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**Affective Priming in Music Listening:  
Emotions as a Source of Musical Expectation**

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### **Abstract**

Three behavioral experiments were conducted to investigate the hypothesis that perceived emotion activates expectations for upcoming musical events. Happy, sad and neutral pictures were used as emotional primes. In Experiments 1 and 2, expectations for the continuation of neutral melodic openings were tested using implicit task that required participants to judge the tuning of the first note of the melodic continuation. This first note was either high or low in pitch (Experiment 1) or followed either a narrow or wide melodic interval (Experiment 2). Experiment 3 assessed expectations using an explicit task, and required participants to rate the quality of melodic continuations, which varied in register and interval size. Experiments 1 and 3 confirmed that emotion indeed modulates expectations for melodic continuations in a high or low register. The effect of emotion on expectations for melodic intervals was significant only in Experiment 3, although there was a trend for happiness to increase expectations for wide intervals in Experiment 2.

**Keywords:** Music, Emotion, Priming, Expectation, Cross-modality.

### **Musical Expectation and Emotion**

Since Meyer's highly influential account of emotion and meaning in music (Meyer, 1956), it is well established that expectations are an important contributor to our perception and experience of music. Meyer defines meaning in terms of expectations: "[Tones] become meaningful only in so far as they point to, indicate, or imply something beyond themselves" (p.34). Furthermore, he highlights the role of expectations in evoking emotional responses to music: "Emotion or affect is aroused when a tendency to respond is arrested or inhibited" (p.14). This tendency to respond is conceptualized as the implied consequence of an event, which may also have the form of an anticipated resolution of a violation of an earlier expectation. Huron (2006) also argues that affect<sup>1</sup> in the listener may arise in anticipation of affectively loaded musical events, in close anticipation of an event, in the evaluation of the predicted outcome and the characteristics of the event, and in retrospective evaluation. This has clear parallels with emotional processes in domains other than music (e.g. Damasio, 1994; Mandler, 1975; Olson, Roese & Zana, 1996; Ellsworth & Scherer, 2003).

Whilst such cognitivist accounts of emotion and expectation in music have become generally accepted, they outline only one of multiple ways in which music may evoke an emotional response (Juslin & Västfjäll, 2008). Most models of emotional responses to music include a bottom-up physiologically driven account in which psychoacoustic characteristics – related to aspects of the performance and the composition – function as cues for emotional expression. Important cues are intensity, tempo, mode and pitch register (e.g. Coutinho & Cangelosi, 2010; Gabrielsson & Juslin, 2003; Juslin, 2000). Proposed mechanisms for emotional response to music include, among others processes of internal mimicry of the

perceived emotional expression, processes related to emotional conditioning, as well as autobiographical memory (Juslin & Västfjäll, 2008).

Apart from playing a role in emotional responses to music, expectations play a crucial role in the perception and performance of music. Schematic knowledge of frequently occurring pitch relationships, chord progressions, rhythmic categories, and melodic characteristics facilitates encoding of music, which in turn aids fluent production of music (e.g. Clarke, 1988; Palmer & Van de Sande, 1993; Sloboda, 1977; 1978) and enhances and shapes memory of music (e.g. Dowling, 1978; Dibben, 1994; Deutsch & Feroe, 1981). At a more local level, schematic expectations influence perception of rhythm and pitch categories (e.g. Clarke, 1987; Desain & Honing, 2003; Burns and Ward, 1978, Trehub and Hannon, 2006), and enhance the perceptual processing of event characteristics (e.g. Besson & Faïta, 1995; Bharucha & Stoeckig, 1986; Tillmann & Bharucha, 2002; Tillmann, Bigand, Escoffier, & Lalitte, 2006).

Stimulus generated bottom-up expectations based on short-term learning are equally powerful. Such “dynamic” expectations (Huron, 2006) may for example lead listeners to expect a repetition of a motive, a continuation of a melodic line based on the principle of good continuation (Meyer, 1956), a balance in phrase length (Ng, 2003, cited in Huron, 2006) or a continuation of performance characteristics (Timmers, 2003).

Perhaps not surprisingly, a growing body of literature investigates expectation processes in music perception. Literature includes formalisations of melodic expectations (Pearce & Wiggins, 2006; Schellenberg, 1997), neurophysiological investigations of conscious and subconscious perception of expectation violations (see Trainor & Zatorre, 2009), and comparisons between musical expectations among musically trained and

untrained listeners (e.g. Besson & Faïta, 1995) to name a few of the major trends. A persistent element in this literature is that the primary source for (top-down or bottom-up) musical expectations is assumed to be musical structure, which is generally the only source considered. The aim of the present investigation is to demonstrate the presence of a secondary source for musical expectations, which is emotion itself. In other words, we are interested in an interaction between emotion and expectation: expectations are a source for emotional responses to music (as argued by Meyer, 1956 and Huron, 2006 among others), but emotional responses may in turn be a source for musical expectations.

### **Emotions as a source for musical expectation**

Our hypothesis is that both perceived and induced emotion may activate associations with frequently co-occurring musical characteristics and so function as a prime for upcoming musical events. Previous research has shown that, in particular, basic emotions such as happiness, sadness, fear and anger are reliably and consistently communicated through music (Gabrielsson & Juslin, 2003). Particular structural characteristics are associated with particular emotions in a probabilistic manner, which allow emotions to be both expressed and perceived in music (e.g. Gabrielsson & Lindström, 2010; Juslin & Timmers, 2010). These characteristics also play an important role in evoking emotional response to music, possibly through a process of emotion contagion between expressed and felt emotion (Juslin & Västfjäll, 2008). We argue that these same associations form a basis to anticipate musical characteristics given an emotional context or primed emotion. For example, a musical (auditory) or cross-modal (e.g. visual) context may establish an anticipation of happiness, which in turn gives rise to the anticipation of happy sounding music. This includes associated characteristics such as a relatively high pitch register (Hevner, 1937; Collier & Hubbard,

2001), major tonality (Hevner, 1936 and many others), wider pitch intervals (Balkwill & Thompson, 1999; Maher & Berlyne, 1982) and a fast tempo (Hevner, 1937 and many others). Conversely, anticipated sadness may lead to the expectation of contrasting characteristics including a low pitch register, minor mode, narrow pitch intervals, and a slow tempo (see Gabrielsson & Lindström, 2010 for an overview).

We use the concept of emotional priming to refer to an associative priming in which emotional content increases the sensitivity to and processing of stimuli that are related in emotional terms. It can be differentiated from semantic priming by having an experiential basis rather than a linguistic basis: Associations between emotion and musical characteristics are established and reinforced through exposure to music.

It is noteworthy that perception of an emotional quality in music can be established within a very short time frame of 300 ms up to 1 second (Bigand et al, 2005; Krumhansl, 2010; Vieillard, Peretz, Gosselin, Khalfa, & Gagnon, 2008), which indicates that it is a readily available source of information. Indeed it is known from neuropsychological case studies (Peretz, Gagnon & Bouchard, 1998) that emotional content can be accessed to make evaluative judgements (e.g. sad or happy) without the ability to process musical structure. Fast activation of an emotional association with music means that we may sense that the music has changed from one emotion to another at the start of a new phrase, and adapt expectations for the continuation of the phrase accordingly. In songs, movies or live performances, the textual and/or visual context can function as source for emotional priming. Evidence for emotional visual images to function as a fast emotional prime is found for example in their effects on attention, sensory processing, and memory of visual scenes (Humphrey, Underwood & Lambert, 2012; Schupp et al, 2003; Todd et al, 2012).

Our hypothesis predicts that listeners expect musical characteristics to be in line with associated and anticipated emotional characteristics. This also includes for example that listeners emotionally engage with patterns of tension and release in music and expect music to continue to rise in tension, to dramatically fall in tension, or to change in emotional characteristic. These emotional expectations become a source of expectations for musical characteristics. As such, emotional engagement is not a passive following of expressive patterns in music, but a dynamic interplay with the music.

### **Supporting Evidence for Our Hypothesis – Prior Investigations**

Previous demonstrations of influences of emotion on cognition are numerous, but few have concerned music cognition. One way in which emotions affect cognition is that affective stimuli such as emotional faces, spiders or snakes tend to “attract” attention. This may be especially strong for fearful stimuli and for anxious participants or participants with fear for a particular target (Yiend, 2010; Öhman, Flykt, & Esteves, 2001). However, these attentional effects have also been demonstrated for positive emotional stimuli (e.g. Holmes, Bradley, Kragh Nielsen, Mogg, 2009; Plichta, Gerdes, Alpers, Harnisch, Brill, 2010). A second way in which emotions may affect cognition is by influencing our evaluations of a situation, person or object. Affective experiences may be correctly attributed to the evaluated stimuli and form a conscious or subconscious source of information (Bechara, Damasio, Tranel, & Damasio, 1997; Damasio, 1994). Experienced emotions may also be misattributed to the evaluated stimulus and bias judgments unwillingly (Schwarz & Clore, 1983; Johnson & Tversky, 1983; Wilson & Brekke, 1996; Winkielman, Zajonc, & Schwarz, 1997).

Most relevant to our hypothesis are findings that emotion influences and informs perception and cognition by strengthening emotion-congruent associations. Bower (1981) has

shown this in memory tasks as well as perceptual tasks and proposed a simple neural network model to explain his findings in which emotions were represented as units in a neural network that excite and are excited by related semantic units. Evidence for his model has been found, for example, by Niedenthal and colleagues (1999) who demonstrated that pictures can be sorted based on affective information rather than only structural information and that such affective associations are more frequently done after mood-induction. However, others find the network associational model too general and argue that influences of emotion apply only in specific contexts. According to Forgas (1995) affect “infusion” is most likely in contexts that involve constructive processing such as in autobiographical recall or free association tasks. Others have found specific patterns of influences. For example, while high anxiety often leads to a shift in attention towards fearful stimuli, depression tends to be associated with more negative memories (e.g. Yiend, 2010).

As regards the applicability to music, it is noteworthy that emotion-congruent effects on memory and cognition have been demonstrated to be strong in the processing of movie scenes. This may not be surprising if we consider that movies (and their accompanying music) often evoke strong emotional responses and require constructive processing of interpretation and meaning. Mood inducing music has been shown to influence the interpretation of visual content and narrative (Boltz, 2001; Shevy, 2007) and influence recall of movie scenes (Boltz, 2003; Boltz et al, 1991), which can be attributed to a directing of attention to specific items within film excerpts.

For similar reasons, we expect that affect infusion processes occur when listening to music. Listeners often experience music emotionally and music is an open ended and often ambiguous stimulus. Houston and Haddock (2007) have demonstrated a mood-congruent

effect on the recall of melodies: melodies in a major tonality were better remembered when learned in a happy mood, than melodies in a minor tonality, which were better remembered when learned in a sad mood. Boltz et al (2009) have started to explore the influence of emotional visual stimuli on the perception of music and found that accompanying affective stimuli (pictures and movies) indeed influence evaluation of musical characteristics such as its tempo. Further support for cross-modal affective influences on sensory cognition is provided by Weger et al (2007), who found an influence of valenced words on judgments of high and low pitches. Others have found that the presentation of emotional visual and auditory information – including musical information – reinforces each other when presented simultaneously and when emotionally congruent (Baumgartner, Esslen, Jäncke, 2006). In case of emotionally ambiguous stimuli, emotional stimuli in another modality influence emotional evaluations even when asked to ignore the other modality (Spreckelmeyer et al, 2006). These studies do not test musical expectation, but they provide support for the general hypothesis that emotional context interacts with perception of music, possibly including musical expectation.

### **The Current Study**

In our study, we tested whether emotional priming influences listeners' expectations concerning the continuation of (neutral) melodic openings. Emotion was primed using affective pictures to vary it independently of the musical material. Affective pictures<sup>2</sup> have been regularly and effectively used as an emotional prime (e.g. Carroll & Young, 2005; Hart, Green, Casp & Belger, 2010; see also Lang, Bradley, Cuthbert, 1998). Brief exposure to emotional stimuli may not evoke an emotional response. Nevertheless, they activate an

association with a certain emotional state and as such influence attentional and perceptual processes (e.g. Schupp et al, 2003).

The beginning of a melody was presented together with a happy, sad or neutral picture. The melodic start was assumed to be a first source of musical expectation, while the cross-modal prime was predicted to be a second source of musical expectation. The melodic start could continue in two ways – one continuation was congruent with a happy emotional association, while the other continuation was congruent with a sad emotional association. The hypothesis was that depending on the primed emotion, expectations for one or the other continuation would be enhanced. The emotion-congruent musical characteristics we examined in this study were pitch register, which can be higher or lower (congruent with happy and sad, respectively), and melodic interval, which can be narrower (stepwise motion, congruent with sad) or wider (larger differences between pitches, congruent with happy).

Three experiments were run to test the hypothesis of emotion-elicited musical expectations. The first two experiments tested the hypothesis by measuring expectations indirectly: The assumption was that if a certain musical continuation is primed / expected, perceptual processing of this continuation would be faster and more accurate. In these experiments, participants judged the tuning of the first note that was different between the two continuations. The tuning could be in-tune or detuned  $\frac{3}{10}$  of a semitone. The two experiments were the same in procedure and very similar in material, except that the first experiment tested emotional priming of a certain musical register (high or low), while the second experiment tested emotional priming of melodic interval sizes (narrow or wide). Participants did Experiments 1 and 2 in one session in counter-balanced order.

The third experiment tested the hypothesis using an explicit measure of self-report: participants (different from Experiments 1 and 2) rated the appropriateness of melodic continuations. A neutral melodic opening was first presented together with a visual image. Thereafter, the melodic opening and continuation were presented without a visual image and the participants rather the fit of the melodic continuation. Melodic continuations differed in register and interval size.

In all three experiments, most participants were musically trained. We assume that this decision has increased the chance to obtain a reliable effect.

### **Experiment 1: Effects of Emotional Priming on Speed and Accuracy of Tuning Judgments of Continuations Differing in Pitch Register**

#### **Method**

##### Participants

36 volunteers participated in the experiment, (25 women, 11 men,  $M_{age} = 22.5$  years,  $SD = 4.5$ ). Most participants were musically trained and had received music lessons for at least five years ( $N = 30$ ). Even though we aimed to also recruit non-musicians, the majority of the volunteers who responded to our call were musically trained. All except two participants were students at undergraduate or graduate level and the majority studied music or a music related subject like psychology of music ( $N = 22$ ). The six non-musicians had taken less than 5 years of music lessons in their life and did not actively play an instrument.

##### Materials

Two musical openings were used, each paired with two melodic continuations. The two continuations belonging to a melodic opening were identical except for a difference in

register: One continuation was an octave higher than the other continuation (see Figure 1).

Note that each melodic opening has its own unique continuations.



Figure 1: Melodic openings paired with two continuations that differ in melodic register.

The melodic openings were composed to be emotionally neutral: the melody in minor mode had larger intervals (consisting of broken chords), while the melody in major mode had narrow (stepwise) intervals and the contours were mixed (up and down or down and up). A test of the stimuli was run to check whether these melodic openings indeed did not have a strong emotional connotation. 7 participants evaluated the stimuli on a scale from 0 to 3, with consecutive numbers referring to “not at all” (0), “a bit” (1), “moderately” (2), and “strongly” (3). Perception of emotions was generally weak and all means were below 2 (“moderately”), confirming that the openings did not have a strong emotional connotation. They did not sound very neutral either. Evaluations of felt emotion had mean ratings below 1. Participants agreed moderately with the statement that the music did not make the participant feel an emotion ( $M = 1.57$ ,  $SE = 0.528$ ;  $M = 1.71$ ,  $SE = 0.421$ , for Openings 1 and 2 respectively).

Opening 1 sounded a bit neutral ( $M = 1.29$ ,  $SE = 0.474$ ) and a bit happy ( $M = 1.29$ ,  $SE = 0.360$ ), but not sad ( $M = 0.000$ ,  $SE = 0.000$ ). Opening 2 was evaluated as sounding to some extent neutral ( $M = 1.57$ ,  $SE = 0.429$ ), but not happy ( $M = 0.57$ ,  $SE = 0.297$ ) or sad ( $M = 0.86$ ,  $SE = 0.404$ ).

One potentially confounding factor for expected melodic continuations was the distance between the last note of the melodic opening and the first note of the continuation. For the major melody, the distance is smaller when the melody continues in a lower register (four semitones down compared to eight semitones up). For the minor melody, the distance is slightly smaller when the melody continues to the higher register, but this difference is modest (five semitones up compared to seven semitones down). The results for the two melodies were averaged to counter-balance intrinsic structural implications, nevertheless this intrinsic bias for the major melody remains present.

A piano sound with well-tempered tuning was used to play the melodies. The excerpts were 6 seconds in duration and the tempo was 80 quarter notes per minute. In the conditions with a detuned target note (first tone of the second bar), the target note was  $\frac{3}{10}$  of a semitone lower than equal temperament tuning. An equal number of trials contained in-tune or out-of-tune target notes. Previous studies used a detuning of a quarter tone (e.g. Bharucha & Stoeckig, 1986). However, in pilot testing, we found this degree of detuning too clearly apparent. To avoid ceiling effects, we decreased the detuning to  $\frac{3}{10}$  of a semitone.

#### Emotional Priming

Affective pictures were used to prime emotional associations (happy, sad or neutral). To prime sadness or happiness, 18 pictures from the IAPS database were used (International Affective Pictures Sample, Lang, Bradley, & Cuthbert, 2008). These pictures showed broadly smiling and happy people or cheerful looking animals, or sadness-inducing scenes containing sad-looking people, such as pictures of a funeral. For the neutral condition, black neutral shapes against a white background were used (a diamond, square, circle etc., 6 in total).

## Procedure

Participants were first familiarized with the four melodies that they would hear in the experiment: the melodies were performed twice in random order and participants were asked to listen to the melodies and to try to memorize them. This familiarization part was introduced to set up expectations for the melodies: participants knew which two melodic continuations to expect after a particular melodic opening.

Next, participants practiced judging the tuning of the target note. The location of the target tone was identified using a diagram that showed a graphical representation of a melody with a star above the target tone. Participants had 4 trials to practice the task and received feedback after each trial. If they were confident with the task, they continued with the instructions for the full experiment.

Participants were instructed that they had three tasks: 1) imagine the emotion portrayed by the picture, 2) judge the tuning of the target tone, and 3) rate the emotion of the picture after the melody had sounded. This rating was done using a scale from 1-7 (from sad to neutral to happy). They were instructed to make the tuning judgment as fast as possible, while being as accurate as possible.

When they understood this, they continued with the experiment, which consisted of 48 trials (2 melodies x 2 continuation x 2 tuning x 3 emotions x 2 repetitions). Affective pictures were shown 1 second before the melody began and stayed on screen for the entire duration of the melody. Despite the concurrence of visual and auditory information, we nevertheless conceptualize the process as emotional priming, given that an expectation for a melodic continuation is tested: Prior emotional information influences the expectation for a melodic continuation.

At the start of each trial and before the presentation of the affective picture, participants were reminded to judge whether the target tone was in-tune (Yes) or out-of-tune (No). They gave their answer by pressing one of two color-coded buttons on the keyboard. After the presentation of the picture and the melody, a text prompt would ask participants to rate the emotion of the picture. Psyscope was used to run the experiment and record reaction times and answers.

### **Results: Experiment 1**

#### Emotion Rating of Affective Pictures

To test the perceived emotion of the pictures, a repeated measures ANOVA was run with emotion (3 levels) and register (2 levels) as independent variables and emotion rating as dependent variable. As expected the main effect of emotion was highly significant ( $F(2,70) = 465, p < .001, r = .96$ ) and this effect was very strong. The neutral pictures were most consistently rated as neutral ( $M = 4.0, SE = 0.06$ ). The happy and sad pictures showed larger variability in ratings. Nevertheless, they were clearly recognised as happy or sad with mean values close to the extremes of the rating scale ( $M = 6.02, SE = 0.10$  and  $M = 1.76, SE = 0.09$  for happy and sad pictures, respectively). The effect of primed emotion was strong and the ratings were different for all pair-wise comparisons using Bonferroni correction for multiple testing ( $p < .001$  in all instances).

Additionally, the main effect of register was significant ( $F(1, 35) = 5.17, p = .029, r = .36$ ). This was a medium strong effect. Pictures accompanying a higher register continuation received on average a slightly higher rating ( $M = 4.0, SE = 0.045$ ) than pictures accompanying a lower register continuation ( $M = 3.87, SE = 0.036$ ). This effect suggests that

the register of the melodic continuation affected the perceived emotion of the pictures.

Pictures were perceived as happier when combined with a high register continuation.

The interaction between the effects of register and emotion was not significant.

Ability to Detect The Detuned Note (Proportion Correct Response).

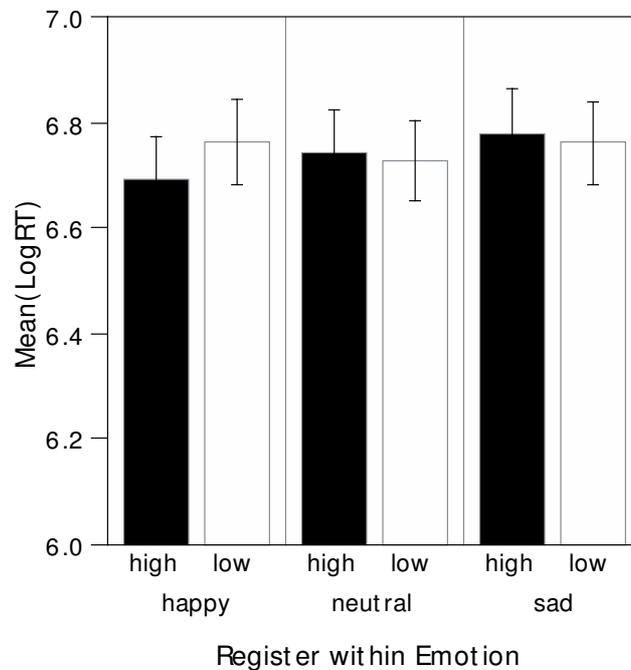
The effects of emotion and register and the interaction between these effects on the ability to detect the detuning of the target note was tested using a repeated measures ANOVA and proportion correct response (PC) as dependent variable. None of the effects were significant. There was no significant main effect of emotion ( $F(2,68) = 0.585$ ,  $p = .560$ ), and no significant main effect of register ( $F(1,34) = 1.022$ ,  $p = .319$ ). The interaction between the effects of emotion and register was also not significant ( $F(2,68) = 0.146$ ,  $p = .864$ ). The ability to detect the detuning was invariably high independent of register or emotion ( $M = 0.915$ ,  $SE = 0.021$ ).

Note that the PC data was pointy due to a clustering of values close to the maximum of 1, violating to some degree the assumptions of normally distributed data. Therefore the effect of register was tested using a non-parametric test (related samples Wilcoxon signed rank test) for each emotion. None of these tests were significant, confirming the non-significant results obtained in the repeated measures ANOVA results.

Reaction Times

A similar repeated measures ANOVA was run with reaction times as a dependent variable to test whether the reaction times were affected by emotion and register. Reaction times were first transformed using a log transformation to correct for skewness in the data. The reaction times peaked around 1000 ms with occasional later responses. The log transformation brought these later responses within a more normal range.

There was no significant main effect of emotion ( $F(1.51, 51.2) = 2.58, p = .099$ , using Greenhouse-Geisser's correction for violations of the assumption of sphericity). There was also no main effect of register ( $F(1,34) = 0.086, p = .77$ ). There was a significant interaction between emotion and register ( $F(2,68) = 3.79, p = .028, r = .33$ ). This interaction is plotted in Figure 2 using log-transformed data. Note that a mean log reaction time of 6.719 corresponds to a reaction time of 828 ms.



*Figure 2:* Means and standard errors of the log-transformed reaction times of the tuning judgments of the first note of the high or low register continuation in the happy, neutral, and sad conditions. The graph illustrates the interaction between emotion and register.

Figure 2 shows that the interaction was in the predicted direction: responses to high register continuations are relatively fast in happy contexts, but relatively slow in sad contexts. Simple tests of the effect of register on reaction times indicated that the difference in reaction

times between the high and low register was significant for the happy context only ( $t(34) = -2.64, p = .012$ ).

The presence of a similar dependency on emotion of reaction time responses for melodic continuations was predicted for continuations varying in interval size, as tested in Experiment 2.

### **Experiment 2: Effects of Emotional Priming on Speed and Accuracy of Tuning Judgments of Continuations Differing in Melodic Interval Size**

Experiment 2 had the same aim as Experiment 1 and followed the same procedure, except that the melodic continuations differed in interval size rather than register.

#### **Method**

##### Participants

The same 36 participants participated in this experiment as in Experiment 1.

##### Materials

Two musical openings were used, each paired with two melodic continuations that were similar in contour and melodic material, but differed in melodic interval size. One continuation consisted of stepwise intervals, while the other contained larger intervals. The two continuations differed from the second note onwards (second note of the second bar, see Figure 3), which was the target note that was either in tune or out-of tune. Note that each melodic opening had its own unique continuations.

The melodic openings were composed to be emotionally neutral: the melody in minor mode had larger intervals, while the melody in major mode had narrow intervals, and the contours were mixed (up and down or down and up). The interval size of the openings

provides structural implications for the continuations. To counter-balance these structural implications, the results for the two melodies were averaged.

A test of the stimuli was run to check whether the melodic openings indeed lacked a strong emotional connotation. 7 participants evaluated the stimuli on a scale from 0 to 3, with consecutive numbers referring to “not at all” (0), “a bit” (1), “moderately” (2), and “strongly” (3). Perception of emotions was generally weak and all means were below 2 (“moderately”), confirming that the openings did not have a strong emotional connotation, although they did not sound very neutral either. Evaluations of felt emotion had mean ratings below 1. Agreement with the statement that the music did not make the participant feel an emotion was stronger ( $M = 1.29$ ,  $SE = 0.522$ ;  $M = 2.00$ ,  $SE = 0.309$ , for Openings 1 and 2 respectively).

Mean ratings showed that Opening 1 sounded to some extent neutral ( $M = 1.57$ ,  $SE = 0.429$ ) and to some extent happy ( $M = 1.86$ ,  $SE = 0.340$ ), but not sad ( $M = 0.000$ ,  $SE = 0.000$ ). Opening 2 was evaluated as sounding to some extent neutral ( $M = 1.71$ ,  $SE = 0.421$ ), a bit sad ( $M = 1.00$ ,  $SE = 0.436$ ), but not happy ( $M = 0.43$ ,  $SE = 0.202$ ).

The same tempo, piano timbre and tuning was used as in Experiment 1. The duration of the excerpts was again 6 seconds long. In out of tune conditions, the target note was 3/10 of a semitone lower than equal temperament.



Figure 3. Melodic openings of Experiment 2 paired with two continuations that differ in melodic interval size.

## Procedure

The same procedure was followed as in Experiment 1: first, participants were familiarised with the melodies to set up expectations for both continuations of a melodic opening. Secondly, participants practiced the in-tune / out-of-tune judgment task. Finally, in the actual experiment, participants judged the tuning of the target tones while imagining the emotion of the affective pictures shown simultaneously. At the end of each trial, participants rated the emotion of the shown picture on a scale from 1-7, which ranged from sad (1) to neutral (4) to happy (7).

## **Results: Experiment 2**

### Emotion Rating of Affective Picture

To test the perceived emotion of the pictures, a repeated measures ANOVA was run with emotion (3 levels) and register (2 levels) as independent variables and emotion rating as dependent variable. As for Experiment 1, the main effect of emotion was highly significant ( $F(1.15, 40.4) = 440, p < .001, r = .96$ , using Greenhouse-Geisser's correction for violations of the assumption of sphericity) and this effect was very strong. The neutral pictures were most consistently rated as neutral ( $M = 3.96, SE = 0.05$ ). The happy and sad pictures showed more variability in ratings, but were nevertheless clearly recognised as happy or sad, with mean values a bit below or above the extremes of the rating scale ( $M = 5.95, SE = 0.11$  and  $M = 1.80, SE = 0.096$  for happy and sad pictures, respectively). The effect of emotion was strong and the ratings were different for all pair-wise comparisons between the happy, sad, and neutral conditions using Bonferroni correction for multiple testing ( $p < .001$  in all instances).

The main effect of interval on emotion judgment was not significant ( $F(1,35) = 1.77$ ,  $p = .192$ ), nor was the interaction between emotion and interval ( $F(2,68) = 0.18$ ,  $p = .836$ ).

#### Ability to Detect the Detuned Note (Proportion Correct Response)

A repeated measures ANOVA was run with emotion and interval size as independent variables and PC as dependent variable to investigate whether the ability to detect the detuned target note varied with mood-congruency of the continuation. No main effect of emotion was observed ( $F(2, 70) = 0.272$ ,  $p = .573$ ). The main effect of interval size was marginally significant ( $F(1, 35) = 4.450$ ,  $p = .042$ ,  $r = .336$ ). The interaction between the effects of interval size and emotion was non-significant ( $F(2, 70) = 0.446$ ,  $p = .642$ ).

Table 1. Mean PC and SE for each emotion and interval size condition.

Emotion	Interval	Mean PC	SE
Happy	Narrow	.831	.030
Happy	Wide	.875	.024
Neutral	Narrow	.811	.032
Neutral	Wide	.881	.024
Sad	Narrow	.836	.030
Sad	Wide	.881	.028

As in Experiment 1, the distribution of PC violated the assumptions of normal distribution by showing a clustering of high values. Therefore the effect of interval was tested using a non-parametric test (related samples Wilcoxon signed rank test). These non-parametric tests confirmed a significant effect of interval size on PC ( $p = .047$ ). The detection ability tended to be less good for narrow intervals ( $M = .826$ ,  $SE = .028$ ) than wide intervals ( $M = .879$ ,  $SE = .022$ ). Tests for each emotion separately showed that the effect of interval size on PC was significant for the neutral contexts only ( $p = .013$ ). For the happy and sad contexts, the differences in PC between narrow and wide conditions were not significant ( $p = .221$  and  $p = .151$ , respectively). However, the difference in judgment of narrow and wide intervals was in the same direction in happy and sad contexts as in neutral contexts (see Table

1), confirming a main effect of interval rather than indicating an interaction effect between emotion and interval.

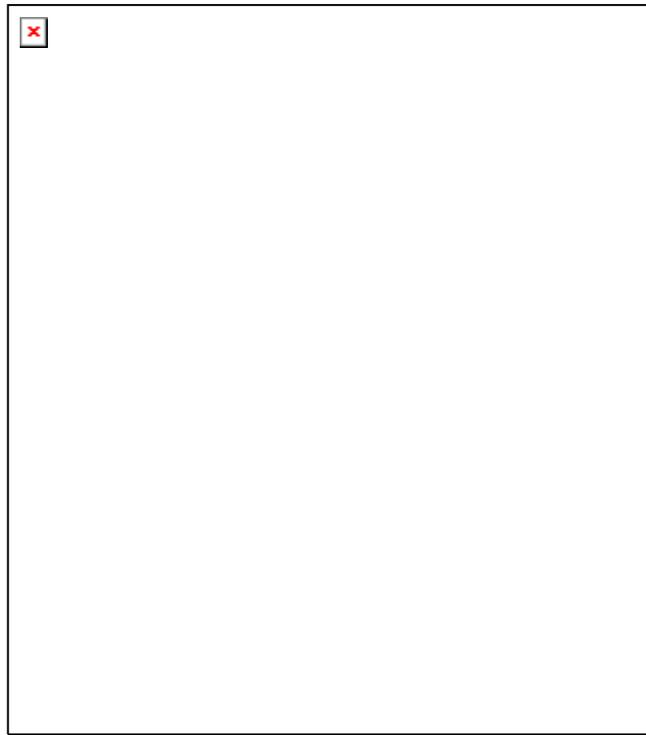
#### Reaction Times

To test whether the reaction times were affected by emotion and interval, a similar ANOVA was run with reaction times as dependent variable. The data were first transformed to correct for skewness of the data by taking the log of the reaction times.

There was a main significant effect of interval on reaction times ( $F(1,35)=5.559$ ,  $p = .024$ ,  $r = .37$ ). Judgments of target tones following a wide interval were on average faster ( $M = 6.787$ ) than judgments of target tones following narrow intervals ( $M = 6.831$ ). The effect of emotion was non-significant ( $F(2,70) = .178$ ,  $p = .837$ ), and the interaction between emotion and interval was non-significant ( $F(2,70) = .686$ ,  $p = .507$ ). Nevertheless, when we tested the single effects of interval on reaction times for each emotion<sup>1</sup>, the effect of interval was significant for happy contexts ( $t(35) = 2.414$ ,  $p = .021$ ), but non-significant for neutral and sad contexts ( $t(35) = -1.066$ ,  $p = .294$ ,  $t(35) = -1.606$ ,  $p = .117$ , respectively). Figure 4 shows the means of log-reaction times per interval and emotion. Although there is a general trend for responses to be faster to wider intervals, this difference is minimal for the neutral condition and particularly strong for the happy condition.

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<sup>1</sup> The interaction between emotion and interval is significant if only happy and neutral contexts are considered, suggesting that the non-significant interaction is related to a lack of statistical power.



*Figure 4:* Means and standard errors of the log-transformed reaction times of the tuning judgments of the second note of the continuation that was a narrow or small interval apart from the first note of the continuation and was presented in a happy, neutral or sad context. The graph illustrates the interaction between the effects of emotion and interval size on the dependent variable log Reaction Time.

### **Discussion of Experiments 1 and 2**

In Experiment 1, participants detected the detuning of the target note well irrespective of register and emotional context, but the speed of the responses was influenced by an interaction effect between register and emotion. Confirming our hypothesis, in happy contexts, responses to high register continuations were faster than responses to low register continuations. This benefit of responses to high register versus low register was not present for neutral and sad contexts.

The results of Experiment 2 did not unambiguously support our predictions. The detection accuracy of the target tones was good, but less consistently good than in Experiment 1. One of the reasons may have been that the target tones were at a weak metrical position rather than a strong metrical position. Target tones following a narrow interval were in general less well detected, although this effect was in particular significant in the neutral context. A benefit of detecting mistunings in wide intervals was confirmed in a significant effect of interval size on reaction times. However, faster reaction times for wide intervals compared to narrow intervals was in particular significant for happy contexts, and not for neutral contexts.

The simple interpretation of the results of Experiment 2 is that there was no reliable interaction between interval and emotion and only a main effect of interval. It may also be true that there was an interaction between emotion and interval, which was masked by lack of statistical power. In any case, the results for happy and sad contexts were similar and the neutral context was the deviant context. It is of particular interest to see that the responses to wide intervals in happy contexts were faster than to narrow intervals, despite this wider interval being relatively low in pitch, supporting the association between wide and happy. In contrast, the association between sad and wide intervals in the context of this experiment is confounded with an association between sad and low pitch. This confound between wide and low pitch may have weakened the contrast between expectations for musical continuations in the happy and sad conditions.

In the final experiment, the effects of register, interval, and emotion were manipulated in a factorial manner, avoiding the possibility for a confound between associations with register and with interval size. Additionally, the experiment used an explicit measure of

quality evaluation to test musical expectations. Although reaction time and accuracy are interesting measures to use, they may not be the most robust measures, being relatively sensitive to random variability due to context factors or personal variability.

### **Experiment 3: Effects of Emotional Priming on The Quality of Melodic Continuations**

This final experiment tested the effect of emotion-elicited expectations on listeners' explicit responses by asking participants to judge the appropriateness of a continuation. Continuations varied in register and in melodic interval size.

#### **Method**

##### Participants

41 volunteers participated in the experiment, who had not participated in the previous two experiments (27 women and 14 men,  $M_{age} = 31.38$  years,  $SD = 11.62$ ). Two thirds of the participants were musically trained and had received music lessons for at least five years ( $N = 28$ ). Among the participants were students (of music or other subjects), music educators, and academic and non-academic personnel from the University of Sheffield. The non-musicians had received less than five years of formal musical training and were not actively playing an instrument.

##### Materials

Two melodic openings were used, each paired with four continuations. These continuations varied register and interval size in a factorial manner: two registers (high and low, see left and right panels in Figures 5 and 6, respectively) were combined with two interval sizes (narrow and wide, see top and bottom panels, respectively). The narrow continuations contained stepwise melodic intervals, while the wide continuations contained melodic intervals of fourths and fifths.

The melodic openings were composed to be “neutral” in affect: the melody in minor mode had larger intervals, while the melody in major mode narrow intervals, and the contours were mixed (up and down or down and up). These wide and narrow intervals provide structural implications for the continuations. The results for the two melodies were averaged to counter-balance the intrinsic structural implications.

7 participants evaluated the stimuli on a scale from 0 to 3, with consecutive numbers referring to “not at all” (0), “a bit” (1), “moderately” (2), and “strongly” (3). Perception of emotion was hardly ever strong and means were generally below the level of “moderately”. Similarly, evaluations of felt emotions had means below 1. Evaluations of the statement that the music did not make the participant feel an emotion were higher than 1 ( $M = 1.14$ ,  $SE = 0.553$   $M = 1.57$ ,  $SE = 0.571$ , for Openings 1 and 2 respectively).

Mean ratings showed that Opening 1 sounded to some extent neutral ( $M = 1.14$ ,  $SE = 0.508$ ) and to some extent happy ( $M = 1.71$ ,  $SE = 0.421$ ), but not sad ( $M = 0.000$ ,  $SE = 0.000$ ). Opening 2 was evaluated as sounding to some extent neutral ( $M = 1.57$ ,  $SE = 0.429$ ), a bit happy ( $M = 1.00$ ,  $SE = 0.378$ ) but not sad ( $M = 0.57$ ,  $SE = 0.429$ ).



Figure 5. Melody 1 with continuations 1-4. The four continuations differ in interval size (top and bottom panels) and in register (left and right panels).

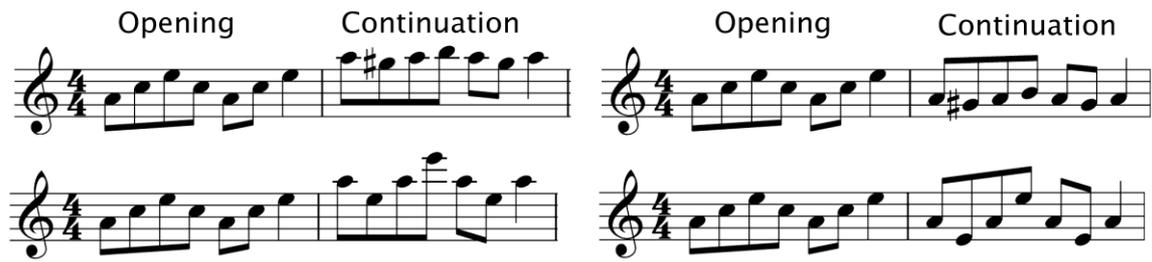


Figure 6: Melody 2 with continuations 1-4. As for melody 1, the four continuations differ in interval size (top and bottom panels) and register (left and right panels).

A piano sound with well-tempered tuning was used to play the melodies. The excerpts were 7.3 seconds in duration and the tempo was 62.5 quarter notes per minute. The tempo, dynamics and articulation characteristics were based on a neutral performance of the material by a professional pianist. These characteristics were used to generate one standard performance for all material.

### Emotional Priming

As in the previous experiment, emotional priming was realised using affective pictures, which was varied within participants. The 3 happy pictures depicted broadly smiling and cheerful looking people, while the 3 sad pictures depicted depressed and grim looking individuals. The 3 neutral pictures showed neutral objects for example a table or wheel. These pictures were piloted and found effective in a previous unpublished experiment.

### Procedure

Participants were asked to rate how well the continuation fitted the melodic opening on a scale from 1-7, where 1 meant bad fit, and 7 meant good fit. It was also explained that the differences between the continuations were quite subtle and none of the continuations would fit very badly. Within a trial, the melodic opening was always presented first followed

by a presentation of the complete melody. Participants made their judgment after the presentation of the complete melody.

Participants had two practice trials before continuing with the main experiment, In the main experiment, the three factors of register, interval and emotion were varied within participants to create 24 trials: each melody was combined with 4 melodic continuations and presented in the context of three emotions (2 melodies x 2 registers x 2 intervals x 3 emotions). The order of trials was randomized.

Affective pictures were presented with the presentation of the melodic start and participants were asked to imagine the emotion of the picture while listening to the music. The affective picture was not shown during the presentation of the whole melody (opening and continuation). Psyscope was used to run the experiments and record the answers.

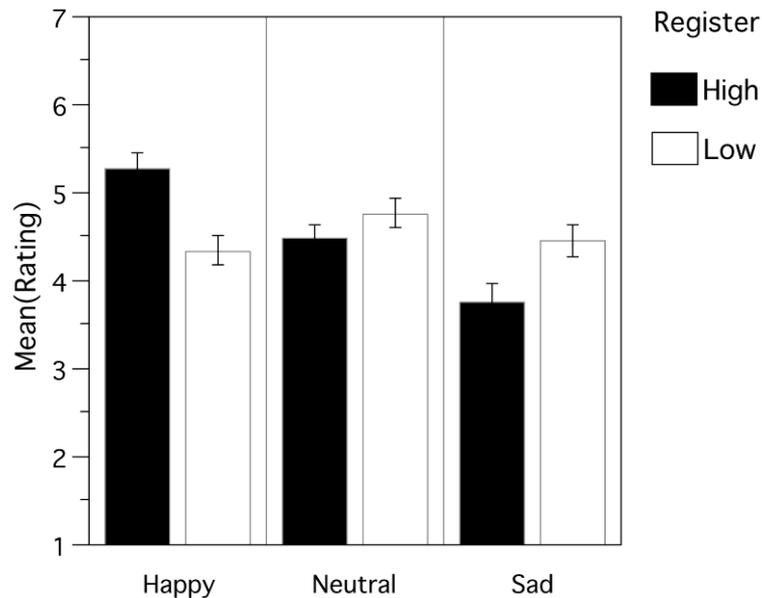
### **Results: Experiment 3**

A repeated measures ANOVA was run with emotion, register and interval as within subjects variables. The dependent variable was the rating of the fit between the opening and the continuation. The ANOVA showed a main effect of emotion ( $F(1.61,64.38) = 9.653$ ,  $p = .001$ , using Greenhouse Geisser's correction for violations of sphericity). Sad continuations received overall a lower rating ( $M = 4.113$ ,  $SE = 0.168$ ) than the neutral and happy continuations ( $M = 4.625$ ,  $SE = 0.129$ ;  $M = 4.808$ ,  $SE = 0.146$ , respectively), indicating a worse fit of the music with a sad than with a neutral or happy prime. The ANOVA showed no main effect of register ( $F(1,40) = 0.02$ ,  $p = .89$ ) and no main effect of interval ( $F(1,40) = 0.42$ ,  $p = .52$ ).

Most importantly for our hypothesis, the ANOVA showed a strong and significant interaction between emotion and register ( $F(2,80) = 21.116$ ,  $p < .001$ ,  $r = .588$ ) and a

significant interaction between emotion and interval ( $F(2,80) = 3.298, p = .042, r = .276$ ).

The three-way interaction between emotion, register and interval was non-significant ( $F(2,80) = 1.661, p = .196$ ).

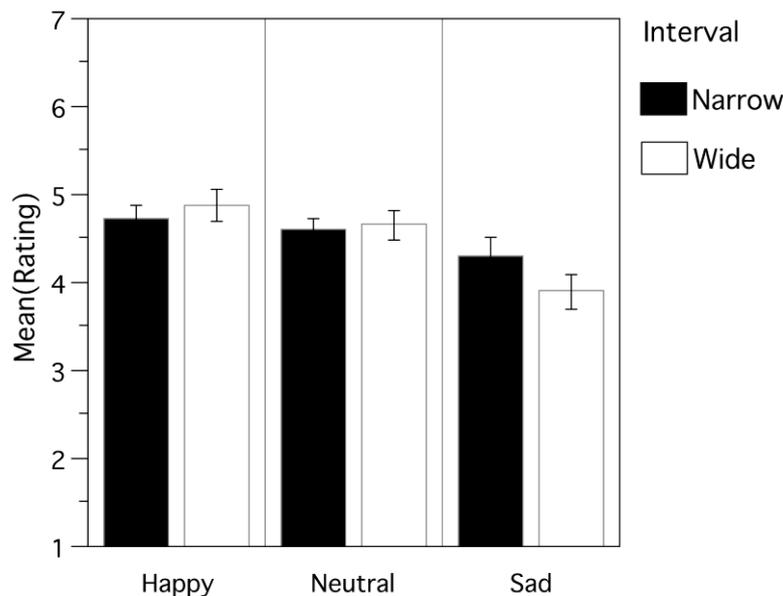


*Figure 8.* Means and standard errors of the ratings of the continuations with high and low register in the context of happy, neutral and sad pictures. The graph illustrates the interaction between register and emotion.

Figure 8 shows the relevant means for the interaction between register and emotion. It shows as predicted that, in happy contexts, the high register was perceived as a better fit than the low register ( $t(40) = 5.106, p < .001$ ). In sad contexts, the lower register was rated as a better fit than the high register ( $t(40) = -3.942, p < .001$ ), while in the neutral contexts, the two registers received an equal rating ( $t(40) = -1.52, p = .136$ ).

Figure 9 shows the interaction between emotion and interval. The results were partly as predicted: in sad contexts, continuations with smaller intervals were perceived as a better fit than continuations with wide intervals ( $t(40) = 2.257, p = .030$ ). In neutral contexts, but

also in happy contexts, the continuations with wide and small intervals did not receive significantly different ratings ( $t(40) = -0.330$ ,  $p = .743$  for neutral contexts and  $t(40) = -0.939$ ,  $p = .353$ , for happy contexts).



*Figure 9: Means and standard errors of the ratings of the continuations with narrow and wide intervals in the context of happy, neutral, and sad affective priming. The graph illustrates the interaction between emotion and interval size.*

### General Discussion

The three experiments have, at least to some extent, confirmed the hypothesised interaction between emotion and expected continuation. They demonstrated that affective images can activate the expectation for continuations with particular characteristics in listeners with extensive musical training. Experiment 3 suggested that the results may also extend to listeners without formal musical training. Nevertheless, the dependency of the effects on musical background warrants further investigation, taking into account that

background and musical familiarity may strengthen and influence associations between musical characteristics and emotions.

The evidence for the interaction between emotion and register was consistent and clear, with strong interaction effects in Experiments 1 and 3. The interaction between emotion and interval was weaker. Part of the reason for this weaker result may have been the less salient metrical position of the interval variations. Replication of the experiments with interval variation at a metrically accented position would make the results for register and interval more directly comparable.

The particular effect of emotion on interval varied with experiment. While in Experiment 2, the association between happy contexts and wide intervals was confirmed in faster responses to wider intervals. Experiment 3 showed a preference for narrow intervals in sad contexts, but did not confirm the association between wide intervals and happy contexts. Nevertheless, the trend in ratings in Experiment 3 of narrow and wide intervals for happy contexts was opposite to the difference in ratings for the sad contexts. The difference between the results of Experiments 2 and 3 may be related to their measurement methods. In particular, the results of Experiment 2 may have been influenced by a processing advantage of wide intervals over narrow intervals. It may have been easier for participants to detect detunings of a perfect interval - a fifth or a fourth melodic motion to the dominant, than of a more ambiguously tuned semi-tone interval to the seventh scale degree (leading tone). It is unlikely that similar processing disadvantages played a role in Experiment 3, given that that experiment concerned an unspeeded task and the intervals were not detuned.

Indeed, in general, the results of Experiment 3 were stronger compared to Experiments 1 and 2, which indicates a better “signal to noise” ratio in Experiment 3 than in

the first two experiments. This could be related to more “calculated” responses by participants in Experiment 3 given that these were explicit responses rather than implicit. On the other hand, it could also be due to less interference of extraneous factors in Experiment 3 than in Experiments 1 and 2. Reaction times are easily affected by extraneous factors, for detection accuracy depends not only on the participants’ skill to detect the deviation, but also on his or her level of concentration.

What are the implications of these findings for our understanding of music cognition and auditory cognition more generally? We have demonstrated that emotional associations primed through the visual domain interact with auditory cognitive processes: visual images influenced schematic expectations that have been assumed to function primarily within a musical – auditory domain. The ability of the emotion of visual images to influence musical expectations highlights that emotions implied through a different source “enter” the processing of the musical material and are used as if relevant for the musical material. Previous literature has already shown the interaction between mood and memory for music and between mood and evaluations of the emotion of music (Houston & Haddock, 2007; Hunter, Schellenberg & Schimmack 2010). The current findings add an important implication of the relevance of emotion for the cognitive processing of music.

The ultimate goal of the investigation was to find a way to investigate the role of emotions in the music perception process, starting from the intuition that emotions are not solely a response to music and secondary to the listening process, but are actually contributing to that process in a constructive manner. In other words, they may inform and facilitate perception. Ultimately, therefore, the primed emotions should not derive from an external source, but should be primed through the music. Also, the emotions would normally

not compete with intrinsic structural properties, but be compatible with the musical properties. Our prediction is that, in these more ecologically valid conditions, the influences of emotions will be stronger than found in the experiments, because they are not inhibited by contrasting structural tendencies (like major or minor mode), and they are not artificially evoked. However, for experimental purposes, we preferred a factorial manipulation between primed emotion and musical characteristics.

The investigation of the influence of emotion on music cognition can be continued in several ways. As Västfjäll (2010) argues, the implicit measuring paradigm used in Experiments 1 and 2 provides a method to investigate associations between emotions and musical parameters, and our study has started to do this. Investigation of how (and how rapidly) emotions may inform expectation may elucidate whether there are necessary and sufficient conditions for expectations to be generated both from musical characteristics and schematic expectations. Interactions with exposure (i.e. a learning phase) and listening background of participants will further be of interest to explore.

It will be important to extend the investigation to other musical characteristics and to a larger diversity of emotions. For example, expectations related to high and low arousal are probably separable and distinguishable from expectations related to positive and negative valence (as indicated by a dissociation in effects, see e.g. Marin, Gingras, & Bhattacharya, 2011). Dependent characteristics may include tempo, loudness, tonal mode and dissonance in addition to pitch register and interval size. Apart from influencing expectations, we also expect emotions to direct attention and so influence perception (in line with effects found in general auditory processes). This hypothesis is investigated within the context of an auditory stream-segregation experiment: Depending on the primed emotion, participants are expected

to focus attention on the upper or lower auditory stream and to perceive the streams as an integrated faster moving sequence or as two separated more slowly moving sequences (Timmers, Crook, & Morimoto, 2012).

Apart from empirically exploring and comparing the influence of perceived and experienced emotions on music perception and cognition, it will be important to work towards more integrated models of music cognition, where affective responses are included as a component of perception: Where music evokes emotions, these emotions mediate perception.

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