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Music can facilitate blood pressure recovery from stress

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Objectives. Interventions that reduce the magnitude of cardiovascular responses to stress are justified, at least in part, by the notion that exaggerated responses to stress can damage the cardiovascular system. Recent data suggest that it is worthwhile to explore, in addition to the magnitude of the cardiovascular responses during stress (reactivity), the factors that affect the return to baseline levels after the stressor has ended (recovery). This experiment examined the effect of listening to music on cardiovascular recovery.

Design and method. Participants ($N = 75$) performed a challenging three-minute mental arithmetic task and then were assigned randomly to sit in silence or to listen to one of several styles of music: classical, jazz or pop.

Results. Participants who listened to classical music had significantly lower post-task systolic blood pressure levels ($M = 2.1$ mmHg above pre-stress baseline) than did participants who heard no music ($M = 10.8$ mmHg). Other musical styles did not produce significantly better recovery than silence.

Conclusions. The data suggest that listening to music may serve to improve cardiovascular recovery from stress, although not all music selections are effective.

The reactivity hypothesis has been the theoretical foundation for a great deal of recent research on cardiovascular responses to stress. In its strong form, the hypothesis maintains that exaggerated blood pressure and heart rate responses to stress can damage the cardiovascular system. Thus, people who exhibit large cardiovascular responses are at risk for the development of cardiovascular disease and hypertension, and situations that lead to large responses put people at risk (Krantz & Manuck, 1984, 1986; Lovallo & Wilson, 1992). As a means of better understanding the processes by which psychological stressors may impact cardiovascular functioning, there has been an effort to find techniques that limit or reduce the magnitude of the stress response.

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Investigators have looked at such factors as the behaviour of supportive others (Gerin, Pieper, Levy, & Pickering, 1992; Glynn, Christenfeld, & Gerin, 1999), the role of self-efficacy and control over outcomes (Gerin, Litt, Deich, & Pickering, 1995; Hilmert, Christenfeld, & Kulik, 2002), and the presence of pets (Allen, Blascovich, Tomaka, & Kelsey, 1991), among others.

While most research stemming from the reactivity hypothesis has focused on acute cardiovascular responses in the immediate presence of the stressor, a more recent expanded view of the hypothesis includes cardiovascular recovery, or stress-associated elevations in blood pressure and heart rate that persist when the stressor is no longer present. A number of studies suggest that the duration of blood pressure elevation, in addition to the magnitude of the initial peak reaction, may contribute to cardiovascular illness (Borghi, Costa, Boschi, Mussi, & Ambrosini, 1986; Gerin & Pickering, 1995; Haynes, Gannon, Orimoto, O'Brien, & Brandt, 1991).

The addition of cardiovascular recovery to the reactivity hypothesis has several potential advantages in ecological validity. It is often the case that a stressor is quite short in duration ('You're fired', 'I'm leaving you'), but the reaction to the stressor lasts far longer. It seems likely that the health impact of the event is not confined to the period when the 'stressor' is actually present, but instead extends to the period after the stressor when the person is thinking about, and recovering from, the episode. Just as past research has focused on factors that affect the magnitude of the cardiovascular response during stress, we hypothesize that it will also prove useful to examine factors that hasten or attenuate post-stress blood pressure and heart rate levels.

There is evidence that psychological manipulations can alter the recovery process. For example, Glynn, Christenfeld, and Gerin (2002) showed that stressors that produced an emotional response were associated with delayed recovery, independent of the blood pressure response evoked during the stressor. They also found that participants who were distracted during a post-stress rest period exhibited faster recovery than those who were not, which suggests that ruminating about the stressful experience may contribute to its psychological and physiological sequelae.

In this study, we hypothesized that listening to music would reduce post-stress blood pressure elevations. There are several reasons that music is a good candidate. First, music has been shown to reduce cardiovascular reactivity. Allen and Blascovich (1994) studied autonomic responses to a laboratory stressor in surgeons who regularly use music in the operating room. Using a within-participants design in the laboratory, surgeons performed a difficult mental arithmetic task while listening to self-selected music, Pachelbel's 'Canon' or silence. Cardiovascular reactivity during the mathematical task was lowest while surgeons listened to the self-selected music they used in their operating rooms and highest during periods of no music.

Music has also been used as an effective audioanalgesic and anxiolytic in applied medical and dental settings. Patients who listened to music in the first and second days following major abdominal surgery reported significantly less pain and distress (Good *et al.*, 1999). Patients experienced less anxiety, pain and discomfort during dental procedures when they listened to music (Anderson, Baron, & Logan, 1991; Goff, Pratt, & Madrigal, 1997). Music has also lowered apical heart rates in coronary patients (Guzzetta, 1989).

Is music in general effective for reducing cardiovascular arousal, or is one style more beneficial than another? There is little agreement in the psychoaesthetic literature on the operational definition of relaxing or sedative music (Hanser, 1985, 1988). Indeed, even 'anti-stress' tapes have been found to be no more effective in reducing stress than an arbitrary collection of popular music (Hatta & Nakamura, 1991). Furthermore, a study by Gerdner (1999) found that persons with Alzheimer's disease experienced less agitation when exposed to an individualized music programme than a 'classical relaxation' music programme. Others caution it may not be so much personal preference as an increased sense of control from the act of selecting music that reduces psychological and physical stress (Anderson *et al.*, 1991). Control over the music heard is generally confounded with getting to hear one's preferred style of music.

The present investigation used music selections from three major and distinct categories—classical, jazz and 'popular' top 40—in order to cover a broad range of music that is commonplace in the participants' (college students) environment. To evaluate the effect of choosing one's music rather than being assigned a particular style, in one condition participants chose which music category to listen to. Given the mixed literature concerning relaxing music, we did not predict that any one style of music would have more of an effect than another. However, given the success of music in reducing reactivity and self-reported pain in a variety of settings, we felt it was an appropriate choice for exploring whether cardiovascular recovery could be facilitated with a psychological manipulation that is presented only after the termination of the actual stressor.

Method

Overview

Participants performed a mental arithmetic task for three minutes while being harassed by the experimenter. The stressor was followed by a ten-minute recovery period, during which participants were assigned randomly to listen to either an assigned music style (classical, jazz or pop music—'no choice' conditions), were allowed to choose one of the three ('choice' condition), or sat in silence (control condition). Participants' blood pressure and heart rate were monitored continuously during baseline, stressor and recovery periods.

Participants

Undergraduates ($N = 75$) at the University of California, San Diego participated in the study (52 females, 23 males, age $M = 20.6$ yrs, $SD = 3.0$ yrs). No participant reported either being in poor health or taking any medication that might affect cardiovascular measurements. Participants received course credit in exchange for participation.

Recording of physiological measures

Systolic and diastolic blood pressures, as well as heart rate, were collected using the Ohmeda Finapres 2300 blood pressure monitor, which takes beat-to-beat pressures in a non-invasive manner, using the Peñaz method. This technique uses a finger cuff, worn on the third finger of the left hand. The Finapres has been demonstrated to be a useful alternative to intra-arterial blood pressure measurement in laboratory testing (Imholtz, Settels, & Meiracker, 1990), as well as in clinical practice (Gorback, Quill, & Lavine, 1991; Wieling, Harkel, & Lieshout, 1991). In addition, it has been shown to track intra-arterial readings extremely well, even during sudden changes of blood pressure (Parati, Casadei, & Groppelli, 1989). The Finapres collects a large number of readings, enhancing reliability (Gerin, Pieper, & Pickering, 1993).

Stressor task

Three minutes of mental arithmetic with harassment was used as the stressor. Participants were instructed to count backward out loud by 13s from 2,397. Thirty seconds into the task, the experimenter informed participants that their counting was too slow and that the task should be started again, but at a faster pace. Thirty seconds after the first interruption, they were informed their performance was still deficient. They were told to start again, but this time counting down by seven, instead of 13, since it would be less challenging. Similar interruptions continued every 30 seconds for three minutes.

Musical selection and presentation

Three different music styles were used for the recovery period: classical, jazz and pop. The classical selections were pieces common to anti-stress tapes: Pachelbel's 'Canon' (Pachelbel, track 3) and Vivaldi's 'The Four Seasons: Spring, Movement I' (Vivaldi, 1725, track 1). The jazz selection included 'Flamenco Sketches' from the album *Kind of Blue* by Miles Davis (Davis, 1959, track 5). The top 40 'popular' music was selected with the aid of a questionnaire distributed to 30 students in an undergraduate psychology course. The questionnaire inquired about the categories of music, artists and particular songs that the participants used to relax. The modal responses, Sarah McLachlan's 'Angel' (McLachlan, 1997, track 7) and Dave Matthews Band's 'Crash Into Me' (Matthews, 1996, track 3) were used.

The music pieces in each category were arranged on high-fidelity cassette tapes, and were played on a stereo cassette recorder at a low-medium volume (approximately 70 dB).

Procedure

Each participant arrived singly for the experiment and was greeted by the experimenter who explained that the participant's blood pressure would be monitored during a mental arithmetic task. After giving informed consent, the participant was seated at a table in an empty room and fitted with the finger cuff of the blood pressure monitor. The experimenter left the room after instructing the participant to sit quietly and not move around during the ten minutes of the baseline period.

After ten minutes, the experimenter re-entered the room. In the music conditions, at this point the experimenter apologized for 'forgetting' to put on music to help pass the time during baseline and offered to put it on after the mathematical task. In the 'choice' condition, participants were then asked to choose either classical, jazz or top 40 music to listen to later. This procedure was implemented so that the music could be started as soon as the stressor-task ended, with no activities to interfere with recovery patterns, and to prevent the participants from developing any suspicions about the post-task music. No participant did voice any such suspicion.

The participant then began the mental arithmetic task. At the end of three minutes, the experimenter asked the participant to sit still during a ten-minute rest period (recovery) and, in the appropriate conditions, turned on the music before leaving the room.

After ten minutes, the experimenter returned, removed the finger cuff, and stopped the music. The participant then filled out several post-session questionnaires (described below). Upon completion of the questionnaires, the participant was debriefed.

Subjective measures

At the end of the recovery period, all participants completed the State/Trait Inventory Form A to assess how anxious they were at that moment (Spielberger, Gorsuch, & Lushene, 1970). Participants also rated, on 7-point Likert-type scales, 'How anxious did the mental math task make you?' (1 = not at all anxious to 7 = very anxious), and 'About how much time did you spend thinking about the mental math task while the music was playing?' or, for the no-music condition, 'in the last 10 minutes' (1 = no time at all to 7 = the whole time). Participants in the music conditions also answered two questions about the music: 'How familiar are you with the selection of music you just listened to?' (1 = never heard it before to 7 = hear it often) and 'How relaxing did you find the selection of music you just listened to?' (1 = not at all relaxing to 7 = very relaxing).

Data reduction and analysis procedures

Three cardiovascular measures were examined: systolic blood pressure, diastolic blood pressure and heart rate. The cardiovascular dependent measures were change scores, computed using the difference between the mean of the recovery period and the mean of the pre-task baseline measurements. These means were computed using the pulse-based technique (Glynn, Christenfeld, & Gerin, 1997). In order to rule out possible reactivity associated with beginning and ending the experiment, the first five minutes of the baseline period and the last five minutes of the recovery period were not used in the analyses.

The systolic blood pressure change scores were the primary physiological measure, as these appear most sensitive to psychological manipulation (Christenfeld, Gerin, & Linden, 1997) and are the most reliable change scores when assessed using the Finapres (Gerin *et al.*, 1998). Diastolic and heart rate change scores were also examined. Raw, rather than residualized, change scores were used (Llabre, Spitzer, & Saab, 1991).

Treatment effects were analysed for each of the three periods by performing a separate one-way ANOVA for each of the cardiovascular measures. An alpha level of.05 was used in the data analysis.

Results

Baseline measures

There were no significant differences between conditions during the initial baseline period for any of the physiological dependent measures, highest $F(4,70) = 1.88$ for diastolic blood pressure, all $ps > .20$.

Stress manipulation check

The mathematical task was effective as a stressor for all conditions (see Fig. 1). Systolic blood pressure rose an average of 19.5 mmHg during the three-minute mathematical task. Diastolic blood pressure rose an average of 13.4 mmHg, and heart rate an average of 10.4 bpm. There was no significant difference between conditions in the cardiovascular change scores from the baseline period to the mathematical task for any of the physiological measures, highest $F(4,70) = 0.55$ for heart rate, all $ps > .70$.

Music preferences of choice condition

Of the 15 participants in the choice condition, four chose to listen to the classical music selections, five chose to listen to jazz, and six chose the top 40 music selections.

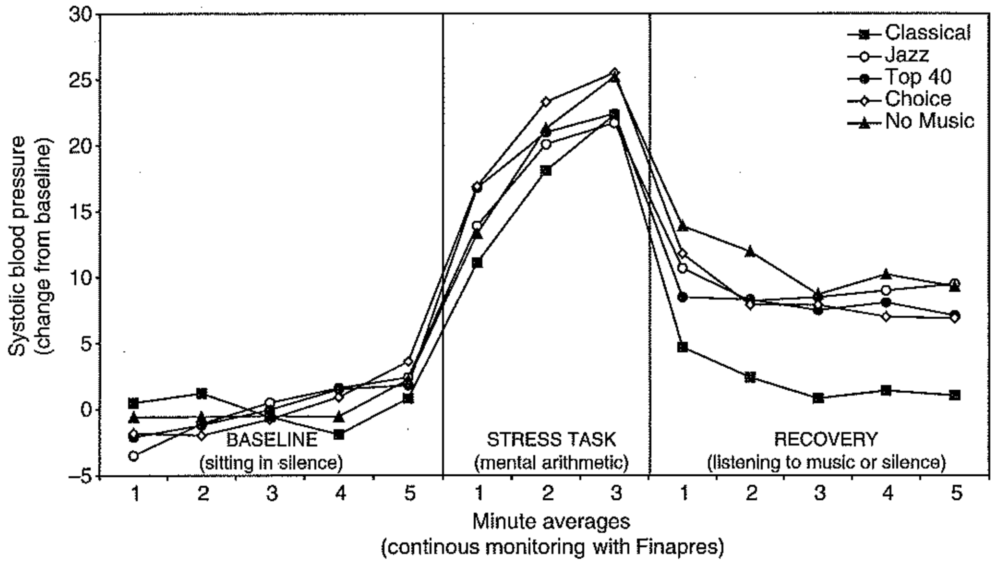

Figure 1. The effect of listening to music after a laboratory stressor on systolic blood pressure (change from baseline).

Effect of experimental conditions on blood pressure and heart rate recovery

For systolic blood pressure, there was a significant effect of music condition on recovery, $F(4,70) = 2.69$, $p < .04$. A *post hoc* Tukey HSD showed a significant difference between the classical and control conditions, ($p < .03$), with classical music returning systolic blood pressure closer to baseline ($M = 2.1$ mmHg) than the control condition ($M = 10.8$ mmHg). Figure 1 displays the systolic blood pressure change scores for all conditions. Diastolic blood pressure followed the same pattern as systolic blood pressure during the recovery period, although it was not significant between conditions, $F(4,70) = 1.85$, $p > .13$. This diastolic pattern is displayed in Fig. 2. Heart rate was not significantly different between conditions, $F(4,70) = 0.32, p > .86$.

While systolic blood pressure differences provide the only statistically significant result, it is worth noting that the control (silence) condition had higher cardiovascular responses during the recovery period than all other conditions on all three physiological measures. (See Table 1 for the average physiological change scores in each condition).

There was little impact of gender on the cardiovascular data. There was a significant difference in resting levels of systolic blood pressure between male and female participants, $F(1,73) = 5.78$, $p < .02$, with men having resting levels of 128.0 and women 119.6 mmHg. The trend was in the same direction for diastolic blood pressure (77.0 vs. 72.5), though the difference did not reach significance ($p > .06$). For heart rate, there was no sign of a gender effect (77.0 vs. 78.5, $p > .53$). During the mathematical stressor task, there were no gender differences in reactivity (all $ps > .15$), and there were also no differences in recovery scores (all $ps > .52$). Furthermore, when gender was added as a factor in the analyses of recovery, the main effect of music on systolic blood pressure remained significant, $F(4,65), 2.59, p < .05$. No effect, either main or interaction, of gender emerged (all $ps > .52$). The specific comparison of the classical music and silence conditions also remained significant, with gender included as a factor in the analyses, $F(1,26) = 18.66, p < .001$.

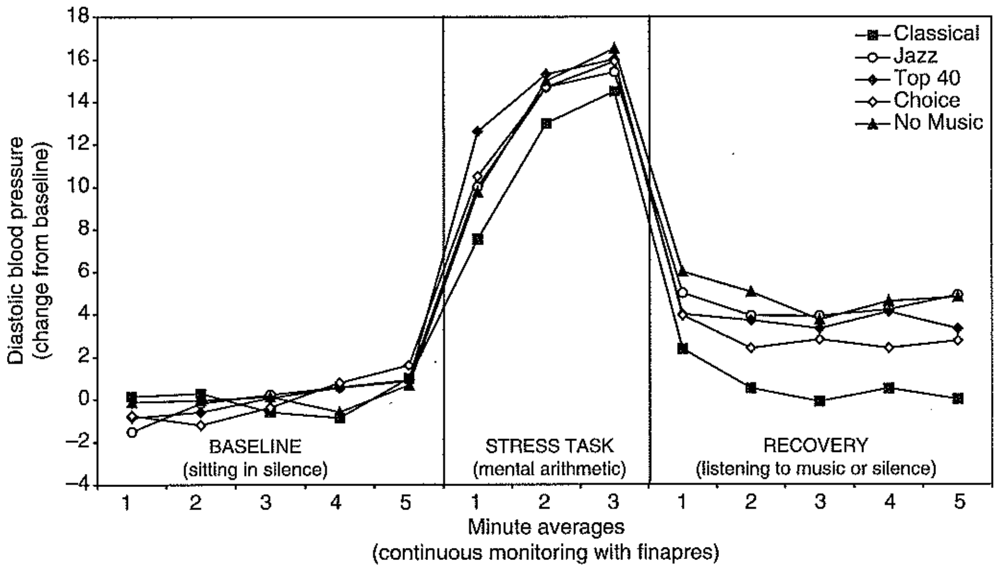

Figure 2. The effect of listening to music after a laboratory stressor on diastolic blood pressure (change from baseline).

Table 1. Mean recovery period cardiovascular change from baseline scores for each condition

Condition	Systolic Bp	Diastolic Bp	Heart rate
Classical ($n = 15$)	2.09 (4.65)	0.66 (3.67)	−3.03 (3.08)
Jazz ($n = 15$)	9.19 (11.50)	4.37 (6.14)	−2.31 (4.83)
Top 40 ($n = 15$)	7.88 (7.52)	3.66 (4.24)	−3.07 (5.82)
Choice ($n = 15$)	8.31 (7.38)	2.85 (3.49)	−2.61 (2.72)
Control ($n = 15$)	10.83 (6.36)	4.81 (5.26)	−1.64 (2.67)

Self-report

Mathematical stress

There were no significant differences between conditions in how stressful participants found the mathematical task, $F(4, 70) = 1.01, p > .41$. The average response was 5.0 on a 7-point Likert-type scale in which 7 = most stressful.

Familiarity

There was a significant difference in how familiar participants found the selections of music, $F(3, 56) = 6.51, p < .001$. A *post hoc* Tukey HSD revealed that the jazz selection was significantly less familiar, ($p < .05$), than the classical and top 40 selections.

Relaxation

There was not a significant difference between the music conditions in how relaxing participants found the music, $F(3, 56) = 1.20, p > .32$. The average response was 5.1 on a 7-point Likert-type scale in which 7 = most relaxing.

Rumination

There was not a significant difference in how much participants reported thinking during the recovery period about the mathematical task they had performed, $F(4, 70) = 0.893, p > .47$. The average response was 5.8, where 7 indicated that they were thinking about the mathematical task the whole time.

State/Trait Inventory Form A

There was not a significant difference in the scores on the State/Trait Inventory between conditions, $F(4, 70) = 0.07$, $p > .99$. However, there was a significant correlation between the State/Trait Inventory scores and systolic blood pressure recovery scores ($r = -0.25$, $p < .05$), indicating a moderate relationship between a self-reported anxious state and delayed cardiovascular recovery.

Discussion

The results suggest that methods for limiting cardiovascular responses to stress do not need to occur in the presence of the stressor. The total amount of time that the cardiovascular system is elevated can be reduced with a psychological manipulation such as music listening during post-stress recovery. However, not all music is appropriate after stress. The data indicate that listening to the classical music selections after the stressor was more beneficial for reducing arousal than sitting in silence after the stressor, but this effect was not found with other music selections.

Of course, these findings should be qualified with respect to certain limitations imposed by the research methodology of the present investigation, including the particular music selections presented as well as the mode of presentation. The main limitation concerns whether the effects of Pachelbel's 'Canon' and Vivaldi's 'The Four Seasons: Spring' can be generalized to all of classical music. Perhaps the reported benefits are particular to the sound mechanics of the chosen pieces. Unfortunately, investigating such psychoaesthetic details was not within the scope of this investigation; the somewhat subjective nature of the music selection in this project does not allow us to get at the more theoretical aspects of music therapy.

The benefits of classical music on cardiovascular recovery could be due to some fairly direct power which music hath 'to soothe the savage breast' (Congreve, 1697/1967, Act I, Scheme i). The benefits of music could also rely on a mechanism, for example, like classical conditioning, with certain types of music associated with calm and relaxation. It is also possible that the music did not reduce arousal in a direct sense, but was distracting and prevented rumination about the stressor (Glynn *et al.*, 2002). However, if distraction is the mechanism behind arousal reduction, it is interesting to note that not all music was effective in reducing arousal, suggesting that either not all music is distracting or that not all distraction leads to arousal reduction. It is also worth noting that subjective reports of how much participants were distracted from thinking about the mathematical task were not sensitive to the type of music listened to. Although we do not know at this point just what it is that is important about these classical pieces, we can conclude that something is.

Some of the findings of this project ran counter to previous research. Several studies in the music therapy literature resulted in measurable changes in self-reported relaxation due to music listening but did not show corresponding physiological changes

(Hanser, Martin, & Bradstreet, 1982; cited in Hanser, 1988). This investigation found an opposite pattern: no differences in self-reported relaxation between music condition, but significant differences in physiological responses. This difference should be qualified by the fact that self-report data are notoriously unreliable.

In addition, the lack of a general effect of music runs counter to research by Hatta and Nakamura (1991), who found no differences in stress reduction among different styles of music. Nor would the literature predict the absence of a significant therapeutic effect for the choice condition. Since participants had more control over their music category, their increased perception of control could have reduced the magnitude of their stress response (Anderson *et al.*, 1991). It may be that having participants choose between three experimenter-selected music styles was not as effective in producing the perception of control as having participants bring in their own selections of music. It could also be that the stress task altered the participants' mood, so that the choice of music made before the stress task may not have been the choice of music they would have made after the stress task. Konecni (1982), for example, has shown that 'people actively seek different types of music at different times in order to optimize their mood' (p. 513).

We consider the particular empirical findings of this project as somewhat secondary to their general value as an indication that cardiovascular responses to stress can be altered, and reduced, even if the stressor is no longer present. The data suggest, consistent with earlier work on psychological interventions during recovery (Glynn *et al.*, 2002), that these effects are most apparent in blood pressure, especially systolic responses, and are not detectable for heart rate recovery following stress. Despite the limitations of this investigation, our conclusions are important within the framework of the expanded cardiovascular reactivity hypothesis, as well as having potential applied significance. People often seek music for psychological benefits and our data suggest that faster cardiovascular recovery from a stressor could be among those benefits. Perhaps music can bring both pleasure and health.

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