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# Emotional Influences on Attention to Auditory Streams

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## ABSTRACT

Perception and experience of emotions are important elements of the appreciation and understanding of music. In fact, they may not only be a response to music, but may also play a directing role in our perception of music. The results of three experiments present corroborating evidence that this is indeed the case: Presentations of affective pictures influence the way participants attend to and group auditory sequences. The experiments used sequences consisting of alternating high and low notes. Participants indicated their perception of the sequences by judging to what extent they attended to the high or low sequence or to both lines (one stream). Happy pictures increased the tendency of participants to focus on the higher line, while sad pictures increased the tendency to focus on the lower pitches. Sad pictures also increased the tendency to segregate the lines and focus on slower melodic movement.

## I. INTRODUCTION

Perception and experience of emotions are important elements of the appreciation of music and much research has been dedicated to uncovering perceptual, cognitive and physiological mechanisms responsible for emotion perception and induction in response to music (Juslin & Sloboda, 2010). However, given the prominence of emotional responses to music, we may expect that these responses also interact with the way listeners perceive music. Influences of affective states on perception and cognition have been frequently demonstrated for other domains than music. For example, emotional stimuli tend to "attract" attention, which is particularly strong for fearful stimuli and anxious participants (Yiend, 2010; Öhman, Flykt, & Esteves, 2001). Emotions also influence our evaluations of a situation, person or object, and inform our decision-making (Bechara, Damasio, Tranel, Damasio, 1997; Damasio, 1994). And, they influence how we perceive and memorize events. For example, mood-congruent objects in movie scenes are better remembered than mood-incongruent objects (Boltz, 2003). First evidence for the role of emotions in music perception and cognition has also been found. In particular, affective states interact with memory for melodies in major or minor mode (Houston & Haddock, 2007), emotional priming influences expectations for melodic continuations (Timmers, 2009), and affective pictures influence judgments of music (Boltz, Ebendorf, & Field, 2009).

Following these findings, we predicted that emotional priming would also influence attention to musical stimuli. Previous research has demonstrated an association between the perception of happiness and relatively high pitched and fast music and the perception of sadness and relatively low pitched and slow music (e.g. Gabrielsson & Lindström, 2010). From this, we may predict that participants will expect and attend to relatively high pitched sequences and faster melodic motion when a happy emotion is primed, while they will expect and attend to relatively low pitch sequences and slower melodic movement when a sad emotion is primed. Given these hypotheses, we predicted that emotional priming would influence perception of the classical auditory stream segregation sequences consisting of alternating high and low pitches (Van Noorden, 1975, as cited in Bregman, 1990).

In three experiments, we tested the hypotheses that emotional priming using affective pictures influences attention to low or high pitches, and influences the tendency to integrate the pitches into a single stream or segregate the pitches into two separate streams. The experiments test the same hypotheses using different musical materials and different tasks for the participants.

## II. EXPERIMENT 1

### A. Method

35 adults participated in the experiment. Most of the participants had received formal musical training and were active performers.

To prime emotions, pictures from the Radboud Affective Faces Database were used (Langner, *et al,* 2010). The pictures were portraits of people looking happy, sad or neutral.

Musical material consisted of a repeating pattern of low and high pitches (Low-High-Low Rest, Low-High-Low Rest etc.). The distance between the pitches was 5 or 6 semitones, which makes the perception of this sequence ambiguous: it can be heard as one stream of low and high pitches, or as two streams – one stream of low pitches and one stream of high pitches. The duration between note (or rest) onsets was 120, 150 or 180 ms. The duration of the sequence was 6 seconds. These sequences were played at 11 different pitch heights to avoid the trials becoming too monotonous.

Previous research has demonstrated that the tendency to segregate the sequence into separate streams is stronger for larger intervals and for faster tempi (Bregman, 1990). Figure 1 illustrates the musical material and the different ways of perceiving the sequence as one or two streams.

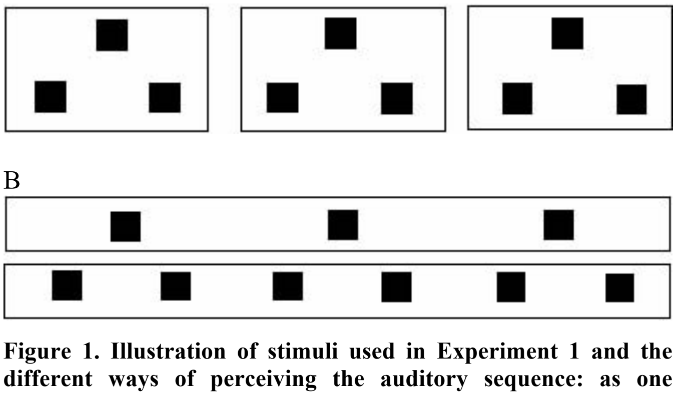


**Figure 1. Illustration of stimuli used in Experiment 1 and the different ways of perceiving the auditory sequence: as one**

**stream consisting of a alternating low and high pitches (A) or as two streams consisting of low notes or high notes (B).**

Participants saw an affective picture and were instructed to imagine the emotion portrayed in the picture. After 7 seconds, the musical sequence started to play. After the presentation of the picture and musical sequence, participants indicated their perception of the sequence using two seven-point rating scales: First they evaluated the extent to which they had perceived sequence as one or two streams, where 1 indicated "strongly as one stream" and 7 indicated "strongly as two streams". A rating of 4 meant "both as one and as two streams". Secondly, participants evaluated the extent to which they had heard the low or high pitches as being on the foreground, where 1 meant "low notes on the foreground", 4 meant "low and high notes on the foreground" and 7 meant "high notes on the foreground". Participants were encouraged to use the entire rating scales.

Musical sequences and affective pictures were presented in random order. All participants received all musical conditions (3 tempi, 2 intervals) and all emotion conditions (3 types of affective pictures). The actual pictures were randomly chosen for each participant and the starting pitches of the musical sequences were varied randomly.

### B. Results

For the first rating (rating of stream segregation or integration), the effects of interval and tempo were significant ($F$ (1, 34) = 6.62, $p$ = .015, $r$ = .40 for interval and $F$ (1.36, 46) = 42.54, $p$ = .000, $r$ = .75 using Greenhouse-Geisser correction for violations of the assumptions of sphericity for the effect of tempo). The effect of emotion was insignificant and none of the interactions were significant. As predicted, wider intervals led to more stream segregation than smaller intervals ($M$ = 3.81, $SE$ = 0.17, for fourth intervals; $M$ = 4.14, $SE$ = 0.15, for augmented fourth intervals,), while slower sequences led to more stream separation ($M$ = 4.54, $SE$ = 0.14, for the fastest sequences; $M$ = 3.96, $SE$ = 0.16, for the intermediate tempo; and $M$ = 3.44, $SE$ = 0.19, for the slowest sequences).

For the second rating (rating of the extent to which the low or high pitches were perceived as being on the foreground), emotion was the only significant effect ($F$ (2, 68) = 3.92, $p$ = .024, $r$ = .32). Planned contrasts confirmed a linear relationship between emotion and attention rating (emotions were coded as -1, 0 and 1 for sad, neutral and happy) ($F$ (1, 34) = 5.54, $p$ = .024, $r$ = .37), rather than a quadratic relationship ($p$ = .528). As predicted, sadness was associated with more attention towards lower pitches ($M$ = 3.18, $SE$ = 0.11), while happiness was associated with relatively more attention towards higher pitches ($M$ = 3.52, $SE$ = 0.14).

### C. Discussion

The first experiment confirmed that affective priming influences attention to lower or higher pitches. However, it did not confirm that affective priming influences the tendency to integrate or segregate sequences. Instead tempo influenced stream segregation most strongly, followed by interval. Some participants commented that the lower pitches had more prominence than the high pitches because they occurred more frequently. Participants also commented on the use of an augmented fourth, which has a negative connotation. These two characteristics of the musical material are improved in the second experiment. Additionally, in the second experiment, we aimed to improve emotion induction by varying the pictures during a musical sequence and by presenting all stimuli for each emotion in a single block. Stronger emotional pictures of various scenes were used in addition to the photographs of affective faces.

## III. EXPERIMENT 2

### A. Method

42 adults participated in the second experiment. 21 participants had received more than 5 years of musical training, were making music regularly and were classified as "musicians", while the remaining participants had received little or no musical training and were classified as "non-musicians".

Two sets of affective pictures were used to prime emotions. The first set was again taken from the Radboud Affective Faces Database (Langner, *et al,* 2010). And the second set of pictures were selected from the International Affective Pictures System (Lang, 1995). The IAPS pictures are more arousing than the RAFD pictures.

Videos of 12 seconds were made by presenting three affective pictures for four seconds in a sequence. Six versions of four videos per emotion were constructed in total. The four types of video differed in picture material: two sets of videos used IAPS material, while the other two sets used RAFD material. The six versions were constructed by varying the order of the three pictures within a video.

Musical sequences consisted of an alteration of low and high pitches. Three patterns were used: An alternation between low and high pitches 5 semitones apart and 7 semitones apart. And a more complex pattern with stepwise motion in the low and high pitches (see Figure 2). The interval of a perfect fifth (7 semitones) was preferred above the previously used augmented fourth (6 semitones), which has a negative emotional connotation. The complex pattern was added to give the low- and high-pitched streams more independence. The musical sequences had a duration of 10 seconds. Different starting pitches were used and the starting pitch was selected randomly.

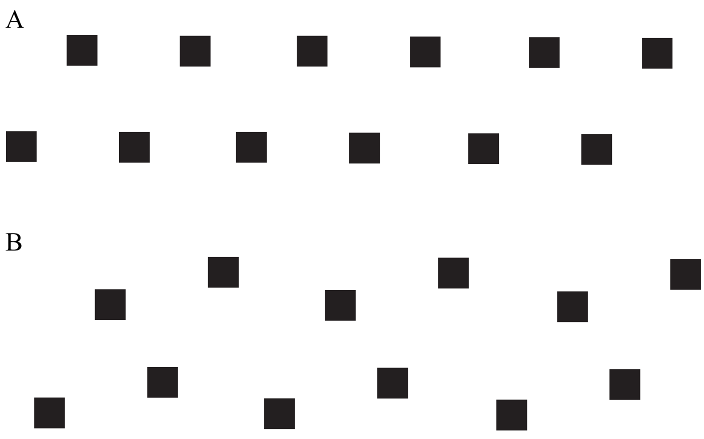


**Figure 2. Illustration of musical material of Experiment 2: Simple alternation between a low and high note (A) and a more**

**complex pattern consisting of stepwise motion in the low and high stream (B).**

Participants saw an emotional video and were instructed to imagine the emotion portrayed in the video. After 2 seconds a musical sequence would start. After the presentation of the video and musical material, participants were asked to indicate their predominant perception of the sequence. Their response was a forced choice of three options: they could have listened predominantly to the high notes, the low notes or both lines together. Next, they were asked to indicate the second predominant perception of the sequence. Again, their response was a forced choice between the same three options.

Musical stimuli were presented in a random order and videos were presented in a random order within each emotion block. The order of emotion blocks was randomized across participants. Each emotion block had 16 trials: 8 trials with complex patterns and 8 trials with simple patterns (simple alternation between low and high pitches). Musical stimuli were faded in to avoid inducing a sense of downbeat on the starting pitch.

### B. Results

The prominence of attention to the lower stream, the higher stream and both streams was calculated using a weighted sum of the responses to the first and second forced choice: If participants answered "low stream" as the first predominant perception, the attention score to the lower stream received two points. If however, "low stream" was answered to the second forced choice, the attention score to the lower stream received one point. Scores for the first and second response were summed together to get a total score. This was done separately for "low stream", "high stream" and "both streams" responses. Responses for repetitions of the same conditions were averaged.

Three repeated measures ANOVA's were run with emotion and pattern as independent variables. For "low stream" responses, the effects of emotion and pattern were significant as well as the interaction between emotion, pattern and musicianship ($F$ (2, 80) = 3.24, $p$ = .044, $r$ = .27 for emotion, $F$ (2, 80) = 3.45, $p$ = .037, $r$ = .28 for pattern, and $F$ (4, 160) = 2.48, $p$ = .046, $r$ = .24 for the interaction between emotion, pattern and musicianship).

Planned contrasts showed a significant linear relationship between emotion and attention to the lower stream ($F$ (1, 40) = 5.44, $p$ = .025, $r$ = .35, emotions were coded as -1, 0 and 1 for sad, neutral and happy), rather than a quadratic relationship ($p$ = .956). As predicted, attention to the lower stream was strongest during sad conditions and weakest during happy conditions.

Planned contrasts also showed a significant linear relationship between pattern and attention to the lower stream ($F$ (1, 40) = 7.35, $p$ = .010, $r$ = .39, patterns were coded as 1, 2 and 3 for patterns made up of a fourth or a fifth melodic interval or the more complex pattern), rather than a quadratic relationship ($p$ = .930). Attention to the lower stream was stronger for the simple interval consisting of a fourth (M = 1.09, SE = 0.08) than for the complex interval (M = 0.88, SE = 0.05). This difference between these two patterns was confirmed by posthoc comparisons.

To investigate the interaction between emotion, pattern and musicianship, a repeated measures ANOVA with emotion and pattern as independent variables was run separately for musicians and non-musicians. For musicians, emotion was the only significant effect ($F$ (2, 40) = 3.32, $p$ = .046, $r$ = .38), indicating that the effect of emotion was consistent across patterns. For non-musicians, there was a significant interaction between the effects of emotion and pattern ($F$ (4, 80) = 3.29, $p$ = .015, $r$ = .38): The effect of emotion was not consistent across conditions, in particular the neutral condition scored relatively high for two of the patterns, but not for the first pattern (alternating pitches a fourth apart). Nevertheless, the difference between the means for the sad and happy conditions was consistent and in the predicted direction for each of the three patterns: the means for the sad conditions were always higher than for the happy conditions.

For "high stream" responses, the main effect of emotion was significant ($F$ (2, 80) = 4.54, $p$ = .014, $r$ = .32) as well as the main of pattern ($F$ (2, 80) = 4.29, $p$ = .017, $r$ = .31). Planned contrasts showed a significant linear relationship between emotion and attention to the higher stream ($F$ (1, 40) = 4.68, $p$ = .037, $r$ = .32), and a significant quadratic relationship ($F$ (1, 40) = 4.28, $p$ = .045, $r$ = .31). The linear relationship was marginally stronger. Posthoc comparisons indicated that there was a significant difference only between the happy and neutral conditions: in the happy conditions, relatively more attention was paid to the higher stream ($M$ = 1.07, $SE$ = .08) than in the neutral conditions ($M$ = .85, $SE$ = .05).

Planned contrasts showed a significant quadratic relationship between pattern and attention to the higher stream ($F$ (1, 40) = 8.38, $p$ = .006, $r$ = .42). The linear relationship between pattern and attention to the higher stream was not significant ($p$ = .968). Attention to the higher stream was relatively strong for the second pattern (simple alteration of low and high pitches a fifth apart), compared to the other two patterns. This may be related to the relatively large width of this interval.

Finally, for "integrated stream" responses, there was a significant interaction between the effect of emotion and musicianship ($F$ (2, 80) = 3.06, $p$ = .053, $r$ = .27), and a significant main effect of pattern ($F$ (2, 80) = 5.14, $p$ = .008, $r$ = .34). To start with the main effect of pattern, planned contrasts showed a significant quadratic relationship between pattern and the integrated stream scores ($F$ (1, 40) = 6.78, $p$ = .013, $r$ = .38): The complex pattern received a relatively high integration score ($M$ = 1.26, $SE$ = 0.08). This was in contrast to the second pattern, which received a relatively low integration score, as predicted ($M$ = 0.95, $SE$ = 0.08). The first pattern received a slightly higher integration score ($M$ = 1.06, $SE$ = 0.09), although the difference between the first and second pattern (simple alternation of a fourth or fifth) did not reach significance in posthoc comparisons ($p$ = .52).

The interaction between musicianship and emotion was investigated by running separate repeated measures ANOVA's for musicians and non-musicians. This analysis showed that the main effect of emotion was only significant for the musicians ($F$ (2, 40) = 4.24, $p$ = .021, $r$ = .42). The responses of musicians showed a significant quadratic relationship between emotion and integrated stream scores ($F$ (1, 20) = 10.48, $p$ = .004, $r$ = .59): The integration of the streams was especially strong for the neutral conditions ($M$ = 1.37, $SE$ = 0.10) compared to the happy and sad conditions.

Integration scores were not significantly different between the happy conditions (*M* = 1.16, *SE* = 0.12) and the sad conditions (*M* = 1.07, *SE* = 0.11).

### C. Discussion

The effects of emotion on attention to high and low streams were as expected: sad promoted the tendency to focus attention to the lower stream, while happiness promoted the tendency to focus attention to higher streams. These two effects may have had the side effect of promoting stream segregation for the sad and happy conditions, which was relatively strong in these two conditions compared to the neutral condition. This effect of emotion on stream integration/segregation partially contradicted our predictions. We expected that the priming of happiness would promote stream integration.

The effects of emotion were significant for the entire group for the attention to high and low streams. However, the effect on stream integration was only significant for musicians.

In addition to the effect of emotion, pattern influenced attention and stream integration. The specific influence of pattern was different for the three types of responses, but in a coherent manner: While attention to the lower stream was most prominent for the simple pattern with a smaller interval, attention to the higher stream was most prominent for the simple pattern with a larger interval. Congruent with these effects, integration scores were strongest for the complex pattern.

While this second experiment confirms the influence of emotional priming on the attention to low or high pitched streams as demonstrated in the first experiment, it also provides evidence for the influence of primed emotions on stream integration, although in a slightly unexpected manner. The final experiment was designed to again confirm the influence of emotional priming on the attention to streams in a way that avoids explicit indication of “high” or “low” streams, because such explicit indication may bias answers through verbal mediation. Additionally, a more musically interesting pattern was used that consisted of a stream of repeating tones and a stream of tones moving in a stepwise motion.

## IV. EXPERIMENT 3

### A. Method

44 adults participated in the experiment. Most of the participants had received formal musical training and were active performers.

The same procedure was used as in Experiment 2 to prime an affective state (happy, sad or neutral). All trials belonging to one emotion were blocked. The order of the emotions was counter-balanced across participants.

As in Experiment 2, musical material consisted of alternating low and high notes, however one of the streams had stepwise motion, while the other stream consisted of a repeating tone (see Figure 3). The interval between the high and low pitches was a fourth, or an octave. The stepwise motion could occur in the lower or higher stream. The stepwise motion was upward or downward. The sequence started with the higher or lower pitched tone. These variations occurred equally often making a total of 16 trials within an emotion block (2 intervals x 2 registers x 2 motion directions x 2 starting tones). Additionally, the sequences were played back at eight pitch heights (semitones apart from each other). Pitch height was chosen randomly and randomized across participants.

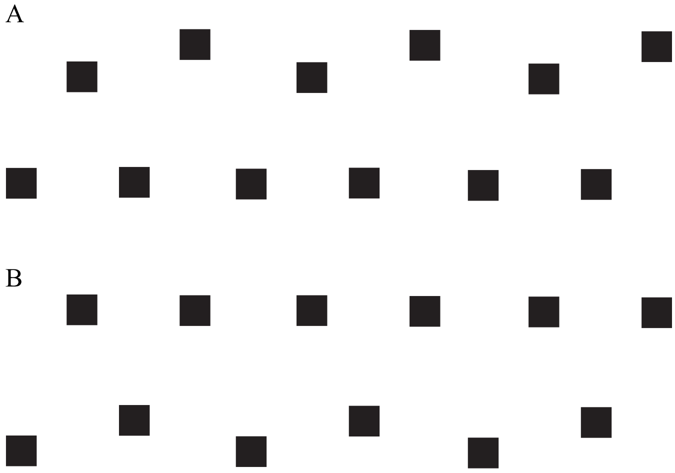


**Figure 3. Illustration of stimuli used in Experiment 3: One stream consisted of repeating tones while the other stream contained stepwise motion. The stepwise motion could be in the higher (A) or lower stream (B).**

Participants watched the emotional movie and heard the musical material simultaneously. Movie and musical material lasted for 12 seconds. They were instructed to imagine the emotion portrayed in the movie, while listening to the musical sequence. Additionally, they were instructed to indicate their perception of the sequence while listening. After the video and music had stopped, they were asked to indicate their predominant perception of the sequence. Three response options were given: integrated perception of the sequence, focus on the repeating tone, and focus on the stepwise motion.

### B. Results

The analysis of the responses will focus on the responses given after each movie and musical sequence. The responses during the movie and sequence were too varied and unreliable with many participants not indicating anything during a trial. Responses for trials with minor variations of the musical material (different directions of the stepwise motion and different starting pitches) were grouped together (responses were averaged). This led to more normally distributed data and a manageable number of variables to test.

Two dependent variables were defined from the three response options: The first dependent variable captured whether attention was primarily focused on the low (0) or high (1) pitched stream or on both streams (.5). For example, if participants had indicated that they focused on the repeating tone and the repeating tone was in the lower stream, the dependent variable (attention score) was assigned to be 0. If however, the repeating tone was in the higher stream, the attention score was 1. If participants had responded that they perceived the stream as integrated, the attention score was .5.

A repeated measures ANOVA was used to test the effects of emotion, interval and register on the attention score. Register referred to the location of the stepwise motion in the musical sequence (low or high stream). The effects of register and interval were highly significant ($F$ (1, 43) = 28.95, $p$

= .000, $r$ = .63, for interval; $F$ (1, 43) = 25.96, $p$ = .000, $r$ = .61, for register). The focus was more often on the higher pitched stream when the interval was larger ($M$ = .50, $SE$ = .02)) than when it was smaller ($M$ = .62, $SE$ = .03). The focus was more often on the higher stream when the stepwise motion was in the higher stream ($M$ = 63, $SE$ = .02) than when the stepwise motion was in the lower stream ($M$ = .49, $SE$ = .02).

The effect of emotion was not significant ($p$ = .149). This could be due to a lack of statistical power, suggested by a marginally significant quadratic relationship between emotion and attention score ($F$ (1, 43) = 3.31, $p$ = .076, $r$ = .27). Indeed, in a repeated measures ANOVA with emotion, interval and register where only two emotions were included (happy and neutral), the effect of emotion was significant ($F$ (1, 43) = 3.98, $p$ = .052, $r$ = .29), indicating that happiness enhances attention to the higher pitched stream even if attention is primarily directed by the presence of stepwise motion in the stream.

The second dependent variable captured whether the participants had perceived the sequence as integrated (1) or segregated (0). If participants had responded that they focused on the repeating tone or the stepwise motion, the integration score was 0, while if participants had responded that they heard the sequence as integrated, the integration score was 1.

A repeated measures ANOVA was used to test the effects of emotion, interval and register and their interactions on the integration score. All main effects were significant ($F$ (2, 86) = 4.44, $p$ = .015, $r$ = .31, for emotion; $F$ (1, 43) = 52.12, $p$ = .000, $r$ = .74, for interval; $F$ (1, 43) = 20.35, $p$ = .000, $r$ = .57, for register). None of the interactions were significant. The effects of interval and register were stronger than the effect of emotion, which was moderate in strength. As expected, a larger interval between the low- and high-pitched streams led to less integration between two streams ($M$ = .439, $SE$ = .04, for a fourth interval, $M$ = .175, $SE$ = .03, for an octave interval). We did not have an a-priori hypothesis for the effect of register on stream integration. The results showed that when the stepwise motion was in the lower register, there was more stream integration ($M$ = .35, $SE$ = .03) than when it was in the higher register ($M$ = .26, $SE$ = .02).

Planned contrasts showed a significant linear relationship between emotion (coded as -1, 0 and 1 for sad, neutral and happy) and integration score ($F$ (1, 43) = 6.06, $p$ = .018, $r$ = .35). The amount of integration was smallest for sad ($M$ = .27, $SE$ = .3) and larger for neutral and happy ($M$ = .32, $SE$ = .3, for neutral $M$ = .33, $SE$ = .3, for happy). Posthoc comparisons confirmed that integration scores were in particular lower for the sad conditions than the neutral and happy conditions, which were not significantly different from each other.

### C. Discussion

This last experiment showed a medium effect of emotion on stream integration and a very weak effect of emotion on attention to the higher or lower stream. Sadness and happiness contributed in distinct ways to these effects: sadness in particular enhanced stream segregation, while happiness increased attention to the higher stream compared to the neutral condition.

## V. Discussion and Conclusion

The results of the three experiments presented corroborating evidence of the influence of emotions on the perception of and attention to auditory streams in a musical context. In Experiments 1 and 2, there was a linear relationship between emotion (ordered as sad, neutral, happy) and attention to the lower or higher stream, indicating a positive association between valence and pitch height. This positive association confirms studies that have demonstrated that listeners' perception of sadness or happiness in music is associated with pitch height. However, we have shown (and argue in a more general sense) that this association also has consequences for the way we perceive and attend to music. In Experiment 3, attention to the two streams was primarily influenced by the stream that contained the stepwise motion, which attracted attention, and by the interval between the low and high stream. The larger interval led to relatively more attention to the higher stream. The larger interval also led to more segregation between the streams and attention to the higher stream may be related to a perception of that stream as "the melody". The effect of emotion on attention was only significant in Experiment 3, when we restricted the comparison to two emotions (neutral and happy), rather than three, perhaps due to stronger statistical power.

The effect of emotion on stream integration was less consistent across experiments. No significant effect of emotion on stream integration was shown in Experiment 1. In Experiment 2, emotion systematically influenced stream integration for the musicians only, in an unexpected manner: Stream integration was strongest for neutral and less strong for both sad and happy. This increased stream segregation for happiness was not predicted. As a posthoc explanation, we think that it might be related to the influence of emotion on attention: More focus on the upper line enhances stream segregation. In Experiment 3, we did find the expected linear relationship between emotion and stream integration, although in particular sadness led to stronger stream segregation and the difference in stream segregation between neutral and happiness was not significant. In other words, while happiness may enhance stream integration as predicted (faster motion and wider intervals). Stronger attention to the upper line may counter-balance this effect.

Experiments 2 and 3 also showed interesting effects of pattern on stream integration: Experiment 2 showed that stepwise motion in both lines enhanced stream integration compared to repeating tones in both lines. In Experiment 3 only one stream had stepwise motion. This experiment showed that stream integration was enhanced when the stepwise motion was in the lower stream.

In these experiments, emotion was primed by showing affective pictures while listening to musical sequences. We expect that emotion induction was stronger in Experiments 2 and 3 than in the first experiment, because in the first experiment the emotion conditions were randomized, while in Experiments 2 and 3, the emotion conditions were blocked allowing for felt emotion to build up during the block. Also, more intense pictures were used in Experiments 2 and 3 in addition to the affective faces that changed after four seconds. We have measured skin conductance and heart rate during the third experiment to check whether physiology was indeed affected.

We have mainly tested musically trained participants. Given that the stream segregation task needs training and explicit reflection on perception, we felt that the task was less demanding for musicians than for non-musicians, who may have a longer trajectory to learn to detect the different ways of perceiving the sequences. In Experiment 2, there was generally no interaction with musicianship, indicating that the effects occurred irrespective of musical training, except for one of the dependent measures. For this measure, the effect of emotion was less strong for the non-musicians than the musicians, but nevertheless in the same expected direction.

We hope that this research will form a starting point for continued investigations of the interaction between emotional responses to music and music listening processes. One of the directions would be to investigate the influence of emotions on music perception for more ecologically valid material. Another direction would be to systematically vary arousal and valence separately and in combination and to test the distinctive effects of these emotion components.

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