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Music and Auditory Distraction Reduce Pain
Emotional or Attentional Effects?

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Abstract

This study investigated the impact of pleasant and unpleasant classical music on experimental pain, compared to silence and to an auditory attention task. Pain measurements were assessed with the nociceptive flexion reflex (NFR), pain ratings, and the cold pressor test on 20 healthy nonmusician participants in a within-participant design. Results indicated that, in comparison to silence and to the unpleasant music, pleasant music increased pain tolerance to the cold pressor test, and decreased pain ratings associated with the NFR but did not reduce the NFR itself. Furthermore, the auditory attention task had pain-reducing effects comparable with those of pleasant music. The findings are discussed with respect to possible underlying mechanisms involving emotions and distraction elicited by music and auditory stimulations.

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Abstract

This study investigated the impact of pleasant and unpleasant classical music on experimental pain, compared to silence and to an auditory attention task. Pain measurements were assessed with the nociceptive flexion reflex (NFR), pain ratings, and the cold pressor test on 20 healthy non-musician participants in a within-subjects design. Results indicated that, in comparison to silence and to the unpleasant music, pleasant music increased pain tolerance to the cold pressor test and decreased pain ratings associated with the NFR but did not reduce the NFR itself. Furthermore, the auditory attention task had pain reducing effects comparable with those of pleasant music. The findings are discussed with respect to possible underlying mechanisms involving emotions and distraction elicited by music and auditory stimulations.

Descriptors : music, pain, emotion, attention, distraction

1. Introduction

Since Antiquity, music is used as an accompaniment of medical treatments to alleviate pain and facilitate recovery[1]. In the last 40 years, a number of controlled clinical studies supported this idea showing that music has pain reducing effects[2,3,4,5] . Beside some evidence for physiological effects of music (e.g., reducted level of stress hormones[6]), the psychological mechanisms underlying these pain reducing effects are still unclear. On the one hand, music can be considered as a cognitive distraction orienting the attention away from the painful stimulus[7]. On the other hand, music has also a strong effect on affective states, especially emotions[8,9], which have been shown to have a significant influence on pain experience[10,11]. Therefore, it could be that music effects on pain are mediated by the emotional valence of music as supported by a recent study[12]. In that case, however, still remains the question whether music has a stronger pain reducing effect through the induction of emotions than a distraction task.

Pain can be defined as “an unpleasant sensory and emotional experience associated with actual or potential tissue damage, or described in terms of such damage”[13]. This definition underlines the complex processes of pain experience involving physiological and psychological factors. Among the psychological variables implicated in the process of pain experience, emotions and attention have already been the center of interest in a number of studies[14]. In these studies, positive emotions are generally found to reduce pain whereas negative emotions tend to enhance pain[15,16,17]. Similarly, the orientation of attention away from the painful stimuli—i.e., distraction—is found to reduce pain[18,19]. However, most of these experiments used pictures[15], films[17], or odors varying in emotional valence[16] but not music. Moreover, many previous studies investigating the pain reducing effect of music[20,21,22,23] only compared musical conditions with silence, which does not allow making some inference about the possible effects of emotions and attention.

The only exception is the recent study of Roy and colleagues[12], showing that pleasant music induced positive emotions and reduced pain experience compared to silence and to unpleasant music, but that unpleasant music inducing negative emotions did not enhance pain experience. In conclusion, their findings offer support for the hypothesis of an effect of the valence of music although only the analgesic effect of pleasant music was confirmed.

To evaluate the contribution of distraction and emotions—positive and negative—on pain experience during musical and non-musical auditory stimuli, the present study investigated the impact of pleasant and unpleasant music on pain assessed with the nociceptive flexion reflex (NFR) and the cold pressor test, compared to silence and to an auditory attention task. We predicted: (1) lower pain when participants listened to the pleasant music compared to silence and to the unpleasant music; (2) higher pain when participants listened to the unpleasant music compared to silence; (3) lower pain when participants listened to the auditory attention task compared to silence but (4) lower pain when participants listened to the pleasant music compared to the auditory attention task. Taken together, these predictions describe a linear increase of pain through the following conditions: pleasant music, auditory attention task, silence, and unpleasant music.

2. Methods

2.1. Participants

Twenty healthy, right-handed and non-musician University students (12 women, 8 men, average age 24 years) were recruited by announcement and received 100 Swiss francs (about US $ 90) for their participation in the study. All procedures in the study protocol were fully approved by the Geneva University Hospital ethics review board.

2.2. Auditory Stimuli

Auditory stimuli were recorded on separate digital compact discs and played with a CD player (SONY CD Player D-111) at a comfortable volume using personal headphones. In the condition of silence, participants also used headphones but without anything being played.

Pleasant music. Participants could choose between three pieces of western classical music that have been already used and validated in previous studies to induce positive emotions in young adults: Bach, *Brandenburg Concertos n°2 and 3, 1st and 3rd movements*[24]; Mozart, *Eine Kleine Nachtmusik, Allegro and Rondo*[25,26]; or Bizet, *Symphony in ut major, 4th*

movement[27]. After listening about 30 seconds to one musical piece of each composer, participants had to select the one which made them feel most joyful. During the experiment, the individually selected musical pieces were played continuously for about 40 minutes.

Unpleasant music. In this condition, we used dissonant excerpts of contemporary music. Twenty seconds samples were extracted from the following musical pieces and looped to last about 40 minutes each: Penderecky, *Symphony n°1, Dynamis II* ; Gyorgy Ligeti, *Concerto for Cello and Orchestra*; Pierre Boulez, *Notations II* for Orchestra. In this way, we had very dissonant short musical excerpts repeated continuously to induce strong negative emotions. Participants had first to choose after listening to the three samples, the one they found to be the most unpleasant. The selected excerpt was then used during the experiment.

Auditory attention task. Based on previous studies on distraction[28], we used an adaptation of an auditory attention task created and recorded with a music production software (Logic Express, Emagic, Apple, Cupertino, CA). Participants listened to single sinusoidal sounds played every two seconds. In 90% of the trials, sounds of 1000Hz were played and in the other trials either sounds of 1050Hz (higher) or 950Hz (lower). Furthermore each sound could be either long (500ms) or short (200ms). Sequence of sounds was randomized, recorded, and was the same for all participants. Participants had to detect when the sound was different from 1000Hz and to say aloud if the sound was higher or lower and long or short. Performance was recorded through a microphone and compared with a list of the sounds recorded.

2.3. Pain Measurements

Nociceptive flexion reflex (NFR). Participants rested comfortably in an armchair to obtain muscular relaxation. A pair of surface electrodes was attached to the left ankle over the retromalleolar pathway of the sural nerve and delivered electrical stimuli consisting of single rectangular impulses (0.5 ms) with an interval of 6-10 seconds between stimulations, by a constant current stimulator at variable intensities (1-100 mA) (Nicolet Vicking IV; Nicolet, Madison, WI). Electromyographic responses were recorded using a pair of surface electrodes placed over the tendon of the ipsilateral biceps femoris. Prior to the application of electrodes, the designated sites on the skin surface had been cleaned with alcohol. The NFR was identified as a multiphasic signal appearing at least 90 ms but less than 250 ms after each stimulation and was considered to be elicited when the corrected computed surface was > 0.5 mV/ms (indicating a positive response of the reflex). The current necessary to reliably elicit the reflex (objective threshold) was assessed following procedures adapted from previous research by Willer[29].

After each electrical stimulation, participants were asked to describe what they felt using three scales: (1) pain was measured with a numerical rating scale (NRS) from 0 (no pain at all) to 10 (worst pain imaginable) with 4.5 as the pain threshold; (2) the sensory aspect of pain was measured with a scale including 7 categories (*Nothing, Hardly perceptible, Tactile sensation, Light pricking, Moderate pricking, Strong pricking or burning sensation, Very strong pricking or burning sensation*), with the 4th category (*Light pricking*) as the sensory pain threshold; and (3) the affective aspect of pain was measured with a scale including 7 categories (*Nothing, Not unpleasant, A bit unpleasant, Rather unpleasant, Clearly unpleasant, Extremely unpleasant, Unbearable*), with the 4th category (*Unpleasant enough*) as the affective pain threshold. NFR, NRS, sensory, and affective pain thresholds were then defined as the intensity of current inducing 50% of positive responses to a series of 30-40 stimulations and were obtained by fitting the percentage of positive response to Hill's equation using the Marquardt algorithm[30].

Cold pressor test. The cold pressor test is based on hand immersion in an iced water bath. The device consisted of a container divided by a mesh screen: one side was filled with ice that maintains the water on the other side at 0°C. A stirring device circulated the water, and the temperature of the water near the hand was monitored by a thermosistor with a digital display (± 0,1°C). The mesh screen prevented direct contact between the ice and the skin of the participant. Participants were instructed to keep their hand in the water until the sensation was "the maximum bearable" (the cutoff time was 2 minutes, to avoid any tissue lesion). The results of pain tolerance were expressed as the latency period of withdrawal, and pain intensity at this time was controlled with a numeric range scale from 0 to 10 (responses around 8 were expected).

2.4. Measurement of Emotions

To examine whether emotions were successfully elicited and whether the auditory task elicited the required level of attention, self-report measures adapted from the Differential Emotion Scale (DES)[31,32] were collected after each condition. Eight items were used consisting of groups of three emotional adjectives as in the DES: (1) *Amused, joyful, merry*; (2) *Sad, downhearted, blue*; (3) *Angry, irritated, mad*; (4) *Fearful, scared, afraid*; (5) *Anxious, tense, nervous*; (6) *Disgusted, turned off, repulsed*; (7) *Surprised, amazed, astonished*; (8) *Warmhearted, gleeful, elated*. In addition, two items were used to assess the attention level on auditory stimuli and on pain (9) *Concentrated on music* or *Concentrated on silence* or *Concentrated on the auditory task* (depending on the condition); and (10) *Concentrated on pain*. Participants rated on 7– point scales (1= “not at all” to 7 = “very intense”) the extent to which they felt the emotional state during the pain measurements. For the sake of brevity, emotional items are henceforth presented with their factor name: *joy*, *sadness*, *anger*, *fear*, *anxiety*, *disgust*, *surprise*, and *happiness*. Items (9) and (10) will keep the same denomination.

2.5. Procedure

A first meeting with the potential participants was arranged to present the study, receive informed consent, carry out a physical examination, let the participants choose the most joyful and the most unpleasant musical pieces, and finally to test if the nociceptive flexion reflex was elicited with tolerable stimulus intensity. The testing session always took place in the morning and in the same quiet room. First participants were asked to evaluate their current emotional state with the adapted DES. Then they were presented with the four conditions in one of the four random orders based on a latin square (ABCD, BDAC, CADB, DCBA) starting with two minutes of music, auditory task or silence depending on the condition to elicit the affective states followed by the NFR assessment and finally the cold pressor test. During all pain measurements, auditory stimuli were played continuously. At the end of each condition, participants evaluated their emotional state with the adapted DES and had a break of 15 minutes. The whole experimental session lasted about 4 hours.

3. Results

Preliminary analyses revealed that gender had no significant main or interaction effects with pain and emotion measurements (ps > .16) and was therefore not considered in the subsequent analyses. As the dependent variables were substantially intercorrelated, we used Greenhouse-Geisser corrections for repeated measures where appropriate (indicated by decimal degrees of freedom values). Follow-up tests for *a priori* hypotheses of nociceptive outcome were one-tailed t-tests.

3.1. Music Selection

Eine Kleine Nachtmusik from Mozart had been selected by 7 women and 5 men, the *Brandenburg Concertos* from Bach by 4 men and 2 women, and finally the *Symphony in C major* from Bizet had been selected by one man and one woman. Preliminary ANOVAs indicated that there was no significant difference in the elicited emotions between the three pieces of music (Fs < 1.45, ps > .25). Concerning music inducing negative emotions, sample from G. Ligeti had been selected by 4 women and 6 men, sample from Penderecky by 2 women and 4 men, and finally sample from Boulez by 2 women and 2 men. Preliminary ANOVAs indicated that there was no significant difference in the elicited emotions between the three unpleasant music excerpts (Fs < 2.73, ps > .09).

3.2. Pain Measurements

A repeated measures MANOVA with the 4 experimental conditions as the repeated factor and the pain measurements as the dependent variables revealed a significant main effect of the experimental conditions, $F(15,156) = 3.12$, $p < .001$. Univariate analyses indicated a significant main effect of the experimental conditions on the NRS threshold, $F(2.03,36.53) = 6.38$, $p < .004$, the sensory threshold, $F(2.57,46.33) = 7.40$, $p < .001$, the affective threshold, $F(1.74,31.29) = 3.82$, $p < .02$, and pain tolerance to the cold pressor test, $F(1.86,33.43) = 4.05$, $p < .02$, but did not reveal a significant effect on the NFR threshold, $F(2.29,41.28) = 1.46$, $p > .20$. Means are presented in Figure 1. Polynomial trend analysis revealed linear increases for all pain measurements (*F*s > 11.79, *p*s < .004) and also a cubic trend for the sensory threshold, $F(1,18) = 13.93$, $p < .002$.

<Insert Figure1 here>

Follow-up tests indicated that compared to silence, pleasant music increased the NRS threshold (*M*s = 37.38 vs. 30.09), $t(19) = 2.94$, $p < .005$, the sensory threshold (*M*s = 23.92 vs. 20.18), $t(19) = 3.35$, $p < .002$, the affective threshold (*M*s = 34.91 vs. 29.18), $t(19) = 2.26$, $p < .02$, and the pain tolerance to the cold pressor test (*M*s = 27.05 vs. 22.58), $t(19) = 2.38$, $p < .02$. Unpleasant musical stimulations did not influence any pain measurement compared to silence (*t*s < 1.57, *p*s > .65). Compared to silence, the auditory attention task increased the NRS threshold (*M*s = 34.72 vs. 30.09), $t(19) = 2.91$, $p < .005$, the sensory threshold (*M*s = 24.45 vs. 20.18), $t(19) = 4.80$, $p < .001$, the affective threshold (*M*s = 31.86 vs. 29.18), $t(19) = 1.95$, $p < .04$, and the pain tolerance to the cold pressor test (*M*s = 27.75 vs. 22.58), $t(19) = 1.77$, $p < .05$. Finally, there was no difference between music and the auditory attention task on any pain measurement (*t*s < 1.27, *p*s > .10).

3.3. Measurements of Emotions

A repeated measures MANOVA with the 4 experimental conditions as the repeated factor and the emotion measurements as the dependent variables also revealed a significant main effect of the experimental conditions, $F(30,133) = 3.71$, $p < .001$. Furthermore, univariate analyses indicated a significant main effect of the experimental conditions on the following items: *joy*, *anger*, *anxiety*, *disgust*, *happiness*, *concentrated on stimuli or silence*, and *concentrated on pain* (*F*s > 3.15, *p*s < .04). No difference was found for the items *sadness*, *fear*, and *surprise* (*F*s < 2.48, *p*s > .07). Means and standard errors of the emotion and attention items are presented in Figure 2.

<Insert Figure2 here>

Follow-up tests indicated that compared to the other experimental conditions, participants listening to pleasant music reported higher scores for the items *joy* (*t*s > 4.21, *p*s < .001) and *happiness* (*t*s > 3.60, *p*s < .001)—i.e. positive emotions. Compared to silence and to pleasant music, participants listening to unpleasant music reported higher scores for the items *anger* (*t*s > 1.94, *p*s < .04), *anxiety* (*t*s > 3.37, *p*s < .002), and *disgust* (*t*s > 1.75, *p*s < .05)—i.e. negative emotions. Furthermore, there was no difference on emotional measurement between silence and the auditory attention task, excepted for the item *anxiety* which was higher after the auditory task (*M* = 3.05, *SE* = .34) than after the silent condition (*M* = 2.00, *SE* = .24), *t*(19) = 2.71, *p* < .01.

Concerning the measurements of attention, participants reported to be more concentrated on pleasant (*M* = 5.65, *SE* = .27) and unpleasant music (*M* = 5.05, *SE* = .31), and on the auditory attention task (*M* = 6.10, *SE* = .21) compared to silence (*M* = 4.25, *SE* = .36), *t*s > 2.22, *p*s < .02. No difference was found between pleasant and unpleasant music, *t*(19) = 1.52, *p* > .08, but participants reported to be more concentrated on the auditory attention task compared to pleasant music, *t*(19) = 1.83, *p* < .05. Moreover, participants listening to pleasant music reported to be less concentrated on pain (*M* = 3.55, *SE* = .37) compared to silence (*M* = 4.80, *SE* = .32) and to the auditory attention task (*M* = 4.25, *SE* = .32), *t*s > 3.90, *p*s < .001. No difference was found with respect to concentration on pain between pleasant and unpleasant music, *t*(19) = 1.13, *p* > .13.

3.4. Performance during the attention task

Participant's percentage of correct responses during the attention task ranged from 59.82% to 97.96% with a grand mean of 86.55% (*SE* = 9.95). Moreover, task performance was not associated with any pain measurements during the attention task or emotions measurements after the task (*r*s < .35, *p*s > .15), with the exceptions of the DES items *angry*, *r*(20) = - .75, *p* < .001, and *fear*, *r*(20) = - .47, *p* < .04.

4. Discussion

The present study was designed to test the pain reducing effects of pleasant music compared to silence, unpleasant music, and to an auditory attention task. Results partially confirmed our hypotheses. Compared to the silence and the unpleasant music, pleasant music had a significant effect on the pain ratings and pain tolerance to the cold pressor test but not on the NFR. This finding suggests that the auditory stimuli used in this study, and more particularly pleasant music, did not produce any central descendent analgesic effect on spinal nociception, which would have resulted in lower NFR. In contrast, music had a significant effect on the numerical rating scale, the sensory and the affective thresholds and on the pain tolerance to the cold pressor test compared to silence and to the unpleasant musical stimulations and these results are consistent with previous studies showing pain reducing effect of music on reported pain experience[20,21,23]. However, the NFR findings contrast with other studies showing effects of emotions on the NFR. For example, a study of Rhudy and colleagues[33] found a spinal nociceptive effect of pleasant and unpleasant pictures. It could be that pictures had a stronger effect than musical stimuli, because of the type of emotions induced by the pictures. However, a second explanation refers to the procedure employed to assess the NFR. In our study, we assessed and calculated the NFR threshold for each experimental condition, and we compared then these thresholds. Rhudy et al. used a different paradigm by assessing the NFR at rest and comparing then the magnitude of the EMG at rest with the magnitude obtained after the presentation of the pleasant and unpleasant pictures. This later method could represent a more sensitive assessment of the NFR that would explain the contrasting results obtained in our study.

Moreover, participants reported less pain during the attention task than during the silent condition. This finding is in accordance with studies showing that focusing participant's attention away from painful stimulation significantly reduces perceived pain[18,19]. But contrary to our hypothesis, we did not find any difference on pain measurement between pleasant music and the auditory attention task. Moreover, the unpleasant music did not enhance pain experience, which is contrary to our hypothesis but consistent with the findings of Roy and colleagues[12] and other studies having observed little or no augmentation of pain during the presentation of unpleasant emotional stimuli[15,17] suggesting an asymmetry in the effects of positive and negative emotions on pain.

Consequently, in the case of music, it seems that emotions played an important role in the pain reducing effect because this effect occurred in the pleasant music condition and not during the unpleasant music condition, suggesting that distraction elicited by music was not the only cause for that effect. In the case of the auditory attention task, however, the pain reducing effect can only be attributed to cognitive distraction. These results could be interpreted in the light of the fact that different types of attention are implicated when listening to music and performing an auditory task. Indeed the auditory task could have required a selective attention whereas listening to music involved a diffuse attention or arousal[34]. The study by Peyron and colleagues[18] indicated that these two types of attention can be distinguished on the basis of the neural structure and, more important, that they have different interactions with pain sensation. Consequently, we can suggest that music involved a diffuse attention, which contributed to reduce pain experience in interaction with positive emotions, while the auditory attention task required a selective attention, which had a strong pain reducing effect by itself.

Emotion measurements indicated that the induction of affective states was in accordance with our predictions. As expected, participants reported more positive emotions and less negative emotions after listening to the pleasant music than to the unpleasant music, the auditory attention task or the silence. More specifically, music inducing positive emotions elicited mainly joy and happiness, whereas unpleasant musical stimulations elicited anxiety, anger, and disgust. Although the auditory attention task was used as a neutral condition regarding to the emotional reactions, it induced the same level of anxiety than the unpleasant musical stimulations. The evaluation of the level of concentration on auditory stimuli did not differ between pleasant and unpleasant music but was higher than in the silent condition indicating that music elicited some distraction. However, participants reported to be more concentrated on the auditory attention task compared to the music conditions. This result is in accordance with the idea that music involved a diffuse attention whereas the attention task involved a selective attention which necessitates more attentional resource than diffuse attention.

Regarding the beneficial influence of music on pain in a clinical context, it is important to note that music selection plays a crucial role. The present experiment demonstrated that pleasant classical music inducing positive emotions reduced pain in healthy young volunteers. But for instance, a recent study of Punkanen, Eerola, and Erkkilä[35] indicated that depressed people tend to dislike highly arousing music, which should therefore also not be effective for pain relief in this case. In general, individual and cultural differences should be considered in music selection to optimize the pain reducing effect of music. In this context, however, the present study suggests that music inducing positive emotions reduces pain whereas music inducing negative emotions does not.

In conclusion, evidence indicates that both music and the auditory attention task have a pain-reducing effect on pain ratings and pain tolerance but not on the NFR. These results suggest that both positive emotions induced by the pleasant music and attention—especially selective attention—elicited by the attention task had a beneficial effect on pain ratings and pain tolerance.

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Figure Captions

Figure 1. Cell means and standard errors of nociceptive flexion reflex (NFR), numerical ratings scale (NRS), sensory, and affective pain thresholds during the experimental conditions (Panel A). Cell means and standard errors of the pain tolerance to the cold pressor test during the experimental conditions (Panel B).

Figure 2. Cell means and standard errors of the emotions elicited during the experimental conditions (Panel A). Cell means and standard errors of the reported concentration on stimuli and silence, and the concentration on pain during the experimental conditions (Panel B).

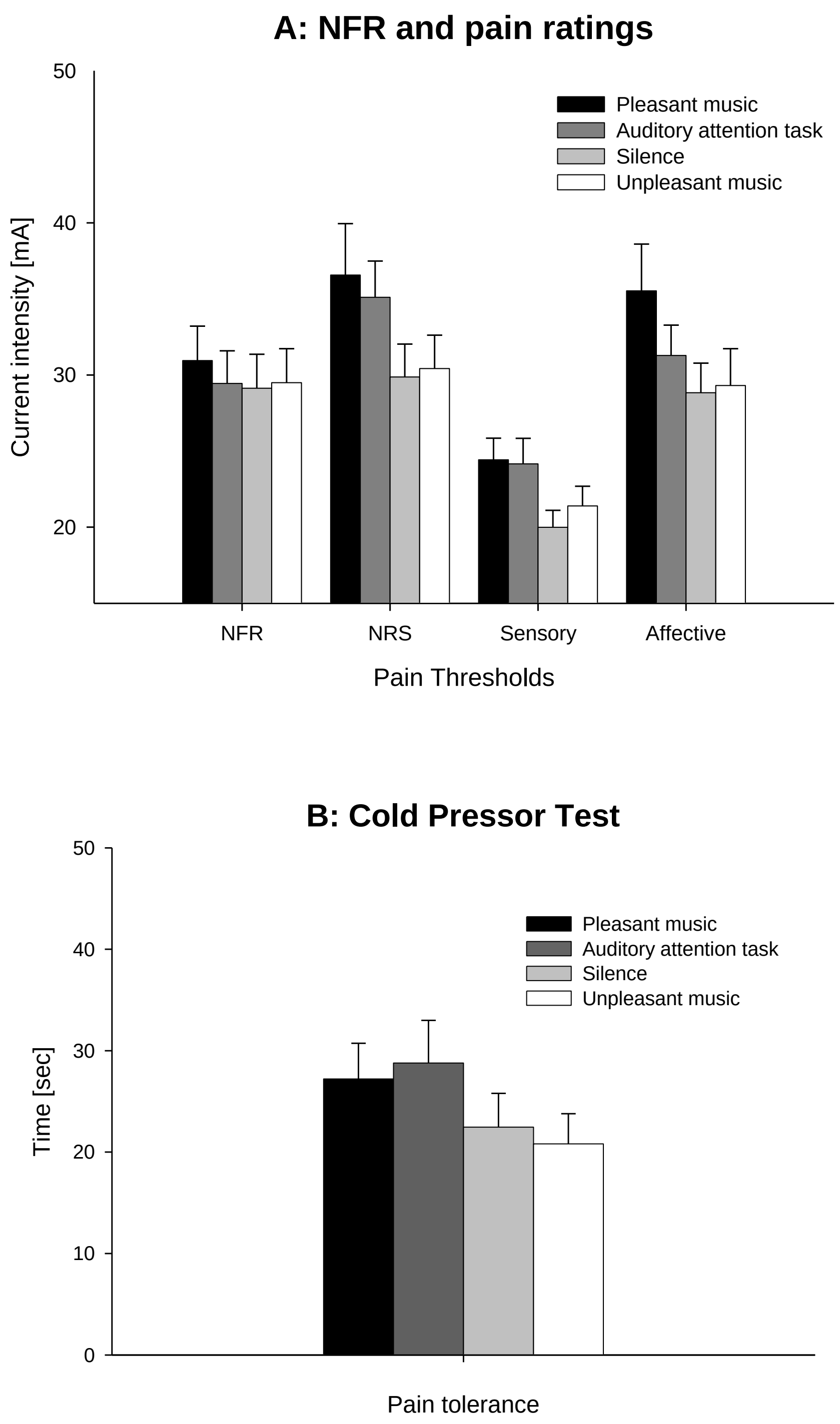
A: NFR and pain ratings
50
40
30
20
Current intensity [mA]
Pleasant music
Auditory attention task
Silence
Unpleasant music
NFR
NRS
Sensory
Affective
Pain Thresholds
B: Cold Pressor Test
50
40
30
20
10
0
Time [sec]
Pleasant music
Auditory attention task
Silence
Unpleasant music
Pain tolerance

Figure 1

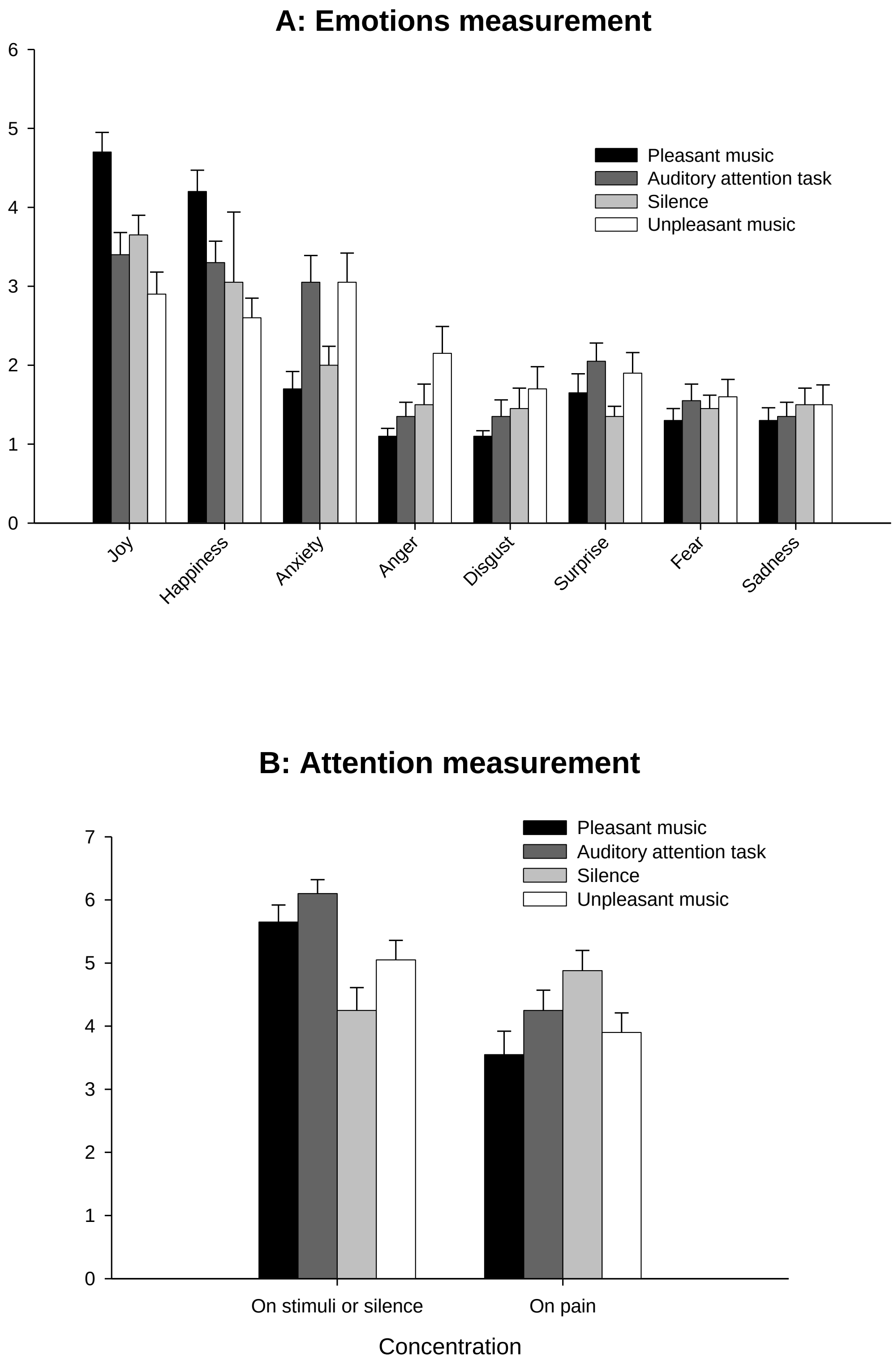
A: Emotions measurement
6
5
4
3
2
1
0
Pleasant music
Auditory attention task
Silence
Unpleasant music
Joy
Happiness
Anxiety
Anger
Disgust
Surprise
Fear
Sadness
B: Attention measurement
7
6
5
4
3
2
1
0
Pleasant music
Auditory attention task
Silence
Unpleasant music
On stimuli or silence
On pain
Concentration

Figure 2