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Original Article

Performance of Music Elevates Pain Threshold and Positive Affect: Implications for the Evolutionary Function of Music

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Abstract: It is well known that music arouses emotional responses. In addition, it has long been thought to play an important role in creating a sense of community, especially in small scale societies. One mechanism by which it might do this is through the endorphin system, and there is evidence to support this claim. Using pain threshold as an assay for CNS endorphin release, we ask whether it is the auditory perception of music that triggers this effect or the active performance of music. We show that singing, dancing and drumming all trigger endorphin release (indexed by an increase in post-activity pain tolerance) in contexts where merely listening to music and low energy musical activities do not. We also confirm that music performance results in elevated positive (but not negative) affect. We conclude that it is the active performance of music that generates the endorphin high, not the music itself. We discuss the implications of this in the context of community bonding mechanisms that commonly involve dance and music-making.

Keywords: dancing, singing, music, endorphins, affect

Introduction

After decades on the sidelines, music has once more become a focus of interest to the evolutionary and neuro-sciences. Most of this interest has been focussed either on physiological responses to music (Krumhansl, 1997; Peretz and Coltheart, 2003; VanderArk and Ely, 1992, 1993; Wallin, 1991; Sevdalis and Keller, 2011) or on the role of synchrony (Janata and Grafton, 2003; Kirschner and Tomasello, 2009; Miles et al., 2009).

However, music also has other important functional properties, having long been recognised as playing an important role in community bonding (Durkheim, 1915/1965; Turner, 1966; Ehrenreich, 2006; Freeman, 2001; Huron, 2001). The suggestion that music-making evolved to promote group or community bonding by increasing cooperation and reducing tension (thereby conveying a fitness advantage to the individuals involved by facilitating more effective coordination of community action) was explicitly proposed by Roederer (1984), but has been advocated in more general terms by Dunbar (2004a,b, 2008). In traditional societies, this use of music-making in community bonding is invariably characterised by active musical performance (singing, dancing, clapping, and performance on instruments) and not by the kinds of passive listening associated with modern day concert halls.

A number of authors have suggested that the sense of elation that comes from engaging in music arises from the way music (or active performance in musical contexts) triggers the release of endorphins (Chiu and Kumar, 2003; Dunbar, 2008, 2009; McKinney et al., 1996) (though plausible claims have been made, at least in respect of dance creativity, on behalf of other neuroendocrines: Bachner-Melman et al., 2005). Goldstein (1980) viewed β-endorphins as mediators between music and the experience of thrills when listening to music, mainly on the grounds that the thrill of listening to music was significantly reduced by naloxone (an opioid antagonist) in some—but by no means all—of his subjects. Although there have been some claims to the contrary (notably studies reporting that endorphin levels after listening to anxiolytic music were, if anything, reduced in both surgical patients and women during labour: Satoh et al., 1983; Spingte and Droh, 1987), most recent studies broadly support Goldstein's claim. Gerra et al. (1998), for example, reported that techno-music, a type of fast electronic dance music, significantly increased β-endorphin levels, while Steptoe and Cox (1988) observed that fast music could have an effect on exercise, improving endurance in participants along with performance perception and β-endorphins titres. Indirect support for endorphins is provided by the fact that music therapy can successfully reduce post-operative pain (Good et al., 2001), improve the quality of life in terminally ill cancer patients (Hilliard, 2003), reduce heart and respiratory rate as well as anxiety levels in individuals receiving ventilatory assistance (Chlan, 1998), and may even be effective in reducing some of the behavioral problems associated with dementia (Sherratt et al., 2004). More importantly, neuroimaging suggests that the 'thrill' associated with music is due to activity in the brain's reward centres (Blood and Zatorre, 2001; Menon and Levitin, 2005), and thus likely involves endorphins (as well as the dopamines commonly associated with a sense of "thrill").

In a broad sense, endogenous opiates serve to combat the effects of physiological and psychological stress, and β-endorphins (and their associated μ receptors) have specifically been linked to the pain control system (Zubietta et al., 2001; Mueller et al., 2010). More generally, it seems that almost any kind of physical exertion or somatic pain is an effective trigger of endorphin release, both peripherally in plasma and centrally in the CNS (Cohen et al., 2010; Colt et al., 1981; Dishman and O'Connor, 2009; Gambert et al., 1981; Harbach et al., 2000; Harte et al., 1995; Howlett et al., 1984). Psychologically, endorphin release is experienced as a mild opiate "high", a corresponding feeling of well-being, and light analgesia (Belluzzi and Stein, 1977; Stephano et al., 2000), and through this plays a role in reward. In primates, endorphin release is triggered by grooming (Keverne et al., 1989) and appears to be deeply involved in the processes involved in social bonding at the dyadic level (Nelson and Panksepp, 1998; Dunbar, 2010; Machin and Dunbar, 2011).

This raises the question of whether music's role in triggering the release of endorphins arises through the perception of music per se or through the actions associated with performing music. We test between these two possibilities using a pain assay as a proxy for CNS endorphin activation. Because CNS endorphins do not cross the blood-brain barrier (Bloom 1983; Boecker et al., 2008; Dearman and Francis, 1983; Kalin and Loevinger, 1983) (and PET scanning, the only viable alternative, is both extremely expensive and at present difficult to do in active subjects), we follow what has become standard practice and assayed endorphin levels using a pain threshold test (Dunbar et al., 2011; Cohen et al., 2010; Depue and Morrone-Strupinsky, 2005; Jamner and Leigh, 1999; Zillman et al., 1993). In each case, we test an experimental group subjected to an active musical intervention, compared to control groups subjected to passive musical or non-musical interventions. Experiment 1 seeks to confirm that we obtain the same results as has been obtained in previous studies (that musical activity elevates pain thresholds, presumably due to endorphin activation), using singing as our experimental manipulation. Experiment 2 seeks to refine this by asking whether the effect is due to active *performance* of music as opposed to passive *perception* of music. In Experiment 3, we focus on dancing, and, finally, Experiment 4 tests whether musical tempo affects pain threshold when passively listening to music.

Methods

The procedure was the same in each experiment, and used a between-subjects pre/post-activity design: subjects took a pain threshold test, performed by an activity and then repeated the pain test. Subjects were advised that we were studying pain, but not what the hypothesis was. Pain thresholds for all subjects in a given group were sampled within a 10 min time-window, with the post-activity assay being completed within 10 min of completing the activity. In Experiments 1 and 2, pain threshold was assayed using a mercurial sphygmomanometer (Medisave Littman Classic II) inflated on participants' non-dominant arm, above the elbow, to induce ischemic pain. Pressure was increased at a steady rate (10mmHG/sec) by gentle pumping up to a pressure of 260-280 mmHg. Subjects were asked to indicate when the pressure became painful; the time elapsed since pressure reached 260mmHg was noted (subject to a maximum of 180 secs), and the pressure released. In Experiment 2, no subjects achieved the target pressure (280 mmHg), and the pressure at the point at which they declared the pressure painful was noted to the nearest 5mmHg. In Experiment 3, the constraints of the experimental circumstances persuaded us to use an alternative pain assay (a bag of frozen ice cubes held in the palm of the right hand), and we retained this approach in the follow-up experiment (Experiment 4) where we used a frozen wine-bottle cooler sleeve on the forearm. In these cases, pain was indexed as the length of time for which the ice could be tolerated without becoming painful, with an upper limit set at 180 secs to avoid skin damage. During Experiment 1, an independent sample of 5 subjects (3 males, 2 females; mean age = 23.2 years, range 22-24) was tested with both methods using laughter as the stimulus (provided by video presentation of episode 95 from *South Park*): the two methods yielded similar results (5/5 positive changes in each case; probability of obtaining two sets of 5/5 positive changes by chance alone, $\chi^2 = 13.86$, $df = 4$, $p < 0.01$), although the cold assay tended to yield quantitatively less consistent results than the sphygmomanometer.

In all cases, participants who were pregnant, lactating or suffering from a medical condition, or who had drunk alcohol or smoked within two hours prior to the experiment were excluded. Diabetics were excluded because of their lack of pain sensitivity (McKinney et al., 1996).

All four studies were approved by the local ethics board, and all subjects provided informed consent.

Experiment 1

This experiment sought to establish that there was an effect of musical activity on pain threshold by comparing two religious services that differed in whether or not there was singing: this enabled us to establish that we could replicate the same effect as has been reported in the literature on music and pain. The experimental group consisted of 13 subjects from a charismatic-type Christian Union meeting (sermon and prayers, but predominantly communal singing, accompanied by clapping and a great deal of upper body movement; 8 males, 5 females: mean age = 20.5 years, range = 19-22); the control group consisted of 9 individuals at an Anglican prayer meeting (sermon with prayers, but no music or singing; 4 males, 5 females: mean age = 31.7 years, range = 18-73). Services lasted 105 and 45 mins, respectively. We were unavoidably constrained by the circumstances in respect of how long these activities lasted. However, our wider experience indicates that as little as 15 mins activity is sufficient to generate an effect if one is going to occur (Dunbar et al., 2011), so we do not believe that the differences in length of service are likely to have influenced the results.

Experiment 2

Experiment 2 sought to establish whether the effect produced by singing generalised to musical performance as opposed to simply listening to music. To do this, we sampled a samba drumming circle and compared it with a control group who listened to ambient music in their work place and a second control group who watched an instructional video that contained no music. The experimental group consisted of 12 individuals (4 males, 8 females; mean age = 44.2 years, range = 30-56) from a local samba drumming school that met weekly on a regular basis; subjects had a median of 4.25 years drumming experience. Individuals participated in roughly 30 minutes of samba drumming, split into two bouts of group performance (16 and 8 minutes respectively) separated by 6 minutes of section practice (during which snares and bass sections practiced their respective parts separately). Control group 1 (*music shop group*) consisted of 9 employees (5 males, 4 females; mean age = 31.1 years, range 19-41) in a city centre musical instrument store working in an environment of continuous lively background music. All were musicians of some description. In this case, the activity consisted of 30 min of normal working (acting as salespersons) while listening to the background music. The second control group (*video group*) consisted of 11 students enrolled in a Masters course (8 males, 3 females; mean age = 24.6 years, range = 20-32) who watched a 31-min speech-only segment of a video lecture on substance abuse (*Substance Abuse: Current Topics*: Episode 5, "Understanding How Drugs Work"; Governors State University, June 2000). In Study 2, all subjects were asked to complete a questionnaire providing background information on age, sex, and employment status. They also completed a PANAS questionnaire (Positive and Negative Affect Schedule: Watson and Clark, 1994) before and after treatment. The PANAS consists of 10 positive and 10 negative affect items which participants rate on a 1-5 scale based on 'strength of emotion at the present time' (1 = "very slightly or not at all," 5 = "extremely"). Only 8 out of 12 individuals in the drum condition fully completed the questionnaire, so the drum sample size for analyses of affect is reduced.

Experiment 3

This experiment sought to generalise the effect to dancing and to determine whether it is the physical exertion of music that is critical. We sampled a series of musical groups divided into two sets: an experimental group of active physical dancers (street dancer, Capoeira class and pop dance class: N = 17 [3 males, 14 females; mean age = 21.4 years, range 18-28]) and a control group of musicians at music practice sessions (a choir, a brass band and a small orchestra: N = 28 [5 males, 23 females; mean age = 22.8 years, range 16-50]). While the performance intensity was lower in this second group (low energy, rather controlled singing), this group also differed from the experimental group in the fact that their performance involved repeated pauses while instructions were given, as a result of which the musical performance was not allowed to "flow" (*sensu* Csikszentmihalyi, 1990).

Experiment 4

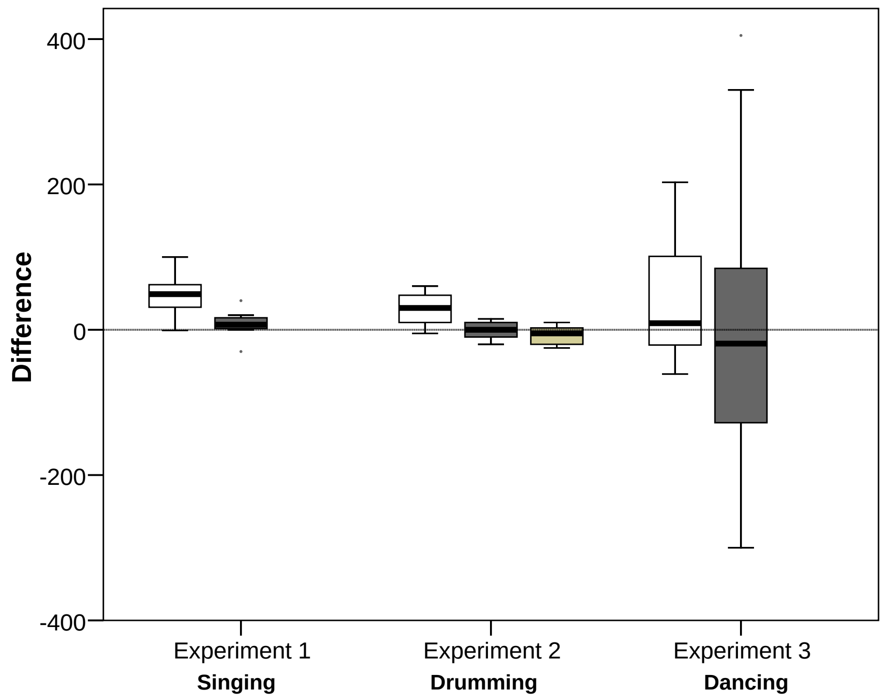
Finally, this experiment directly explored the effect of listening (as opposed to performing) music in more detail by asking whether musical tempo makes a difference. In contrast to Experiments 1-3, Experiment 4 used a within-subjects design. The participants (20 males and 15 females; mean age = 27.4, range 20-50) listened successively to two sets of classical music excerpts through headphones, the two tasks being separated by a rest period of 15 mins. The first set (*strong tempo* group) consisted of fast, rhythmically strong pieces (*Sabre Dance* from Khachaturian's *Gayaneh*, the Allegro from Copeland's *Appalachian Spring*, *Primavera* from Vivaldi's *Four Seasons*, *Storm* from Britten's *Four Sea Interludes* from *Peter Grimes*, the Presto from Ravel's *Piano Concerto in G*) and the second (*slow tempo* group) of slow, rhythmically weak pieces (excerpts from Tchaikovsky's *Swan Lake*, Pachelbel's *Canon*, *Moonlight* from *Four Sea Interludes* from Britten's opera *Peter Grimes,* Barber's *Adagio for Strings*, the Moderato/Coda from Copeland's *Appalachian Spring*, and the *Moderato* from Dvořák's *String Serenade*). Because this was a within-subjects design, pain threshold was measured on opposite forearms for the two tempo conditions. As a check, participants were also asked to rate their emotional response to the music on a simple categorical scale (emotional state more positive, more negative or the same compared to before the experiment).

Results

The results for Experiments 1 to 3, inclusive, are summarised in Figure 1, which plots median and ranges for the pre-to-post difference in pain tolerance thresholds ('post' score minus 'pre' score) for individual conditions. Comparing the experimental (active music) group against combined control groups in each case for the three active music performances yields significant differences between conditions in Experiments 1 and 2, and marginally so in Experiment 3 (Expt. 1: $F_{1,25} = 14.33$, $p < 0.001$; Expt. 2: $F_{1,30} = 26.10$, $p < 0.001$; Expt. 3: $F_{1,43} = 1.91$, $p = 0.087$; 1-tailed in each case because a directional hypothesis is being tested). Combining the results of the three experiments using Fisher's meta-analysis (Sokal and Rohlf, 1981) confirms that there is a consistent trend across experiments for differences in pain threshold in the experimental conditions to be more positive than those in the control conditions ($\chi^2 = 16.26$, $df = 6$, $p = 0.012$). (Fisher's meta-analysis is specifically recommended when the various experiments use different designs or different statistical analyses to test the same underlying hypothesis.) The differences in pain tolerance methods make it difficult to compare directly between experiments. However, we converted pain threshold differences (pre to post) into a binary variable (positive change vs. negative or no change) and compared the three experiments directly using a 2x2 χ^2 test (with the two controls in Experiment 2 pooled). Positive changes are significantly more likely to occur in the experimental conditions than in the control conditions ($\chi^2 = 9.62$, $df = 1$, $p = 0.002$).

We checked for two possible sources of confound: age and gender. The age ranges of the subjects differed between conditions, notably in Experiments 1 and 2, so we reanalysed the data for these two experiments using only subjects aged below 35. The results are identical to those previously obtained (Experiment 1: $F_{1,15} = 7.70$, $p = 0.007$; Experiment 2: $F_{2,17} = 28.92$, $p < 0.001$, with post hoc tests confirming that the drumming condition differed significantly from the two control conditions [$p < 0.001$], while the two controls did not differ significantly [$p = 0.656$].) Checking for an effect of gender was more problematic: the methods used to assay pain differed across the three experiments, so the data are strictly speaking not directly comparable. However, because the only way to handle several IVs is with parametric tests (e.g., ANOVA), we nonetheless combined the three experiments in a single analysis with experiment as a random variable and gender and condition as fixed factors and simply note that the results should be regarded as indicative rather than definitive. There is a significant difference in the predicted direction for condition (experiment > control), but neither experiment nor gender, nor the experiment x gender interaction had a significant effect (see Table 1). Repeating the analysis with the two control groups in Experiment 2 treated separately does not change the outcome: only condition is significant. Within the limits of the experimental design, it seems unlikely that gender is a serious confound.

Figure 1. Median (±50% and 95% ranges) difference in pain threshold after test activity (post-minus-pre threshold) for Experiments 1 to 3



Note: Open bars: experimental condition (active music performance); filled bars: control conditions. For Experiment 1 (the religious services), the experimental condition was a charismatic service with singing plus upper body movement (clapping, vigorous swaying), and the control condition was a quiet prayer meeting without singing. For Experiment 2, the experimental condition was a samba drumming circle, and the control conditions were ambient music in a work environment (dark grey) and watching a factual video with no music (light grey). For Experiment 3, the experimental group involved active dancing, and the control group involved choral or instrumental practice sessions. In Experiments 1 and 3, the dependent variable was the length of time that the subject could stand the pain; in Experiment 2, it was the pressure (mmHg) at which pain was experienced. In Experiments 1 and 2, pain was assayed using a blood pressure cuff; in Experiment 3, it was a frozen vacuum wine cooler on the arm.

Between them, Experiments 2 and 3 compared active (uninhibited drumming in Experiment 2) with passive (rehearsal condition, Experiment 3) performance on musical instruments, and two forms of vigorous musical activity (drumming in Experiment 2 vs. dance in Experiment 3). Using a sign test to compare the frequencies of increases vs. decreases in pain threshold, the difference between active and passive music is significant ($\chi^2 = 4.286$, $df = 1$, $p = 0.038$), but the difference between the two active music conditions is not ($\chi^2 = 1.54$, $df = 1$, $p = 0.215$).

Table 1. Summary of analysis of variance in pre-to-post difference in pain threshold for the three active music experiments combined (with experiment as a random variable)

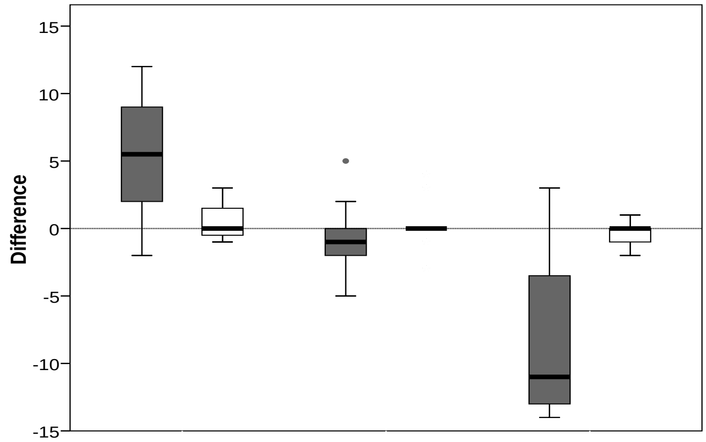
Variable	*F*	*df*	*p*
condition*	5.58	1,93	0.020
gender	0.066	1,93	0.797
gender x condition	0.352	1,93	0.554
covariate: experiment	0.070	2,93	0.933

Note: *experimental vs. control manipulation (all controls pooled)

In Experiment 2, we tested whether musical performance (in this case, drumming) affected subjects' affect: Subjects completed a PANAS questionnaire before and after the relevant activity. Pre-activity scores did not differ significantly across conditions for either positive affect ($F_{2,26}$ = 1.92, p = 0.167) or negative affect ($F_{2,26}$ = 2.75, p = 0.082). However, pre/post differences varied significantly across conditions for positive affect ($F_{2,25}$ = 18.97, p < 0.001), but not for negative affect ($F_{2,25}$ = 0.47, p = 0.630) (see Figure 2). *Post hoc* tests reveal that the positive affect difference scores for the three conditions all differ significantly from each other (Bonferroni tests: 0.05 ≤ p ≤ 0.002 two-tailed). Testing both PANAS dimensions together in the same ANOVA reveals a significant difference due to condition ($F_{2,50}$ = 18.85, p < 0.001) and a significant interaction (condition x affect dimension: $F_{2,50}$ = 15.30, p < 0.001), confirming that only positive affect differs significantly across conditions.

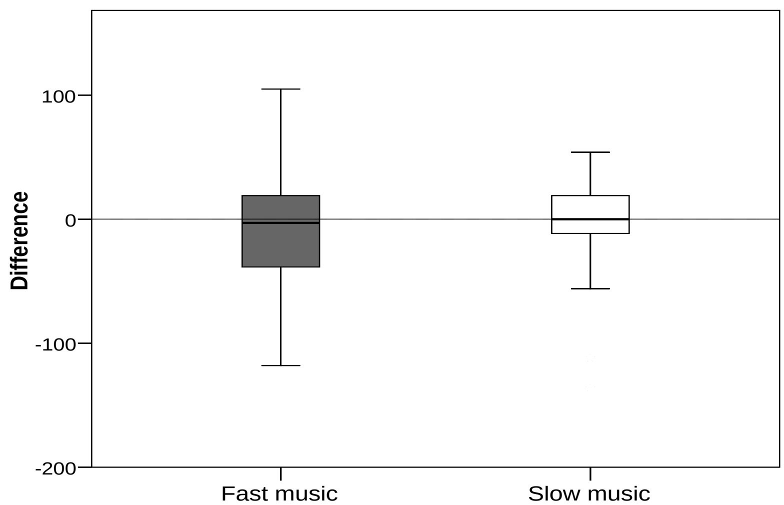
In sum, Experiment 1 confirmed that singing results in an elevated pain threshold; Experiment 2 confirms this with respect to drumming and demonstrates that it is the active performance of music that is critical rather than just hearing music; and Experiment 3 demonstrates that dancing also produces a heightened pain threshold (though the effect was marginal in this case, probably because using the frozen wine cooler yields more variable results as a pain assay). This suggests that physical effort seems to be important. In addition, Experiment 2 showed that musical performance results in concurrently heightened positive affect, but no effect on negative affect. Thus, musical performance increases pain threshold as well as positive affect.

Figure 2. Mean (±SD) change in positive (grey bars) and negative (open bars) affect scores of the PANAS scale for the three conditions in Experiment 2



Drumming circle **Music shop** **Video**
(Control groups)

Figure 3. Median (±50% and 95% ranges) difference in pain threshold after test activity for Experiment 4 to test the effect of music tempo when simply listening to music



Note: In a within-subjects design, subjects listened to both fast, rhythmically strong classical music (grey bar), or slow, rhythmically weak classical music (open bar) through headphones. The dependent variable is the length of time that the subject could stand the pain, using a frozen wine-cooler on the arm.

Finally, to check whether tempo had an effect when passively listening to music, Experiment 4 looked explicitly at music tempo in a within-subjects design in which each subject listened to music through headphones under two conditions (rhythmically strong, fast tempo versus rhythmically weak, slow tempo music). Figure 3 suggests that simply listening to music does not result in an increased pain threshold (combined dataset: t_{70} = -0.85, p = 0.200, one-tailed), confirming the results obtained in Experiment 2. Nor did the two tempo conditions differ significantly from each other (matched pairs t-test: t_{34} = 1.404, p = 0.169), indicating that tempo itself did not have any clear effect. We should note that we considered only tempo here, since this is likely to be the major influence on associated activity (tapping, nodding). It remains possible (but we suspect unlikely) that other aspects of music (e.g., key, meter, instrumentation, familiarity) might have a positive effect.

Given the results for Experiment 4, it was perhaps no surprise that, in contrast to Experiment 2, most participants (23) in Experiment 4 recorded no change in emotional state after listening to the music, while only 9 indicated an increase and two a decrease. There was no difference between the two conditions: just 7 of the 34 participants indicated a more positive emotional state after listening to the fast tempo pieces, but only 4 did so after the slow tempo selection.

Discussion

Experiment 1 demonstrated a strong effect of singing (at least when combined with upper body movement) on pain threshold. In Experiment 2, there was no difference in pain threshold in either the passive listening or no music control conditions, but a significant difference when actively performing vigorous music (drumming), indicating that it is probably the active performance of music rather than the music itself that is responsible for this effect. In Experiment 3, we demonstrated that active dancing similarly heightens pain threshold. Finally, Experiment 4 confirmed that passive listening to music *per se* did not have a significant effect, irrespective of the tempo.

Between them, experiments 2 and 3 compared two very different forms of vigorous musical activity (drumming in Experiment 2 vs. dance in Experiment 3: they were not significantly different) and active (Experiment 2) versus passive/interrupted (Experiment 3) performance on musical instruments (they were significantly different). Thus, the three conventional forms of musical activity (singing, playing instruments and dancing) all produce an increase in pain threshold when performed sufficiently vigorously. This suggests that it is the physical exertion involved in making music that produces the elevation in pain threshold, and hence, by implication, the accompanying sense of elation. Finally, Experiment 2 suggested that the increase in post-intervention pain tolerance is associated with a concurrent increase in positive affect (with no equivalent effect on negative affect).

We interpret the effects on pain threshold as being the consequence of the release of endorphins in the CNS. Taken together, these results suggest that it is the physical exertion in musical performance (whether the performance be singing, dancing or playing an instrument) that is important rather than the music itself in triggering endorphin activation. Moreover, it is probably the uninhibited ‘flow’ (*sensu* Csikszentmihalyi, 1990) or continuity of action that is important: if the music is frequently interrupted (as in rehearsals), any effect is markedly reduced (if not obliterated). This conclusion is given weight by a comparison of the ‘inhibited’ performance rehearsal control condition in

Experiment 3 with the ‘uninhibited’ experimental conditions in Experiments 1 and 2. In the first case, the performance of music was not allowed to ‘flow’ (the nature of practice sessions is that performance is continually interrupted while the conductor gives instructions), whereas in the second case, performance was uninterrupted. There was no change in pain threshold (and hence no inferred endorphin surge) in the first case, but significant effects in both the second cases.

One implication of these results is that the role of the music may be to provide rhythm and beat so as to entrain synchrony, something that may well be dependent on the mirror neuron system. This conclusion is given added weight by Cohen et al.’s (2010) finding that synchronised activity (in this case, sweep-oar rowing) significantly heightens the pain threshold over and above any effect due to the activity itself, even when there is no music involved.

Our results showed that passive listening per se does not induce heightened affect (Experiments 2 and 4), and that participants in practice sessions (the control groups in Experiment 3) did not give the impression of being roused by their performances This suggests that circumstances such as passive listening to music do not produce quite the same response as active musical performance. The changes in affect alone are unlikely to explain the changes in pain threshold, since we have shown in a parallel series of experiments on laughter that inducing affect without laughter (another physically demanding activity that elevates pain thresholds) does not of itself elevate pain thresholds (Dunbar et al., 2011). In short, the change in affect is more likely to be a *consequence* of endorphin activation rather than its cause (see also Zubietta et al., 2003).

In so far as endorphins seem to underpin primate social relationships (Curly and Keverne, 2005; Dunbar, 2010; Keverne et al., 1989), these results provide *prima facie* evidence in support of the suggestion that active participation in musical events (including both musical performance and dancing) is likely to stimulate the same neuropeptide system and thereby give rise to the kinds of euphoric effects noted by Durkheim (1915/1965), Turner (1966), Roederer (1984) and others. These effects may play a particularly important role in bonding large social groups in humans (see also Dunbar, 2008; Miles et al., 2009; Mueller et al., 2003). Given the finding by Wiltermuth and Heath (2009) that synchrony enhances cooperation in economic games, this offers a plausible explanation for the role of human capacities like music that involve highly synchronised behaviour and trigger the release of endorphins in the evolution of the hyper-cooperativeness that is so characteristic of humans. Our findings at least provide *prima facie* evidence that music generates the kinds of endorphin ‘highs’ that would function in this way in a communal context. Further work will be needed to confirm that endorphins are explicitly involved (e.g., by using a naloxone antagonist) and that there is the same kind of heightened effect when performing in groups similar to that for sweep-oar rowers reported by Cohen et al. (2010). A further question of interest with respect to the bonding of large social groups (see Dunbar, 2012) is how many individuals can be integrated into a single functional group by musical performance of this kind, and whether the different kinds of musical performance (singing, dancing, performing) have different limits in this respect.

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