-Navarro, Martínez-Selva, & Román, 2006). Visual inspection of the graph suggests that the music excerpt may affect the extent of deceleration in the second phase of this defense response.

Ten participants were excluded from HR analyses because their HR data were deemed problematic; for these individuals, visual inspection of the photoplethysmograph signal revealed no discernible peaks in the waveform and/or lack of periodicity. Nineteen participants were excluded because we could not induce stress-related increases in HR; study of recovery following stress is contingent on successfully inducing stress. A total of 8 participants were excluded from the agitated condition, 7 from the happy condition, 6 from the peaceful condition, and 7 from the sad condition. The substantial number of exclusions for the HR data urges caution when interpreting these results.

A 14 (time point) × 2 (positive vs. negative valence) × 2 (high vs. low arousal) repeated measures ANOVA was

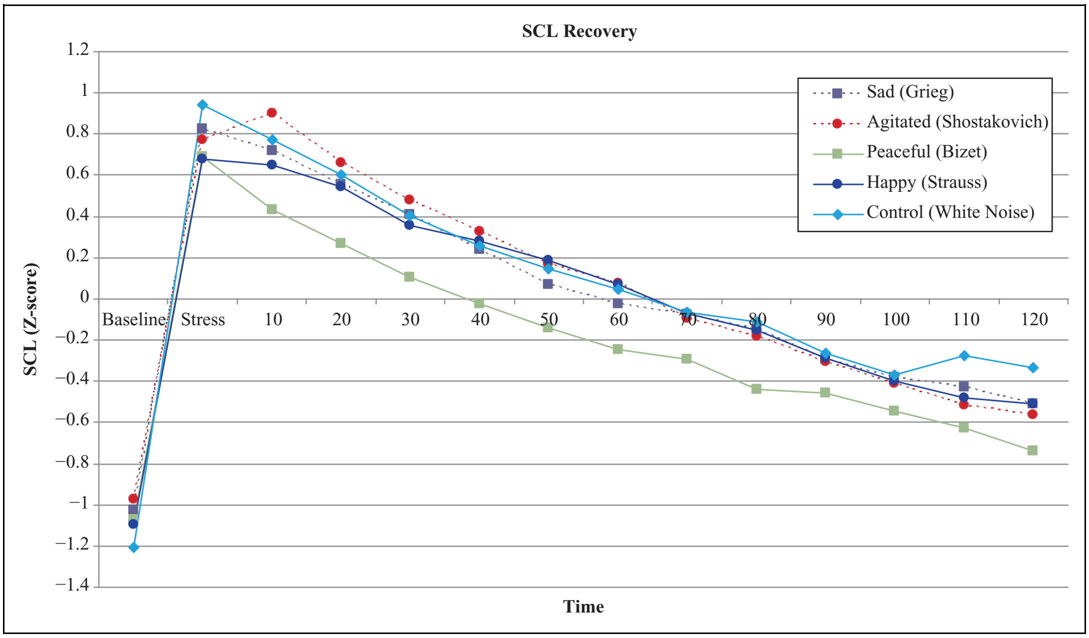

Figure 2. Standardized skin conductance level (SCL) response activity (z scores) during the baseline window, stress window, and every 10 seconds poststress in the 2-minute recovery window (10-120 seconds)

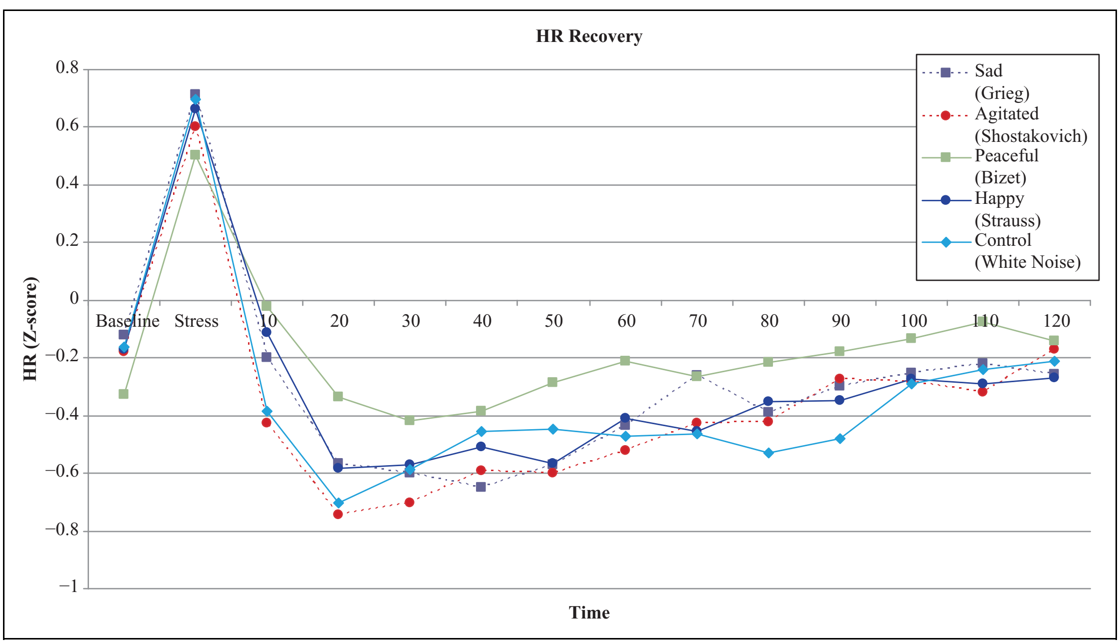

Figure 3. Standardized heart rate (HR) activity (z scores) during the baseline window, stress window, and every 10 seconds poststress in the 2-minute recovery window (10-120 seconds)

conducted on the standardized HR data (*z* scores). The ANOVA revealed a main effect of time point, $F(13, 650) = 52.91$, $MSE = 0.09$, $p < .001$. The significant pairwise comparison between the baseline window ($M = -0.20$) and the stress window ($M = 0.62$), $p < .001$ (Bonferroni-corrected), validated the effectiveness of our stress induction procedure.

There were significant pairwise differences due to valence after 60 seconds of music, such that individuals had recovered more at that time when they listened to music with a positive valence ($n = 27$, $M = -0.31$) instead of music with a negative valence ($n = 27$, $M = -0.48$), $p < .05$. The difference was also marginally significant after 10, 20, 40, and 50 seconds of music, $p < .10$. As with the SCL analysis, there are a large number of comparisons (one per time point). Without a correction to control for increases in Type I error, it is possible that some significant differences could be spurious. Although the results should be considered exploratory, the sustained effect can be clearly seen in Figure 3.

There were significant pairwise differences due to arousal after 20, 70, and 110 seconds of music, such that individuals had recovered more at those times when they listened to low-arousal music (n = 28; M = –0.45, –0.26, –0.15, respectively) instead of high-arousal music (n = 26; M = –0.66, –0.44, –0.30, respectively), $p < .05$. The differences were also marginally significant after 50 and 60 seconds of music, $p < .10$.

We followed up by testing whether peaceful music ($n = 13$), which emerged as the most effective, was different from white noise ($n = 17$). A 14 (time point) × 2 (peaceful music vs. white noise) repeated measures ANOVA revealed a main effect of condition, $F(1, 28) = 4.52$, $MSE = 0.58$, $p < .05$, suggesting that HR recovery was improved when individuals listened to peaceful music instead of white noise. The recovery time course for white noise appears to be similar to that of the happy, sad, and agitated music conditions (see Figure 3).

There was a significant correlation between liking and HR after 20 seconds of music, $r = .31$, $p < .05$, but at no other time point. The correlation between musical training and HR was also significant after 20 seconds of music, $r = –.28$, $p < .05$, but not at any other time point. These results do not support the notion that HR recovery may be affected by liking for the music excerpt or by amount of music training. However, it must be acknowledged that the range of variability in liking was somewhat limited.

Discussion

The central aim of the current study was to explore the effects of the valence and arousal characteristics of music during the time course of recovery from induced stress. Participants' subjective reports indicated that the type of music they listened to affected how well they recovered; they reported recovering 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.

All participants eventually regress to their baseline physiological levels following an acute stressor. In order to find differences in recovery that are due to the type of music, it is important to understand how each physiological measure is affected over time. Low-arousal music and music with a positive valence facilitated SCL recovery immediately following the acute stressor. Low-arousal music and music with a positive valence also improved HR recovery following the stressor but in a more sustained fashion. These findings suggest that music affects recovery from stress at different points in the time course for different physiological subsystems.

Physiological data suggest that peaceful music was significantly more effective than an emotionally neutral control (white noise). Because stimuli in both conditions were equated for intensity, we can conclude that it was the emotion conveyed by the peaceful music—that is, positive valence and low arousal—that led to the distinct pattern of improved recovery from stress.

Variables other than the emotion conveyed by music may have contributed to the differences in recovery from stress. Peretti and Swenson (1974) found differences in SCL recovery between those with music training and those without, but we found no significant correlations between amount of music training and the SUD score difference, or the SCL at any time point, and only at one time point for the HR. Enhanced physiological responses have been found for preferred, self-selected music (Davis & Thaut, 1989), suggesting degree of liking as a possible mediator. However, we found no significant correlations between degree of liking and the SUD score difference, or the SCL at any time point, and only at one time point for the HR.

Further research is needed 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-age and older adults would exhibit the same patterns of recovery in response to music. There is no obvious reason to think that they would not; Allen and colleagues (Allen & Blascovich, 1994; Allen et al., 2001) found stress-reducing effects of music for surgeons (M age = 52) in one study and ophthalmic surgery patients (M age = 77) in another. Another question concerns the applicability of these findings to different 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. The most important consideration for possible health care applicability is to determine whether music can provide the same physiological benefits in response to different acute stressors. Given the ease and low cost of providing music to patients, this is an intriguing possibility.

To add to our findings regarding the effects of musical characteristics over time, it would be interesting to present the music before the stressor and map out the time-related changes. Knight and Rickard (2001) showed that music can attenuate the stress-induced increases in subjective and physiological arousal when presented before the stressor. An intervention that can both limit stress reactivity and speed recovery from stress would be a valuable clinical tool.

This study suggests that music can be used to promote physiological and subjective recovery following acute 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. The results suggest that music with both positive valence and low arousal is the most effective choice to promote both subjective and physiological recovery. We also showed that the effect of the musical characteristics on SCL is short lived, whereas the effect on HR is longer lasting. Previous studies that have presented music following a stressor have used music excerpts of different lengths, ranging from 2 to 20 minutes, and have generally analyzed overall recovery at a single point in time after the music excerpt concludes. The current study suggests that there is value in looking at the complete time course of physiological recovery. Each physiological measure has a different recovery timeline and is affected differently by music interventions. These considerations, as well as the nature of the stressor, may influence decisions as to the length of the music excerpts used in future studies and the type of analyses used to investigate the effects of the music. Individuals are intuitively drawn to music to help them manage their emotions. Much more work is needed, but this study begins to provide a systematic outlook on the effectiveness of music for recovery following acute stress.

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Declaration of Conflicting Interests

The authors declared no potential conflicts of interests with respect to the authorship and/or publication of this article.

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Bios

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