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Affect-matching music improves cognitive performance in adults and young children for both positive and negative emotions

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Abstract

Three experiments assessed the hypothesis that cognitive benefits associated with exposure to music only occur when the perceived emotion expression of the music and the participant's affective state match. Experiment 1 revealed an affect-matching pattern modulated by gender when assessing high-arousal states of opposite valence (happy/angry) in an adult sample (n=94) in which mood classification was based on self-report, and affective valence in music was differentiated by mode and other expressive cues whilst keeping tempo constant (139 BPM). The affect-matching hypothesis was then tested in two experiments with children using a mood-induction procedure: Experiment 2 tested happy/angry emotions with, respectively, 3-5- (n=40) and 6-9-year-old (n=40) children, and Experiment 3 compared happy/sad emotions (i.e., states differing both for valence and arousal profiles) with 3-5-year-old children (n=40), using music pieces differentiated also by fast vs. slow tempo. While young children failed to discriminate systematically between fast tempo music conveying different emotions, they did display cognitive benefits from exposure to affect-matching music when both valence (e.g., mode) and arousal level (e.g., tempo) differentiated the musical excerpts, with no gender effects.

Keywords:

Arousal, Central executive, Child development, Mozart Effect

In music psychology, the beneficial effects of music on psychosocial functioning, and the role played by emotion and mood in producing those effects, are currently important topics of research (MacDonald, Kreutz, & Mitchell, 2012). One area of experimental research that has received particular attention is the study of the 'Mozart effect', a term that refers to findings of temporary improvements in cognitive performance after listening to music (for a review, see Schellenberg, 2012).

Doubts about the theoretical underpinnings of the original study that spawned research on the 'Mozart effect' (Rauscher, Shaw, & Ky, 1993) led Schellenberg and collaborators to formulate an alternative theory called the 'arousal and mood hypothesis', which proposed that temporary improvements in cognitive performance were not a direct product of listening to music, but were rather a product of arousal and positive affect induced by listening to music. According to this hypothesis, the 'Mozart effect' is neither Mozart-specific nor music-specific: any piece of music, or any nonmusical stimulus, that induces arousal and positive affect can be used to produce temporary improvements in cognitive performance. This proposal is consistent with a wide range of studies finding that positive affect enhances performance on cognitive tasks (e.g. see Isen, 2008). A series of studies conducted by Schellenberg and collaborators supported the arousal and mood hypothesis (Husain, Thompson, & Schellenberg, 2002; Schellenberg, Nakata, Hunter, & Tamoto, 2007; Thompson, Schellenberg, & Husain, 2001; for a review, see Schellenberg, 2012).

A key assumption made by Schellenberg and others is that happy-sounding music (i.e. music that is perceived to express happiness) induces states of higher arousal and positive affect, whereas sad-sounding music induces states of lower arousal and negative affect. For example, in Thompson et al. (2001), a Mozart piano sonata (K. 448), which has a relatively fast tempo and is in a major key, was used to induce higher arousal and positive affect in listeners. This was the same piece used in the original study by Rauscher et al. (1993). By contrast, an Albinoni Adagio, which has a relatively slow tempo and is in a minor key, was used to induce lower arousal and negative affect in listeners. To justify this use of music, Schellenberg (2012), for example, has stated that "It is well established that fast-tempo and major-mode music tends to make listeners feel happy, whereas slow-tempo and minor-mode music makes listeners feel sad" (p. 331).

The assumption that happy-sounding music induces happy (positive, higher arousal) states in listeners whereas sad-sounding music induces sad (negative, lower arousal) states is problematic for at least two reasons. First, sad-sounding music is known to produce arousal and pleasure in some listeners some of the time. For example, a number of sad-sounding music tracks (e.g. Barber's Adagio for Strings, Beethoven's Moonlight Sonata, the Lacrimosa from Mozart's Requiem, and Elgar's Elegy) were selected by participants and used by Salimpoor et al. (2009) to induce physiological arousal, pleasure and chills. Vuoskoski, Thompson, McIlwain, and Eerola (2012) found that sad music induced, in addition to sadness, a range of positive emotions (see also Kawakami, Furukawa, Katahira, & Okanoya, 2013), and that participants who scored highly on trait empathy and openness to experience enjoyed sad music the most.

A second problem with the assumption is that listeners are not just 'passive' recipients of music. Rather, listeners use music strategically to regulate their current emotions or moods in everyday situations (Miranda & Claes, 2009; Saarikallio, 2010; Thoma, Ryf, Mohiyeddini, Ehlert, & Nater, 2012; van Goethem & Sloboda, 2011). In other words, music is not just a means to induce affective responses; it is also a means to strategically respond to current affect. This is a key point for our understanding of the benefits of music because *how* individuals habitually respond to their affective experiences (e.g. with acceptance, avoidance, problem solving, reappraisal, rumination or suppression strategies) is considered by many to have important implications for mental health and well-being (Aldao, Nolen-Hoeksema, & Schweizer, 2012).

Given these problems with the assumption that happy-sounding music induces positive, higher arousal states in listeners whereas sad-sounding music induces negative, lower arousal states, we sought to test an alternative model of the role of affect in facilitating cognitive benefits through listening to music. We conceptualise music as a social signal whose expressive characteristics are modified in response to the affective state of the listener (see Trehub, Hannon, & Schachner, 2010, for a similar view), and we differentiate between signals whose perceived expressive characteristics are either congruent or incongruent with the current affective state of the listener. We use the term 'affect-matching music' to refer to congruence between, on the one hand, the emotion that is perceived by the listener to be expressed by the musical signal, and, on the other, the listener's current affective state. Our hypothesis is that improvements in cognitive performance are facilitated by listening to affect-matching music. In theory, then, music that is perceived to be expressive of low arousal or negative affect could have enhancing effects on cognitive performance if affect-matching is present. This is our point of departure from Schellenberg and collaborators' studies of the 'Mozart effect'.

Although our studies still treat listeners as 'passive' receivers of musical signals, in the sense that participants did not self-select the music used in the experiments, our approach is intended to move a step closer to understanding music as a means to strategically respond to listeners' current affective experiences. In our experiments, the strategic response can be thought of as being extrinsically produced by the signal producer (i.e. the composer / the experimenter) rather than intrinsically produced by the signal receiver (i.e. the participants), in a similar vein to what is found, for example, in mother-infant interaction (Shenfield, Trehub & Nakata, 2003). This distinction between extrinsic (other-generated) and intrinsic (self-generated) influences on emotion regulation is particularly relevant for an understanding of how musical communication can mediate the process in which one person (e.g. a therapist) influences the emotion regulation strategies employed by another (e.g. a client) (see Swaine, this issue, for a discussion of this point).

Some studies have considered the issue of congruence or incongruence between the perceived emotion expression of music and the current affective state of the listener. For example, Hunter, Schellenberg, and Griffith (2011) found that listeners in a sad mood failed to show the typical preference for happy-sounding rather than sad-sounding music. Vuoskoski and Eerola (2012) found that participants' ratings of perceived emotion in music was influenced by their current mood (and their personality), and North and Hargreaves (1996) and Thoma et al. (2012) found that listeners preferentially selected music that was emotionally congruent with the (hypothetical) emotional situation. However, because none of these studies were about the cognitive benefits of listening to music, the question of whether or not congruence/incongruence is a factor of influence in music's facilitating effect on cognitive performance remains open.

Other studies have used music to induce affective states in listeners in order to test recall of information that is either congruent or incongruent with the induced affect (see Tesoriero & Rickard, 2012). In these studies, it is the congruence between the affective state of the listener and the information to be recalled that is treated as a factor of influence on cognitive performance, rather than the congruence between the affective state of the listener and the perceived expression of the music.

In summary, the present study addresses problematic assumptions in Schellenberg and others' investigations of the 'arousal and mood hypothesis' as an explanation for findings of temporary improvements in cognitive performance after listening to music. Our study embodies an alternative conceptual model of music and affect and tests the affect-matching hypothesis, which proposes that improvements in cognitive performance will be facilitated by listening to music that is perceived by the listener to express emotions that are congruent rather than incongruent with the listener's actual affective state. This alternative model is relevant for our understanding of, for example, the benefits of a technique that is commonly used in improvisational music therapy, in which the therapist creates music that is intended to expressively match the inner state of the client (e.g. Ansdell & Pavlicevic, 2005).

Finally, the manner in which we conceptualised perceived emotions and felt moods in our experiments is broadly consistent with Barrett's (2006) conceptual act model of emotion, which may provide a means to bridge discrete and dimensional models, and biological and social construction accounts, of emotion in music research (see Zentner & Eerola, 2010, for background). According to Barrett's model, categories of emotion are the result of a process in which people conceptualise their experiences of 'core affect', a term that refers to ongoing changes in feelings of pleasure or displeasure (the 'valence' dimension of core affect) and activation or deactivation (the 'arousal' dimension, which is associated with activation of the sympathetic and parasympathetic nervous systems) (see also Russell, 2003). The ability to experience core affect is biologically given, whereas the conceptualisation of experiences of core affect is a learned and enculturated process (Barrett, 2006). We suggest, on the basis of Barrett's model, that some of the acoustic cues that mediate the recognition of emotions in music are based on familiarity with the bodily sensations associated with core affect (e.g. faster and slower rates of movement associated with, respectively, higher and lower arousal), while other cues are based on familiarity with the conventions of a particular genre of music (e.g. major and minor mode associated with, respectively, happiness and sadness in Western classical music) (for a review of research on the structural correlates of musically expressed emotions, see Gabrielsson & Lindström, 2010). The relevance of these points will be highlighted in subsequent sections. Within this perspective, we would expect developmental trends, with older children experiencing stronger affect-matching effects as a result of their higher familiarity with Western music cues associated with different emotions. Therefore the present study also includes developmental samples.

VALIDATION OF THE MUSICAL MATERIAL USED IN THE EXPERIMENTS

In order to avoid personal associations or other uncontrolled confounding effects of familiarity, novel music composed ad-hoc by Joel Swaine was used in the experiments. For Experiments 1 and 2, two one-minute music tracks with identical instrumentation (solo piano) and tempo (139 BPM) were used. The 'happy' and 'angry' tracks were differentiated by other expressive characteristics: the 'happy' track was in G-major, with more harmonic consonance and off-beat accentuation, and the 'angry' track was in G-minor with more harmonic dissonance and greater density of note onsets.

In Experiment 3, music specifically composed for children was used, with both 'happy' and 'sad' tracks lasting one minute. In this case 'happy' and 'sad' music were differentiated at all levels: respectively, mode (G-major vs. G-minor), tempo (fast BPM= 134 vs. slow BPM= 75), articulation (staccato vs. legato), and instrumentation (faster vs. slower attacks, and shorter vs. longer decays). (The music tracks used in Experiments 1-3 are provided online as supplementary materials.)

Validation tests were preliminarily conducted in order to assess whether listeners perceived the intended emotional quality in the music composed for this study. Two tests were conducted, the first including the 'angry' and 'happy' tracks plus four distracter tracks (two 'happy', and two 'sad' form a child-directed set), and the second targeting 'happy' and 'sad' affect (three child-directed tracks for each emotion, including those used in the last experiment). The order of presentation of the excerpts was randomized across participants.

An opportunity sample of twelve participants took part in each test. They were all adult naive listeners recruited from the same population providing the participants for Experiment 1 (university students, see below). Testing took place in a quiet cubicle at the university and participants used headphones adjusted to a comfortable level of loudness, connected to a computer presentation which they conducted at their own pace. Participants assessed each music excerpt on four 7-point scales: happy, sad, angry, enjoyable (not at all=1, to extremely=7). Correct emotion identification was attributed when participants gave both a score >5 on the target emotion and a score <3 on the remaining emotions.

In each test, all participants identified correctly the intended emotion in each music excerpt. Thus, the music composed for the experiments was deemed to adequately express the intended emotions.

ETHICS STATEMENT

Ethical approval for all studies was granted by Middlesex University Psychology Ethics Committee. Written consent was collected from adult participants following information, and debriefing was provided after testing. For the developmental samples, parents were fully informed about the study and an opt-in written parental consent procedure was used.

EXPERIMENT 1

The first experiment aimed to test the affect-matching hypothesis with a sample of adults, using a naturalistic procedure for the classification of moods (participant self-assessment). In order to eliminate the possibility of explaining results on the basis of arousal levels induced by musical exposure, two affective states of contrasting valence (positive vs. negative) but similar arousal profiles (high) were chosen: 'happy' and 'angry'. It was predicted that only participants exposed to affect-matching music, even if with negative valence, would show cognitive performance benefits, whilst participants in mood-mismatching conditions (happy mood/angry music and angry mood/happy music) may display performance deterioration.

Method

Participants

Participants were recruited among students on the campus of a university in London (UK) from a multi-ethnic community with 51% white students (Middlesex University OFFA Access Agreement 2014-15), in which South-Asian, African- and Caribbean-Black are the other largest groups. Initial mood screening was based on self-assessment, using a selection of 24 randomised items from the POMS-short questionnaire (*Profile of Mood States* - McNair, Lorr, & Droppleman, 1989), with eight items each describing 'positive' states (*quite cheerful, happy, active, lively, alert, energetic, satisfied*), 'annoyed' states (*stressed, resentful, frustrated, irritated, rebellious, grumpy, angry*), and 'sad' mood states (*down, blue, discouraged, worthless, lonely, miserable, depressed*), to which a final item *'none of the above'* was added. Participants were asked to tick as many items as needed to describe their current mood. Only participants who scored proportionally ≥ 2/3 items in either 'positive' or 'annoyed' mood subscales were included in the study ('happy' and 'angry' mood groups, respectively). The final sample comprised 92 participants after removing one participant who did not produce any data and one that was mislabelled (classified in different groups across files – experimental error). The final sample is shown in Table 1. Involvement with musical training or activities was probed by asking the participants to describe themselves by choosing one of the following alternatives: 'no / minimal experience of training or participation in structured musical activities' (58.7%), 'some past experience of training or participation in structured musical activities as a child / growing up' (29.3%), and 'current experience with training or ongoing participation in structured musical activities' (11.0%, with approximately twice as many males than females in this sub-group).

Table 1.

Adult participants distributed across music conditions in Experiment 1.

MOOD	MUSIC	GENDER	N
Happy	Happy (26)	female	13
		male	13
	Angry (26)	female	11
		male	15
Angry	Happy (21)	female	12
		male	9
	Angry (19)	female	13
		male	6

Procedure

Participants in each mood group were randomly allocated to mood/matching or mood/mismatching musical conditions, and were provided with an explanation of the experiment and familiarisation (once) with the visual digit span task (see below). The experiment was run on an iMac computer, in a quiet laboratory, using Superlab 4.5.4 software. The experimenter asked participants to wear headphones adjusted to a comfortable level of loudness and left the room.

In order to control for individual differences in cognitive abilities or possible influences of different moods on cognitive performance, a pre-/post-test design was adopted, which would allow us to compare participants at baseline and thus separate the effects of treatment from confounding variables.

Cognitive performance measures targeted working memory, an aspect of executive function (Miyake, Friedman, Emerson, Witzki, & Howerter, 2000) that has been associated with findings of no improvement in 'Mozart effect' studies (Rauscher, Shaw, & Ky, 1995; Schellenberg et al., 2007; Steele, Ball, & Runk, 1997), but that is specifically related with our hypothesis that affect-matching music enhances cognitive resources (see General discussion below). In consideration of the preliminary assessment of participants' mood, and aiming to keep a simple flow in the sequence of experimental phases, a forward digit span task was created which was demanding but rapid and proportionally similar in duration to the musical exposure. Given the rapid succession of experimental phases, the task was presented visually so as not to explicitly engage auditory memory. The dependent measure was the number of digits recalled in the exact order of presentation.

The first task was a pre-test visual forward digit span, presenting ten digits (0-9), one digit per second on the computer screen, following which a computer prompt asked the participants to type into the keyboard the sequence of digits as they recalled it. The music exposure phase then automatically followed, during which instructions on the computer screen asked the participants to concentrate on the music. Finally, a post-test digit span equivalent to the pre-test was run (with the digit order randomized at every trial and across participants). Before leaving the laboratory, participants were asked to fill in a very brief questionnaire (paper and pencil) collecting musical background information (see above).

Concerning the materials, two music excerpts composed ad-hoc were used, each 1-min. long as described above ('Validation of the musical material'), one for 'happy' and one for 'angry' musical expression.

Results

Preliminary analyses were conducted to confirm the comparability of the experimental groups at the start of the experiment. Groups were found not to differ in the number of digits recalled at pre-test based on their moods t(90) = -.877, p = .38, allocated music condition t(90) =-.561, p = .58) and gender t(90) = -.420, p= .67). The effects of experience (repeating the same type of test pre/post-music, albeit with different digit order) revealed a small but significant effect of test, with participants' recall being 0.66 digits higher at post-test (M=3.770 post-test vs. M=3.105 pre-test, paired t(91) =-2.27, p = .03).

In consideration of the possibility that the increased recall at post-test was due to music exposure rather than learning per se, an additional group of 20 participants (45% female) was tested in identical experimental conditions but exposed to 1 min. pink noise rather than music. In this case the pre/post digit recall comparison did not reveal a significant difference, t(19) = -.656, p = .52.

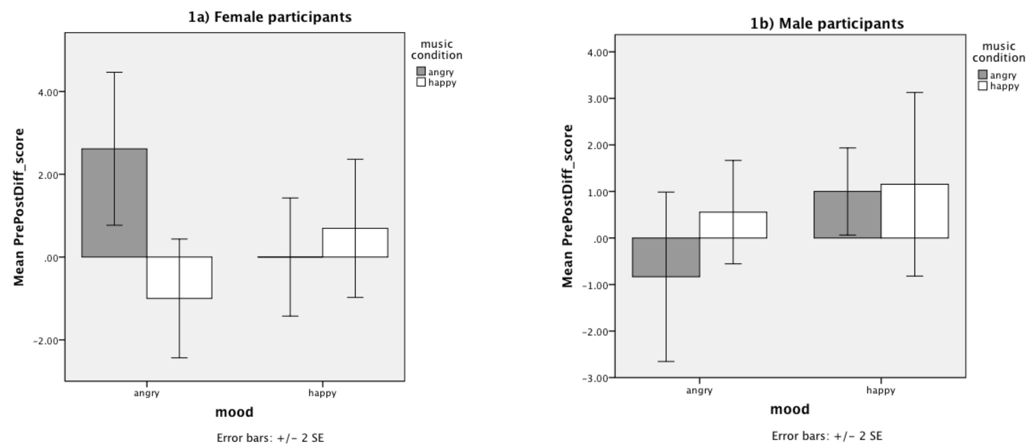
The first analysis to test the affect-matching hypothesis was conducted on the differential score of digits recalled pre/post-music exposure; for ease of comprehension, this was calculated as [post-digit] - [pre-digits] so that a gain would appear as a positive and a loss as a negative number. An independent group mood X music X gender ANOVA showed a non-significant interaction of gender with music condition, F(1,84) = 3.66, p = .059, η_p^2= .042, due to women and men improving performance following exposure to the different music tracks, irrespective of mood: 'angry' music for women (+1.31 digit) but 'happy' music for men (+.855 digit) respectively, whereas 'happy' music for women and 'angry' music for men were associated with minimal change (±0.15 range). More importantly, the analysis revealed a significant three-way interaction, F(1,84) = 5.64, p = .02, η_p^2= .063 (Figure 1a,b), which suggested that the relationship between mood and music in affecting participants' performance was modulated by gender. Thus, separate follow-up

ANOVAs were conducted for female and male participants in order to detail this effect.

The analysis yielded a significant mood X music interaction for female participants, $F(1,45) = 6.96$, $p = .01$, $\eta_p^2 = .134$. As seen in Figure 1a, ‘angry’ women exposed to ‘angry’ music recalled more digits at post-test (an increase of over +2.5 digits) while ‘angry’ women exposed to ‘happy’ music recalled fewer (-1 digit compared to the pre-test). A similar, if less pronounced, pattern can be seen for ‘happy’ women exposed to ‘happy’ music (nearly +1 digit post-test), while ‘happy’ women exposed to ‘angry’ music showed unchanged performance with respect to pre-test. There was no such difference for men (Figure 1b), $F(1,39) = .58$, $p = .45$, $\eta_p^2 = .015$.

<u>Figure 1.</u>

Mean differential pre/post score (number of digits recalled) after exposure to affect-matching or –mismatching music characterised by emotions associated with similar arousal levels but different valence (angry, happy) (1a: female sample, 1b: male sample).
NB pre/post scores are reversed in the figures, so that + indicate gain and – loss.



<u>Summary</u>

The affect-matching hypothesis was partly supported: cognitive performance was enhanced in mood/music matching conditions (including negative states) whereas in mood/music mismatching conditions there was a trend for performance to decline. However, this effect was moderated by gender, with women only displaying the effect. The following experiments with developmental samples served to elucidate the implications of these findings.

EXPERIMENT 2

Experiment 2 aimed to explore the affect-matching hypothesis with pre-school children, using the same design adopted in Experiment 1. The gender effect found in Experiment 1 may be attributed to a process of enculturation in which women are encouraged or expected to express their feelings more openly and outperform men on 'emotional intelligence' measures (Baron-Cohen, 2002, 2010; Furnham, 2001; Petrides, Furnham, & Martin, 2004, among others), which may include accurate self-assessment (Petrides & Furnham, 2000). If this is the case, gender may not moderate the mood/music-matching enhancement of cognitive performance in young children.

Some evidence exists that children display enhanced performance in situations similar to those originally employed by Raucher et al. (1993) in the 'Mozart effect' studies. For instance, in Ivanov and Geake (2003), upper-primary school-aged children exposed to musical pieces by Mozart or Bach in a school setting outperformed children in a control class on a Paper Folding Task. Furthermore, children remained engaged for longer in a drawing task when exposed to cheerful, familiar, age-appropriate music rather than classical music including Albinoni's Adagio in G-minor for Strings and Organ (Schellenberg et al., 2007). However, other studies failed to find cognitive benefits resulting from music exposure. Črnčec, Wilson, and Prior (2006) tested a large number of ten-year-old children on a spatiotemporal task following exposure to Mozart piano sonata K. 448, popular music, and silence, without finding any significant differences across the three conditions (see also McKelvie & Low, 2002).

We hypothesised that the affect-matching effect on cognitive performance will be found in a developmental sample, without gender modulation. In order to test young children with no literacy and with still limited verbal and self-assessment abilities, a mood induction procedure was used (Brenner, 2000), which may also mitigate possible influences of gender differences in emotional intelligence.

Method

Participants

Forty children (50% female) aged 3-5 years (M = 3.93 years, SD = .89) were recruited at a university nursery in London (UK) and snowballing via the researchers' personal acquaintances in London (UK). As in Experiment 1, a 2 (happy vs. angry mood) X 2 ('happy' vs. 'angry' music) independent design was adopted and children were randomly assigned to one of four mood/music matching or mismatching conditions (n=10 per condition).

Procedure

When they began the experiment, all children were familiar with the female researcher. They were tested in a quiet environment individually, unless they preferred to have their mothers or a teacher with them – in the latter case the adult was instructed to remain silent and neutral. At the start children were provided with a brief verbal description of each part of the experiment; they were given a few minutes to familiarise themselves with the laptop and mouse and given a short demonstration of how to click and play. Given that adult cognitive performance at pre-test was not affected by mood in Experiment 1, baseline cognitive performance measures were taken prior to mood induction with children in order to keep as vivid an impression as possible of the mood induced when children were exposed to music. First, a baseline measure of cognitive performance was obtained on an age-appropriate on-line working memory game ('Fruity Fruit Match', http://www.learninggamesforkids.com/memory_games/fruity-fruit-match.html). Aimed at developing visual spatial memory skills in young children, this game consists of eight pairs of matching fruit picture cards. All the cards are over-turned at the start of the game. Fruit pictures are displayed by clicking on each over-turned card, and the player must correctly remember the location of each fruit to make a matching pair. Fruit pictures appear in different locations at the start of each run of the game. A performance score is automatically calculated based on errors made and the time taken to successfully complete the game (range 0 to over 200). The game was played using a laptop (ASUS UL30A, 13.3 inch) and mouse (Dell).

Following this, a mood induction procedure was used, in which participants were asked to watch a short children's cartoon clip (approx. 1 minute) with muted sound.

Children were asked to watch the video clip and, later, listen to the music carefully without talking. A happy mood was induced using a video clip of cartoon character '*Pingu'* enjoying a birthday party. A corresponding clip of '*Pingu'* getting angry when being told he cannot go out and play was used to induce an angry mood. (The video clips were first tested in a small pilot to confirm their suitability for the research.) The Ottawa-Georgia Mood Scales (Cheng & Ward, 2004) were then used to assess the extent to which the mood induction procedure conveyed the required mood to participants. Either the sad-to-happy or calm-to-angry scale was shown to participants on a large card, depending on the mood condition they were exposed to (happy or angry, respectively). Each scale consists of schematic faces depicting opposite emotional states. Using gender-matching versions of the scales, children were asked to choose the face they felt most closely matched their mood upon watching the cartoon clip – see Figure 2. The majority of 3-5 year olds (92.5%) indicated faces that correctly corresponded to the intended mood induction.

Figure 2.

3-year old boy choosing the happy schematic face from the Ottawa-Georgia mood scales (Cheng & Ward 2004). © K. Zaborowska 2012

Immediately after, participants were asked to listen to affect-matching or -mismatching music. The tracks used for 'happy' and 'angry' music were the same as in Experiment 1 except that following pilot testing with six young children, the level of dissonance in the 'angry' track was increased (atonal clusters were added to the melody on strong beats) in order to facilitate negative affect recognition (Koelsch, 2010; Pallesen et al., 2005). Lastly, a post-test measure of performance on the visual memory game was taken. All children were exposed to a new piece of 'happy' music in the end, in order to conclude the session on a positive note.

Results

A preliminary one-way ANOVA was conducted on pre-test baseline memory performance to confirm the comparability of the mood/music matching or mismatching groups at the start of the experiment, which revealed no significant baseline differences between the groups, $F(3,36) = 1.37$, $p = .267$, $\eta_p^2 = .102$.

In order to test the affect-matching hypothesis, a 2 (moods) X 2 (music affect) ANOVA was conducted on the pre/post-musical exposure differential score, which showed no significant effect of the mood X music interaction, $F(1,36) = .111$, $p = .74$, $\eta_p^2 = .003$. Children's performance was not significantly differentiated by any individual factors, either mood $F(1,36) = 3.5$, $p = .07$, $\eta_p^2 = .09$ or music, $F(1,36) = .011$, $p = .916$, $\eta_p^2 = .000$. Gender yielded no main or interaction effects (all $p > .05$).

Preschoolers did not show any differential effects on cognitive performance following exposure to affect-matching or mismatching music for states with similar arousal profiles but opposite valence (angry/happy). Aiming to investigate developmental trends, a further group of older children was tested using the same procedure and materials.

Additional school-age participants

Forty children (57.5% female) aged 6-9 years (M = 7.73 years, SD = 1.06) were included in the sample. As in Experiments 1 and 2, a 2 (happy vs. angry mood) X 2 ('happy' vs. 'angry' music) independent design was adopted and children were randomly assigned to one of four mood/music matching or mismatching conditions (n=10 per condition). Mood induction was successful also with this sample, with the majority of 6-9 year olds (85%) indicating the intended felt mood (either happy or angry) correctly. The experimental groups were not different at baseline and displayed similar performance scores at pre-test, $F(3,36) = .79$, $p = .508$, $\eta_p^2 = .062$.

A 2 (mood) X 2 (music) independent factor ANOVA using the pre/post musical exposure was carried out on the differential score on the 'Fruity Fruit Match' game. There was a clear trend for children to achieve higher performance scores after musical exposure in the mood/music matching conditions (Happy/Happy M= 74.87 and Angry/Angry M= 123.22), than in the mismatching conditions (Happy/Angry

M= 35.92, and Angry/Happy M= 46.27). However, the mood X music interaction was statistically non-significant, $F(1,36) = .454$, $p = .505$, $\eta_p^2 = .012$, even when controlling for modulating effects of gender, $F(1,32) = .023$, $p = .881$, , $\eta_p^2 = .001$.

Summary

Taking together the results of Experiment 2, a developmental pattern is emerging indicating that, differently from preschoolers, school-age children begin to show a trend to improved cognitive performance after exposure to affect-matching music for states with similar arousal profiles but opposite valence. However, the statistical analyses remained non-significant also in the school-age group.

There are two possible explanations for these results, both based on the failure to produce the intended mood-music affect matches or mismatches: (i) the 1-minute mood induction, although leading to the intended mood, did not last beyond the Ottawa-Georgia test, and (ii) children did not recognise the intended emotion expressed by the music. This second possibility is consistent with the literature identifying a developmental progression in which the recognition of emotion in music is initially based on tempo distinctions and only later would include mode, after 6 years of age (Dalla Bella, Peretz, Rousseau, & Gosselin, 2001; see also Mote, 2011). It is then likely that the lack of tempo differentiation in the musical parameters used to characterise the two different affects (angry/happy) in the musical excerpts proved insufficient for children aged 3 to 9 years of age.

EXPERIMENT 3

In order to separate the effect of a developing ability to recognise the intended emotion in music from the presence of an affect-matching effect, Experiment 3 compared children's performance in mood/music matching and mismatching conditions contrasting states differentiated also by their arousal profiles (sad and happy emotions), thus involving also different tempi as one of the key musical expressive cues used in the task. As tempo appears to be one of the first musical aspects used by children to recognise emotion in music (Dalla Bella et al., 2001) it was hypothesised that the inclusion of tempo differentiation in the music would allow us to reveal an affect-matching effect on cognitive performance also in young children.

In this experiment we also increased the duration of the mood induction in order to facilitate a lasting impression of the intended mood that would carry the children through the mood identification test and the post-test game.

Method

Participants

Forty children were recruited snowballing from the researcher's circle of acquaintances in London (UK) (32.5 % female), aged 3 - 5 years (*M* = 3.7 years, *SD* = .78), with 10 participants randomly assigned to each experimental condition.

Procedure

The experiment used a 2 X 2 design, with mood (happy, sad) and music ('happy', 'sad') as independent factors. The children were familiar with the researcher and testing conditions were the same as in Experiment 2 (see above). After a baseline memory game ('Fruity Fruit Match', as in Experiment 2), a mood induction procedure was used for a sad or happy feeling – respectively, a muted video-clip showing Mufasa's death from the Disney cartoon *The Lion King*, and the same *Pingu* birthday party clip used in Experiment 2. Notably, in Experiment 3 the duration of the mood induction phase was increased, with both clips lasting 3:16 minutes. On completion of this part, the children were asked to describe their mood upon watching the cartoon by using the happy-sad Ottawa-Georgia Mood Scale (Cheng & Ward, 2004), with 95% of the children selecting the intended affect. Afterwards, in each mood group, half the participants listened to a 1-minute 'sad' music track and half the participants to a 1-minute 'happy' music track (see above for details of the material). Once the music listening was over, children were asked to again play the memory game (post-test). Finally, all children were exposed to a new piece of 'happy' music in order to conclude the session on a positive note. The dependent measure was as in Experiment 2: the performance score (calculated automatically within the game), namely the differential score achieved pre/post-music exposure.

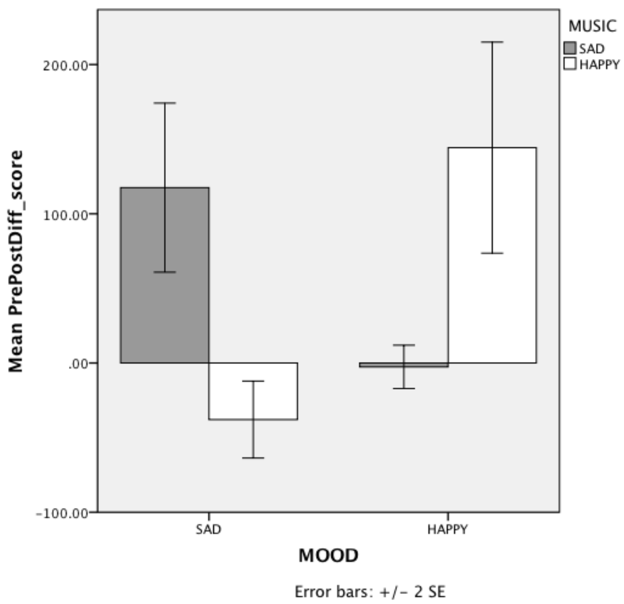
Results

A preliminary independent group ANOVA conducted on the pre-test visual recall scores in the four mood/music matching and mismatching groups showed no significant difference, $F(3, 36) = .653$, $p = .59$, $\eta_p^2 = .052$, hence the four groups of children were equivalent at baseline.

Subsequently, a 2 (mood) X 2 (music) ANOVA was performed on the visual recall differential score, which yielded only a large significant effect for the mood X music interaction, $F(1, 36) = 40.23$, $p = .000$, $\eta_p^2 = .53$. As can be seen in Figure 3, children in both mood/music matching conditions (happy mood/'happy' music, and sad mood/'sad' music) displayed higher positive differential scores, indicating gains in cognitive performance at post-test. On the contrary, affective misalignment between mood and music (happy mood/'sad' music, and sad mood/'happy' music) was associated with no gain or even marginal loss of memory performance in the preschoolers. No gender effects were found (mood X music X gender: $F(1,32) = .113$, $p = .74$, $\eta_p^2 = .004$).

Figure 3.

Mean differential pre/post score (performance score in the 'Fruity Fruit Match' memory game) by 3- to 5-year-old children after exposure to affect-matching or –mismatching music characterised by emotions associated with both different arousal levels and valence (sad, happy).



Summary

Experiment 3 was successful in showing a gender-independent affect-matching effect in young children: pre-schoolers performance in a working memory game improved only in the mood/music congruent conditions.

GENERAL DISCUSSION

Overall, the results of this study partly support the hypothesis that improvements in cognitive performance are produced by listening to affect-matching music (i.e. music that is perceived by the listener to express emotions that are congruent with the listener's current affective state). Initial support was provided specifically by Experiments 1 and 3. Experiment 1, with adults, investigated the effects of listening to 'happy' versus 'angry' music, that is, emotions having contrasting valence (positive versus negative) but similar arousal levels (high), and found an affect-matching effect moderated by gender, with only women showing the expected effect. Experiment 3, with 3-5 year olds, used 'happy' versus 'sad' music, that is, emotions which have both contrasting valence (positive versus negative) and contrasting arousal (high versus low), and found a large significant effect with no gender interaction.

How might our finding of a gender effect in adults in Experiment 1, but no gender effect in 3-5 year olds in Experiment 3, be interpreted? Given the multiethnic population from which the sample was derived (involving different cultures and faiths) and the high level of individual differences, several factors may have contributed. For instance, it is possible that the males were less accurate than the females in their self-assessments of current mood (Baron-Cohen, 2002, 2010; Beyer, 1990; Beyer & Bowden, 1997; Dillman Carpentier, Brown, Silk, Forbes, & Dahl, 2008; McClure, 2000; Petrides & Furnham, 2000; Petrides, Furnham, & Martin, 2004; Reiff, Hatzes, Bramel, & Gibbon, 2001), or perhaps cultural influences on the males' preferred affect regulation strategies have somehow negated the benefits of affect-matching music (see also Karageorghis et al., 2010). Future studies could develop a more precise and nuanced representation of the affect-matching effect if demographic, personal and cultural variables are carefully planned and controlled. However, given that the 3-5 year olds showed a significant affect-matching effect with no gender interaction in Experiment 3, we suggest that the gender effect found in Experiment 1 is unlikely to be of a biological nature.

Experiment 2, with children, using ‘happy’ versus ‘angry’ music as in Experiment 1 with adults, found no affect-matching effect in both 3-5 and 6-9 year olds, although the older children's performance displayed a trend in the adult direction. How may the different outcomes in Experiments 2 (no affect-matching effect) and 3 (affect-matching effect) be interpreted?,We propose that the absence of tempo amongst the musical expressive cues used in Experiment 2 to differentiate happy/angry affect may have significantly reduced the emotional discriminability of the intended affects for children (consistently with what was found in other studies, e.g. Dalla Bella et al., 2001). Experiment 3 also used a longer mood-induction phase (lasting 3 minutes instead of 1), which might have been more effective in allowing a lasting impression to keep the children in the intended mood until the end of the experiment. Further research will be able to clarify the relative importance of what in this case was an experimental manipulation (tempo difference) and a procedural enhancement (longer mood induction). Nonetheless, taken together, the developmental results suggest that, as far as they can recognise emotion in music, young children are susceptible to cognitive benefits derived from exposure to music with an emotional profile consistent with their own affective state. This may be considered an intra-personal effect possibly developing from responsive and sensitive musical interactions in infancy, in which parents adjust their singing in function of effective emotion regulation of their babies (e.g. Shenfield et al., 2003; Trehub & Trainor, 1998) – an interactive pattern associated with positive outcomes in overall cognitive performance and emotional development (Bergman, Sarkar, Glover, & O'Connor, 2010; Mikulincer, Shaver, & Pereg, 2003).

The developmental results are also consistent with our proposal that the ability to recognise emotions in music is an inherent component of the mechanism that mediates improved cognitive performance in listeners. In other words, affect-matching involves congruence between, on the one hand, the emotion that is perceived by the listener to be expressed by the music, and, on the other, the actual affective state of the listener. If the listener does not perceive the emotion that is intended to be expressed by the music, then, by definition, affect-matching has not occurred. In such cases, we would not expect improvements in cognitive performance to follow. This point is consistent with the lack of improvements in children who were likely not to recognise the emotions that we intended to express through the music. Based on Barrett's (2006) conceptual act model of emotion, we suggest that some of the perceptual cues that mediate the recognition of emotions in music are based on a biologically endowed capacity to perceive bodily sensations associated with arousal (e.g. faster or slower heart, breathing and somatic movement rates), and a corresponding tendency to associate faster (or slower) perceived tempos with higher (or lower) levels of arousal. On the other hand, we suggest that the effectiveness of other perceptual cues (e.g. major and minor mode) as mediators of the recognition of categories of emotion (e.g. happiness, sadness, anger) is based on a familiarity with particular musical-cultural conventions. These speculations may help to explain findings, discussed earlier, that tempo, compared with mode, is a better predictor of younger children's ability to recognise and differentiate between musically expressed emotions.

Previous studies of the 'Mozart effect' have found no improvement in performance on working memory tasks (Rauscher, Shaw, & Ky, 1995; Schellenberg et al., 2007; Steele, Ball, & Runk, 1997), which has led Schellenberg (2012, p. 332), in his discussion of the 'arousal and mood' hypothesis, to suggest that some cognitive abilities may be relatively impervious to the effects of arousal and mood. Our findings suggest that working memory performance, which is an aspect of executive functioning (Miyake et al., 2000), may indeed be temporarily improved through listening to music, but that, contrary to assumptions made in investigations of the 'arousal and mood' hypothesis (see earlier for a discussion), it is the congruence between the perceived emotion expression of the music and the affective state of the listener, rather than the emotion expression of the music per se, that seems to be the key factor in producing a cognitive benefit. How might this be explained?

Outside the music domain, a large body of research has looked at the influence of emotion and mood on psychosocial functioning. For example, positive affect has been found in a wide range of studies to enhance cognitive performance (e.g. Isen, 2008). This is a research area that Schellenberg and others pointed to in their explanation of the 'Mozart effect' (e.g. Thompson et al., 2001). However, other findings on the influence of affect on psychosocial functioning should be of interest to music researchers. For example, suppressing the expression of emotion has been found to be physiologically costly (Gross & Levenson, 1997; Roberts et al., 2008), and to impair both memory (Richards & Gross, 2000, 2006), and social functioning (Srivastava et al., 2008). Other lines of research have found that positive or negative affective states facilitate the recall of information that is, respectively, positively or negatively valenced (Bower, 1981; Ellis & Moore, 1999), and that emotional arousal enhances explicit, long-term memory of experienced events (Cahill & McGaugh, 1998).

Studies of the costs of emotion suppression may be particularly relevant here. Different emotional/mood states are associated with different action tendencies (e.g. Frijda, 1987, 2004), and recent theoretical perspectives have elucidated embodied dimensions in emotions (Niedenthal, 2007; Goldman & de Vignemont, 2009). Given that listening to music has been found to activate motor areas of the brain (Chen, Penhune, & Zatorre, 2008; Fadiga, Craighero, & D'Ausilio, 2009; Grahn & Brett, 2007; Koelsch, 2010; Janata, 2005; Janata, Tomic, & Haberman, 2012), we may speculate that, when motor activation associated with music listening has a profile that is congruent with the spontaneous action readiness associated with the listener's affective state (e.g. fast tempo and high intensity matched with an aggression tendency), music would support (rather than diminish or interfere with) goal-directed attempts to maintain states of action readiness. That is, there would be less need for the listener to override prepotent response tendencies in order to maintain a readiness to resonate with (i.e., act 'in tune' and 'in time' with) the music. Given that the overriding of prepotent response tendencies has been found to deplete energetic resources and to diminish the capacity for subsequent acts of self-control (e.g. acts of attention control, emotion suppression or impression management: see Baumeister et al., 2007), listening to affect-matching music may be less resource-depleting (i.e. less 'effortful') than listening to affect-mismatching music, which would enable more resources to be devoted to subsequent tasks requiring self-control (presumably, each of the cognitive tasks we used in the experiments required self-control in the form of attention control) (see Swaine, this issue). These ideas may help to explain why preferences for music are directed to pieces that are emotionally congruent with a listener's internal state (Thoma et al., 2012; see also response synchronization: Scherer, 2005).

Some evidence compatible with our model and findings is provided in a study by

Tukaiev and Zima (2013), who found that participants who were affected by burnout expressed irritation and less than optimal brain activity following exposure to 'happy' music. Nevertheless, the experiments reported here are providing initial evidence that needs to be strengthened by future research. If our study can be considered relatively valid ecologically, being based on naturalistic rather than induced mood, methodological aspects need to be systematically explored in future studies. For example, mood induction proved effective in the developmental sample and may be used with adults to avoid cultural or personal interferences with reporting moods. This would also facilitate recruitment (there would be no need to find participants experiencing particular moods at a particular time) and support the planning of demographic, educational (e.g. type and extent of musical training) and cultural variables whose exploration would greatly refine our understanding of the benefits of music for cognitive functioning. Parameters of the experimental setting also need to be carefully diversified and controlled. Our experiments point to a potentially important effect of the duration of the mood-induction phase with children, hence such a variable would need to be taken into consideration if mood-induction was also adopted in adult studies. Finally, of particular importance is a systematic exploration of the tasks and measures to be used in future experiments, as it is possible that, at least in part, our results diverge from the 'arousal and mood' literature because of the task used in our experiments.

Future research must also thoroughly consider the musical variables, and possibly isolate and test different musical expressive cues both in isolation and systematically combined. The results with the developmental samples showed that when both mode and tempo varied across musical tracks, as in the sad/happy distinction, children displayed an affect-matching effect that was not found, instead, when children of the same age were exposed to music tracks differentiated by mode. Thus, multiple cues may facilitate affect-matching effects in naive listeners. This question could also be profitably explored contrasting naive versus expert listeners when considering musical variables.

In conclusion, our finding of an affect-matching effect supports a view of musical communication in which emotionally expressive signals are responsively modified to match the affective states of receivers, and provides further evidence to support the intuitive practices of parents (e.g. Stern, 2000) and music therapists (e.g. Ansdell &

Pavlicevic, 2005) who expressively 'mirror' or 'match' the infant's or client's affect. In this respect, we aim to develop a research programme that will specifically investigate ontogenetic and applied aspects of the proposed model. Concerning the latter, interesting developments may be considered, aiming to assess cognitive functioning in naturalistic settings in which, for example, the range of naturally occurring moods might be reduced and more stable with respect to a university campus (e.g. a dementia ward), and settings that would allow the use of trained music therapists to provide the music interactively.

Supplementary materials

The following MP3 audio files are submitted as supplementary material for the article: "Affect-matching music improves cognitive performance in adults and young children for both positive and negative emotions":

(1) Expts1&2_happy
(2) Expt1_angry
(3) Expt2_extraangry
(4) Expt3_happy
(5) Expt3_sad

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