Citation

Merrill, Julia; Omigie, Diana and Wald-Fuhrmann, Melanie. 2020. Locus of emotion influences psychophysiological reactions to music. PLoS ONE, ISSN 1932-6203 [Article] (Forthcoming)

Persistent URL

http://research.gold.ac.uk/id/eprint/29414/

Versions

Locus of emotion influences psychophysiological reactions to music

Running head: Locus of emotion is reflected in psychophysiology

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Abstract

One's locus of attention may influence emotional responses in many situations. In general, focusing on the objective features of a situation may have a different emotional impact than focusing on how the situation affects oneself. With regard to aesthetic stimuli, in particular, it is now widely accepted that the perception of emotional expression in music can be vastly different from the feelings evoked by it. However, less understood is how the locus of emotion affects the experience of music. In other words, it is unclear how the act of perceiving the emotion in music compares with the act of assessing the emotion induced in the listener by music. In the current study, we compare these two attentional loci (music and the experiencing self) using measures of facial electromyography, skin conductance, respiration and heart rate. 40 participants were required to assess either the emotion expressed by, or the emotion they felt in response to, 32 musical excerpts taken from movie soundtracks. Using linear mixed effects models, we found a higher mean response in psychophysiological measures for the "perceived" than the "felt" task. This result suggests that the focus on one's self distracts from the music, leading to weaker bodily reactions during the "felt" task. In contrast, paying attention to the expression of the music and consequently to changes in timbre, loudness and harmonic progression enhances bodily reactions. This study has methodological implications for emotion induction research using psychophysiology and the conceptualization of emotion loci. Firstly, different tasks can elicit different psychophysiological responses to the same stimulus and secondly, both tasks elicit bodily responses to music. The latter finding questions the possibility of a listener taking on a purely cognitive mode when evaluating emotion expression.

1 Introduction

The assumption that the emotion a musical piece expresses is the same as the emotion felt in response to it was long the cornerstone of Western music pedagogy and music-aesthetic discourse (Plato: *Republic*, *Laws*; Aristotle: *Politics;* see 1). A possible dissociation of the two phenomena has long been theoretically discussed (2–4) and more recently begun to be empirically examined. In his seminal work, Gabrielsson (5) developed a model of this relationship drawing the distinction between perceived and felt emotions in music. The former is the expression ascribed to a piece of music ("external locus"; 6) while the latter is the feeling that it sparks in the listener ("internal locus", 6). The current study aims to identify underlying mechanisms of both loci using continuously measured psychophysiological responses.

Proposing two main relationships (6), one with both loci in a matched relationship (e.g., a perceived positive emotion fits to a positive emotion felt by the listener) and another with both loci in an unmatched relationship, some studies have sought to examine the extent to which felt and perceived emotions show congruency during music listening. In the majority of cases, the emotion felt is congruent with, but often rated lower in intensity than the emotion expressed (6–9). Using functional magnetic resonance imaging (fMRI), Tabei (10) compared each locus to baseline (passive listening) suggesting that the brain areas involved in the perceived task (bilateral inferior frontal gyri) reflected the assessment of musical expressions, while the felt task (precuneus) reflected self-representational processes of assessing one's own emotional responses. The results would seem to give support to the assumption that while the perceived emotion is understood as a perceptual-cognitive process such as perception or categorization of an emotional character, the felt emotion is understood as the listener's emotional response, that is, feelings reflecting the introspective perception of psychophysiological changes (5, 11–14).

Evidence is needed that these two processes are indeed distinguishable in terms of psychophysiological reactions. A pure cognitive approach would not lead to any reactions at all in a perceived emotions task or lead to at least much lower reactions than the actual felt (or induced) emotions task. Or, differences might only be visible when investigating the central nervous system which actually reflects cognitive processes (e.g. with fMRI). Responses by the autonomic nervous system might therefore be the same, regardless of the locus of emotion. First evidence that these differences should be visible in the autonomic nervous system comes from a study that explored the effect of different task instructions on psychophysiological responses to the same pieces of music. Miu and Baltes (15) demonstrated that instructions to either adopt an ‘objective’ or an empathic perspective while listening to and watching a recorded opera performance led to significant differences in psychophysiological responses. Therefore, investigating psychophysiological responses to perceived and felt emotions will shed light on the processes behind the two loci and will also have methodological implications on which instructions on music induced emotions will lead to higher and meaningful bodily responses.

1.1 Psychophysiological investigations of induced emotions

Studies using psychophysiological measures have investigated music evoked emotions (e.g., 16–20), mainly asking participants to report on discrete emotions or on emotion dimensions. A typical experimental design in these studies involves participants evaluating the expression of a musical excerpt by self-reports in one session, and then the same or a new set of participants reporting in another session the emotions felt while psychophysiological measures were recorded. Results often showed matched relationships between both loci, resulting in the conclusion that emotion contagion plays an important role in emotion induction (6, 21).

Typical measures for physical arousal comprise heart rate (HR) or blood volume pulse (BVP), respiration rate (RR) and skin conductance (SC). For the current approach, studies reporting on effects related to the dimensional model (such as investigating the different reactions to pleasant vs. unpleasant music) are of most interest. Positively arousing music such as happy, pleasurable and even preferred music (22), results in bodily reaction increases (SC, RR, and HR; 23–25). Negatively valenced music and unpleasant music lead to decreases/deceleration in HR (e.g., 20, 26, 27; but see also 28, 29 for no changes), and lead to increases in SC response to fearful music (11). The latter makes a problem obvious in separating valence and arousal in discrete emotions: SC responded stronger to arousing stimuli such as happy and fearful than sad and peaceful music (11, 23). Also, a presumption that seems to exist is that sadness in music is unpleasant, which is not always true as sad music can be pleasurable (30, 31). Therefore, musical excerpts used in the current study were chosen to represent the poles of the emotional dimensions, namely negative and positive valence, and high and low energy and tension.

Facial electromyography (EMG) is usually recorded through the zygomaticus major (32), associated with smiling and therefore positive valence, and the corrugator supercilii muscle, associated with frowning and therefore negative valence (for pleasant and unpleasant stimuli, see 33, 34). Accordingly, positively valenced music has been associated with increases in zygomaticus activity while negatively valenced music has been associated with an increase in corrugator activity (in combination with movies, see 35, 36). This clear-cut pattern has, however, not consistently been reported in music studies (e.g., 19, 23). In contrast to arousal measures, which are considered measures of psychophysiology, EMG is considered a measure of behavior (37). This points to the idea that EMG could be understood to also indicate aesthetic emotions, which could explain some of the heterogeneous results (e.g., zygomaticus activity could be the result of a positive aesthetic evaluation of a negatively valenced stimulus).

In summary, relations between psychophysiological measures and emotion perception have been investigated under different premises, methods as well as concepts and terminology such as in discussions on aesthetic emotions and utilitarian/real emotions (38–41). The inherent problem lies in the multidimensionality of both emotion perception and expression in music. A first step to reducing this complexity is to test the two emotion loci of perceived and felt emotions with simpler tasks while measuring psychophysiology. In a broader context, with this study, we investigate the potential impact of task instructions on emotion-related psychophysiological responses to music, and thus, make a novel contribution to understanding emotional processes during music listening.

1.2 The present investigation

The current study compares for the first time the psychophysiological correlates of the act of perceiving musical expression with those of the act of assessing feelings sparked by music listening. Stimuli and ratings scales corresponded to a study by Eerola and Vuoskoski (42). Ratings scales included adjectives from the dimensional model as favored by the authors, although, we asked participants to choose only one adjective out of four, representing two dimensions: ‘positive, negative, tense, relaxed’. For further analysis, the validated expression ratings from 116 participants tested by Eerola and Vuoskoski (42) were used and therefore, the ratings of our own participants for the perceived task were disregarded. Stimuli were taken from movie soundtracks, which musical and stylistic properties as well as the film context they originated from, were ideal for the differentiation between felt and perceived emotions. The stimuli varied in ambiguity and explicitness to keep the participants’ attention focused on the musical expression in the perceived task. For the felt task, we asked our participants to report on the intensity of their emotions only, to check that the stimuli were capable of inducing emotions of different intensities. In combination with psychophysiological measures, we opted for an event-related design, randomly mixing the tasks as well as musical pieces in one session to keep the participants’ attention high (6, 38).

Excerpts were 30 seconds long to investigate potential changes in response over time to musical excerpts that maintained a constant musical expression over their duration. With regard to participants, we chose the same approach as Rickard (18) and did not control for musical training, i.e., did not select participants because of their musical expertise, but checked for possible influences of musical training on physiological responses.

1.3 Hypotheses

We hypothesized that the locus of attention would influence the amplitude of physiological responses: If the act of introspecting on one's emotional state boosts emotional response, we would expect to see a greater physiological response for the felt emotion task in which the emotion locus is internal. If the act of perception necessarily involves simulation of the emotion, we can expect that the physiological response would be at least as large as for the felt task. Finally, if, however, the act of focusing on the internal emotion locus distracts from the music itself, we should expect to see larger physiological responses during the perceived task.

With regard to physiological response as a function of emotion dimensions, we hypothesized that high energy would result in greater skin conductance, respiration rate and heart rate than low energy clips. We also predicted that positive valence would result in greater zygomaticus activity than negative valence and that negative valence would result in greater corrugator activity than positive valence reports. We hypothesized that the relationship between loci would be mostly matched because the chance of musically external events (such as reliving a specific autobiographical episode) interfering with the perception is low due to the music being experimenter-selected and not polarizing (e.g. in terms of its ideology; see, 42).

With regard to a time course of emotion processing in music, we hypothesized that the responses would decrease (in line with 23) because the musical excerpts were chosen to be constant over the course of approximately 30 seconds (in terms of loudness, tempo, tonality, instrumentation etc.).

2 Methods

2.1 Ethics statement

All experimental procedures were ethically approved by the Ethics Council of the Max Planck Society, and were undertaken with written informed consent of each participant.

2.2 Participants

40 participants (mean age = 26.48 years, SD = 7.77; 12 male) were tested. Participants showed various musical backgrounds (mean musical instrument playing = 7.28 years, 6.58 SD, range 0-20 years), ranging from musically untrained individuals, to amateur musicians or music students.

2.3 Materials

32 excerpts from movie soundtracks were selected on the basis of evaluations and emotion ratings reported in Eerola and Vuoskoski (42). They were selected based on the emotion groupings (Table 1) with highly and moderately representative examples of the poles of the respective emotion dimension: positive (N = 8) and negative rated valence (N = 8), low (N = 4) and high tension (N = 4) as well as low (N = 4) and high energy (N = 4). Note that all excerpts were rated on all emotion dimensions. The original 15 second pieces reported in the study were extended to approximately 30 second excerpts to ensure emotion induction (see also 43) taking care that there was no change in musical expression in the resulting longer excerpts.

--- Table 1 about here ---

2.4 Procedure

Participants were informed about the study and carefully instructed regarding the meanings of and difference between the concept of perceived and felt emotions. They were then prepared for the recordings of psychophysiological measurements, which included the measurement of the zygomaticus major (smiling) muscle and corrugator supercilii (frowning) muscle with Ag/AgCl electrodes, respiration rate (RR) with a custom prepared respiration belt wrapped around the upper rib cage (level with sternum), skin conductance (SC) with electrodes attached to the fingers of the left hand, as well as a plethysmograph clip used to measure the blood volume pulse (BVP), from which heart rate (HR) could be inferred.

For facial EMG, after cleansing the skin to reduce interelectrode impedance, Ag/AgCl electrodes were filled with EMG gel and were placed on the left side of the face according to 32 (32) and 44 (44) guidelines. Two electrodes were placed over the eyebrow to measure the activity of the corrugator muscle, while two others were placed on the cheek to measure the zygomaticus muscle. The ground electrode was placed in the middle of the forehead. Impedance of facial EMG electrodes was kept below 5 kΩ. Electrodes were connected to the amplifier with a 10 s low cutoff for EMG and a DC-cutoff for arousal measures and a 250 Hz high cutoff (to reduce electrical interference). Activity was sampled at a 500 Hz rate.

Participants were seated in front of a monitor and listened to the music over loudspeakers (Neumann KH 120 A). Loudness was adjusted to a comfortable level for each participant. Participants were instructed to make all ratings with a computer mouse using their right hand, and to avoid moving their left hand during recordings. A set of six training trials was performed by the participants in order to give them an impression of the study and to familiarize them with the two different tasks.

Each trial commenced with a prompt on the screen indicating one of the two tasks, either perceived (German ‘Ausdruck’ = expression) or felt (German ‘Gefühl’ = feeling) for 4 seconds. After the music ended, the rating scale for the respective tasks appeared. Participants were instructed to carry out two tasks as follows: “One task asks for the expression you perceive in the music. To describe this, please select one of the four given adjectives: ‘positive, negative, tense, relaxed’. It is possible that more than one could fit; please choose the one, which in your opinion fits the best; there is no right or wrong answer. The other task asks for the intensity of feeling that the music evokes in you. Focus on yourself and observe your own reaction. The music can touch you a little or greatly. Please indicate this on a scale from 1 (little) to 5 (strong). Here no description of your feeling is needed."

The main study took about 60 minutes and trials were separated into four blocks with the opportunity for breaks in between them. Each block started with a 30 second rest period before the presentation of a fixed number of musical excerpts was presented in randomized order. The two tasks also occurred randomly but were balanced in numbers. Over the course of a recording session, each excerpt was played twice, once in the context of each task. Following the recording session, participants filled out a debriefing questionnaire in which they were asked about the strategies used to fulfill the two tasks.

2.5 Analysis

All signal processing was carried out using custom scripts written in MATLAB 2017b (45). To obtain a continuous measure of facial muscle activity over time, the zygomaticus and corrugator facial muscle signals (EMGZ and EMGC) were band-pass filtered between 20 and 249 Hz, and the absolute value of the Hilbert transform of the filtered signal was extracted and then convolved using the *conv* function in MATLAB as recommended (http://www.fieldtriptoolbox.org/documentation; 46). Heart and breathing rate over time were estimated over several steps. In the first step, the raw respiration and BVP signal were low pass (40Hz) and high pass filtered (0.05Hz) to remove body and hand movement artifacts, as well as drifts that can affect the ability to identify peaks reliably. Next, peaks in the signal were identified using functions that identified local minima and maxima with visual inspection used to confirm that all peaks were correctly identified. Finally, rate for each signal was estimated by taking a differential of the timings of maxima *(1./diff(timing of peaks)),* and the resulting rate time-series were interpolated to a regular sampling frequency.

To obtain a time-series of the phasic component of the skin conductance data (SC) for each piece, functions from the *Ledalab* toolbox V.3.4.9 were used (47). Note that no threshold was used for estimation of SC but rather, as recommended (47), a time integration of the continuous measure of phasic activity (average value) was taken as a direct indicator of event-related sympathetic activity.

Finally, to reduce the inter-individual variance of absolute amplitudes for the physiological data, activity for all physiological measures during the music listening tasks was normalized across all trials within a participant.

For statistical analysis, the mean response of the first and the second half of the musical pieces (i.e. 15 second intervals) was calculated to account for changes in physiological measures during the duration of musical pieces.

Analysis was based on the expressiveness ratings provided by Eerola and Vuoskoski (42) which were collected from a large group of participants, i.e., ratings by our own participants for the perceived task were discarded at this stage. (Note, the choice of adjectives was only to help participants to focus on the task and a comparison with the expression ratings was not planned, hence participants had to only choose one adjective out of four, i.e., their answer only represented one dimension, either valence or arousal.) Accordingly, for each dimension, stimuli were grouped into three categories based on the rating scale from 1-9 (42), i.e., for Energy and Tension, 1-3 = low, 4-6 = medium, 7-9 = high, and for valence, 1-3 = negative, 4-6 = neutral, 7-9 = positive. To investigate a potential effect of time on the physiological measures, the musical excerpts were divided into two parts, the first and the second half of the excerpt (e.g., for fMRI data, 48).

2.6 Statistical analysis

Statistical analyses were carried out using *R* (49). Data and analysis scripts are available via a repository (*link tba*).

2.6.1 Effects of emotions and tasks on psychophysiological measures

The *lme4* package within *R* (50) was used to perform linear mixed effects analyses of how the different physiological variables responded to the experimental manipulations. In contrast to analysis of variance (ANOVA), which relies on data aggregation, linear mixed models allow for the control of the variance associated with random effects without data aggregation (51, 52).

Each psychophysiological measure was separately analyzed. We took as fixed effects in the linear mixed models one of the emotion dimensions with three levels each, that is: Valence (negative, neutral, positive), Tension (high, medium, low), or Energy (high, medium, low), along with Task (felt, perceived). As we had no hypotheses regarding relationships between the emotion dimensions, we did not include them into one model but fitted three separate ones.

Models were fitted with random intercepts of subject, item (i.e., musical piece) and interval (first and second half). Random slopes were not included because no variance between subjects with regard to Emotion or Task had to be accounted for as we used external ratings and items were the same between conditions.

F- and *p*-values were obtained by the *anova* function and confidence intervals were calculated using the *confint* function from the *lme4* package. Two (Pseudo-)R^2 values were calculated with the *MuMin* package (53), which is designed for general and linear mixed effects models. The *r.squaredGLMM* function produces two coefficients of determination, one represents the variance explained by the fixed effects ('marginal' $R^2(m)_{GLMM}$), the other the variance explained by the entire model ('conditional' $R^2(c)_{GLMM}$), including fixed and random effects (Table 2). Note that computing effect sizes for linear mixed models is still a matter of debate (54).

--- Table 2 about here ---

2.6.2 Participants’ ratings and self-reports

To evaluate the relationships between loci, we investigated whether the felt intensity ratings matched the perceived emotion ratings (as rated by the participants in the study by 42) and whether they were reflected in the psychophysiological measures. To this end, two additional analyses were carried out. Firstly, the participants’ self-reported intensity ratings were correlated (Pearson) with the perceived emotion ratings by Eerola and Vuoskoski (42). Secondly, the intensity ratings were compared to the psychophysiological measures using linear mixed effects models. The models were fitted with z-transformed intensity ratings taken as fixed effects.

From a debriefing form with open questions the participants filled out after the study, we derived categories on the strategies the participants used to solve the task.

3 Results

3.1 Zygomaticus muscle activity

Valence affected the Zygomaticus muscle ($F(2,29) = 8.781$, $p = .001$), increasing its activity from neutral to positive valence by .186 ± .046 (Estimate ± standard error, SE) and decreasing it slightly from neutral to negative by .002 ± .020 SE (for details, see Table 2). Task only marginally affected the Zygomaticus muscle ($F(1,5086) = 3.477$, $p = .062$), increasing its activity slightly from felt to perceived by .038 ± .020 SE.

Energy affected the Zygomaticus muscle activity ($F(2,29) = 7.820$, $p = 0.002$), decreasing its activity from high to medium to low energy (for parameter estimates, see Table 2). Tension did not show a significant effect ($F(2,29) = .896$, $p = .419$).

--- Figure 1 about here ---

3.2 Corrugator muscle activity

Valence affected the Corrugator muscle (*F*(2,29) = 4.320, *p* = .023), increasing its activity from positive to neutral to negative valence. Task affected the Corrugator muscle (*F*(1,5086) = 13.464, *p* = .0002), increasing its activity from felt to perceived, i.e., perceived being higher in activation than felt. Energy affected the Corrugator muscle activity (*F*(2,29) = 3.774, *p* = .035), increasing its activity from high to medium to low. Tension did not affect Corrugator muscle activity (*F*(2,29) = 2.162, *p* = .133). Note that the R^2_{GLMM} values for these models are the smallest compared to other measures in the current study, i.e., the effects of Valence and Energy on Corrugator activity have to be considered small (mirrored in the *p*-values < .05).

3.3 Skin Conductance response

Energy affected the SC response (*F*(2,29) = 12.165, *p* = .0001), decreasing its response from high to medium to low energy. Task affected SC response only marginally (*F*(1,5086) = 3.602, *p* = .058), increasing it from felt to perceived. Valence affected the SC response (*F*(2,29) = 6.760, *p* = .004), increasing its response from middle to positive valence and slightly from middle to negative valence. Tension did not affect the SC response (*F*(2,29) = .475, *p* = .627).

3.4 Heart Rate response

Energy affected HR (*F*(2,29) = 6.317, *p* = .005), decreasing its response from high to medium to low energy. Task affected HR (*F*(1,5086) = 8.015, *p* = .005), increasing its response from felt to perceived. Neither Valence (*F*(2,29) = 1.617, *p* = .216) nor Tension (*F*(2,29) = .294, *p* = .748) affected HR response.

3.5 Respiration Rate response

Energy affected RR (*F*(2,29) = 5.603, *p* = .009), decreasing its response from high to medium to low energy. Task affected RR (*F*(1,5086) = 13.722, *p* = .0002), increasing its response from felt to perceived. Valence affected RR (*F*(2,29) = 3.378, *p* = .048), increasing its response from neutral to positive and slightly from neutral to negative valence. Tension did not affect RR (*F*(2,29) = 2.070, *p* = .144).

3.6 Felt-intensity ratings

The participants' self-reported intensity ratings were correlated (Pearson) with the perceived emotion ratings by Eerola and Vuoskoski (42) and revealed significant positive correlations with energy (Pearson *r* = .43, *p* < .05) and tension (*r* = .42, *p* < .05), but not with valence (*r* = -.30, *p* = .10), showing that the response was related to perceived arousal as intended (Figure 2).

--- Figure 2 about here ---

Relations between the felt-intensity ratings and the psychophysiological measures were investigated with linear mixed effect models, which were fitted as described above, with z-transformed intensity ratings as fixed effects. *P*-values were obtained by the *anova* function from the *car* package (55): Zygomaticus muscle activity was affected by the felt-intensity ratings ($\chi^2(1) = 12.194$, *p* = .0005), increasing its activity with higher felt intensity by .051 ± .014 SEs z-scores. RR was also affected ($\chi^2(1) = 10.347$, *p* = .001), increasing its response by .022 ± .007 SEs. Other measures were not affected by the felt ratings: Corrugator muscle activity ($\chi^2(1) = 1.917$, *p* = .166), SC ($\chi^2(1) = 2.915$, *p* = .088) slightly increased its response by .023 ± .014 SEs, HR ($\chi^2(1) = 2.738$, *p* = .098) slightly decreased its response by .021 ± .013 SEs.

3.7 Strategies for solving the tasks

In a debriefing session, participants were asked to describe the strategy they used to carry out the tasks. Participants reported paying attention to one or more of the typical cues of expressivity in Western music (such as tempo, harmonic progression, loudness, timbre, melody or musical structure) during the perceived emotion task. They also reported trying to imagine a real-life situation or movie scene to which the piece could serve as background music or musical illustration.

In contrast, the focus of the felt task was directed inward in line with the instructions. Participants described their strategy with a German metaphor for introspection (to “listen into themselves”) and reported three kinds of cues to evaluate their feelings: 1) bodily reactions (like goosebumps, chills, heartbeat), 2) being moved, touched or carried away by the music, and 3) aesthetic judgments about the music (liking and interest).

4 Discussion

The current study aimed to investigate potential differences in psychophysiological measures during music listening across two emotion loci: the emotion perceived and the emotion felt. Our results showed stronger bodily reactions when participants’ attention was directed towards the music (i.e., when participants were asked to perceive the emotion expressed in the music) than when it was directed inward (i.e., in order to assess the emotion induced by music). Our findings have implications for the understanding of physical reactions to the emotions conveyed by music, especially the mechanism of emotion induction through different attentional loci.

4.1 Effects of Task

Results revealed a higher mean activity/response for the perceived emotions task in psychophysiological measures. The effect became significant in corrugator muscle activity, HR and RR response, in zygomaticus muscle and skin conductance response the effect marginally failed to reach significance. This result is in line with previous studies (6–10) that have shown participants’ self-reports to be higher for the perceived emotion in music than the felt emotion. One other study has investigated the effect of different instructions on psychophysiological responses to the same music performance (15). While this study is only partly comparable to our study since it did not include a task in which participants had to focus solely on themselves, the results point in the same direction: When feeling with the performer (‘high empathy’), i.e. focusing on the performer/music, in contrast to ‘not getting caught up’ (‘low empathy’), bodily reactions were more influenced by the expression of the piece (SCL decreased supposedly because of the nostalgic/sad expression and RR increases because of the positive expression). One can conclude that focusing on the main ‘attraction’ in the music (performer, instrument, melody etc.) leads to enhanced psychophysiological reactions. Thus, we conclude from the current study that the focus on one's self distracts from the music itself (in effect operating as a distractor (task)) and leads to less responsive bodily reactions. In contrast paying attention to the expression of the music and consequently to tempo, timbre, loudness, harmony (all strong predictors of changes in autonomic response), enhances bodily reactions. This interpretation of the source of the enhanced physiological responses is reflected in the participants’ self-reports obtained in the debriefing. During the perception task, they reported having mostly paid attention to musical features and imagined situations that matched with the musical expression. During the felt emotion task, they reported having directed their attention to their own (bodily) reactions and aesthetic feelings such as being moved or touched by the music as well as aesthetic judgments such as liking.

Methodologically speaking, the instructions given to the participants for the perceived task might be interpreted as being more effective to induce emotions in the listener in response to the music itself. Therefore, our results contribute to research on the cognitive processes behind the perception of musical expression, i.e., whether musical emotions should be conceptualized as cue decoding processes or as the subjective interpretation of physiological activation or feelings (e.g., 12, 38, 56). We suggest that, even though participants rely on external information during perception tasks, a purely cognitive mode of emotion decoding without bodily mirroring may not be possible in such tasks. We suggest that directing attention inwardly (as in the felt task) may be a problematic emotion induction task as responses are potentially reduced or masked by other sources. It is worth pointing out, however, that focusing on the felt emotion might actually lead to higher psychophysiological responses than perceived emotions when strong personal attitudes influence bodily reactions such as in the specific case of highly pleasurable and self-selected music (8, 25).

According to typical experimental designs in studies on music-induced emotions, the matched relationship between loci is suggested by the participants' felt intensity ratings that reflect expressed energy and tension. In the bodily response, though, a slight relationship could be seen between high intensity ratings on the one hand and zygomaticus activity and respiration rate on the other, suggesting that an intense felt emotion was positively valenced. Therefore, self-reports on felt intensity might be based on aesthetic judgments as also suggested by the participants' reported strategies on how to solve the task (such as being moved or experiencing pleasant feelings etc.). Hence, a straightforward interpretation of bodily responses via emotion contagion needs to be re-evaluated, because aesthetic judgments have to be taken into account as an emotion (co-)induction mechanism (which has already been argued by 57).

4.2 Effects of Valence and Arousal

Our results showed patterns that were largely in line with previous studies and accordingly our hypotheses. With regard to valence, the zygomaticus muscle was greater for music with a positive expression and the corrugator muscle in response to negative valence (e.g., 20, 36). As the valence effect of the corrugator muscle was not particularly large and other studies showed heterogeneous results with regard to facial muscle reactivity (e.g., 19, 23), one might also want to take into consideration that music in general may elicit more positive than negative feelings – even in response to sad music. This has been thoroughly discussed in the context of mixed (31) and aesthetic emotions (30) and will need further investigations with regard to psychophysiological responses.

Reports of perceived high energy correlated, as hypothesized, with SC, HR and RR as well as facial muscle activity. Previous studies used mainly stimuli representing discrete emotions, showing that arousing music such as highly pleasurable music or happy and fearful music has an effect on arousal measures (11, 23–25), which does not always allow to separate arousal from valence effects. Differentiating into emotion dimensions such as valence, energy and tension, we showed that SC and RR (albeit the latter with a small effect) were higher in response to positive than negative valence; HR was not affected by valence. With regard to valence measures, zygomaticus and corrugator activity was higher in response to high energy in music. While further investigations are needed to investigate the role and interplay of psychophysiological measures in reported valence and arousal, one might suggest from the current study that valence effects in music might be difficult to be separated from arousal effects.

Finally, perceived high tension did not correlate with any of the measures we recorded. Eerola and Vuoskoski (42) already noted that two dimensions (of valence, energy, tension) were a good model fit, supporting the idea that one of the dimensions is redundant in reflecting arousal in music. One could also conclude that behaviorally rated tension in music may not be well reflected in bodily reactions, because of its interplay with relaxation and its major component of uncertainty (58), which needs further investigation.

The influence of musical training on emotion processing in music has not yet gained much interest. In the current study, participants’ various musical backgrounds was not investigated further as Rickard (18) did not find differences relating to music training in a group of participants, who were not selected because of their musical expertise, in measures of SC, HR, temperature and EMG while listening to relaxing and arousing musical excerpts. Only in homogenous groups of professional musicians or music students differences in SC and cortisol were found while listening to music (29). Still, especially in music emotion research, the common differentiation between musicians (with classical music training) and non-musicians might not be a satisfactory grouping given the significant role that musical attitudes (such as taste and musical behavior etc.) likely play, which future studies need to account for by testing for musical sophistication in general (59).

4.3 Conclusion

With regard to research on psychophysiological markers of music listening and facets of the aesthetic experience of music, our study produces new evidence on at least two research topics. Firstly, it showed that one and the same musical stimulus can result in different psychophysiological responses depending on the listening mode a person adopts, due to differing instructions. Even though sympathetic activation is generally thought to be an automatic and comparatively low-level process caused by basic acoustic properties of musical pieces, top-down processes come into play. Evoked feelings as well as emotion decoding processes in music involve bodily reactions. Secondly, it shed light on commonalities as well as differences between the external and internal emotion locus. In the perceived emotion task, stronger bodily reactions likely evolve due to a focus on (external) acoustical and musical properties in contrast to in the felt task where response patterns are likely weaker due to introspection and hence distraction from the music itself.

In terms of methodological implications, our study demonstrated that a perception task in which attention is directed to the music may be more reliable as an emotion induction task than one that focuses attention inward.

5 Acknowledgement

We thank Sandro Wiesmann, Freya Materne and Elena Felker for help with data collection and Christoph Seibert for comments on an earlier version of the manuscript.

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6 Tables

Table 1. List of stimuli. L = looped stimuli. The last five columns refer to the final stimulus set ‘2’ from (42). The chosen stimuli form the ‘Emotion Grouping’ consisted of highly (HIGH) and moderately (MOD) representative examples of the poles of the respective emotion dimensions.

Excerpts in current study				Stimulus set ‘2’ from Eerola and Vuoskoski (2011)				
Album Name	Track	Start	End	Index Reference	Ratings: Valence	Energy	Tension	Emotion Grouping
Batman	4	02:31	02:48L	79	7.25	8.12	5.03	ENERGY POS MOD
Batman	9	00:56	01:23	63	4.76	3.96	6.04	VALENCE NEG MOD
Big Fish	8	00:11	00:42	110	6.75	3.90	2.82	TENSION NEG HIGH
Big Fish	15	00:18	00:49	65	4.07	5.04	6.93	VALENCE NEG MOD
Big Fish	15	00:54	01:26	82	5.24	3.70	4.79	ENERGY NEG MOD
Blanc	12	00:39	01:09	52	6.82	4.97	3.46	VALENCE POS HIGH
Blanc	10	00:12	00:42	88	5.03	2.96	4.10	ENERGY NEG HIGH
Cape Fear	2	01:13	01:44	100	3.22	5.09	7.43	TENSION POS MOD
Dances with Wolves	10	00:18	00:46	55	7.04	7.27	4.66	VALENCE POS HIGH
Dracula	5	00:11	00:44	99	4.16	5.22	6.84	TENSION POS MOD
Gladiator	17	00:00	00:29	53	7.07	6.76	4.55	VALENCE POS HIGH
Hellraiser	5	00:00	00:30	69	2.36	7.09	8.24	VALENCE NEG HIGH
Juha	2	01:55	02:26	101	7.57	4.60	2.46	TENSION NEG MOD
Juha	10	00:07	00:40	51	7.30	5.00	3.18	VALENCE POS HIGH
Juha	16	00:00	00:31	81	5.60	3.07	4.01	ENERGY NEG MOD
Juha	18	02:28	03:00	61	5.78	5.97	5.99	VALENCE NEG MOD
Lethal weapon 3	7	00:00	00:29	67	4.72	4.72	6.67	VALENCE NEG HIGH
Man of Galilee CD1	2	00:09	00:42	56	6.67	6.75	5.16	VALENCE POS MOD
Man of Galilee CD1	2	03:02	03:18L	72	7.45	8.39	5.61	ENERGY POS HIGH
Oliver Twist	7	00:53	01:20	80	5.88	6.78	6.10	ENERGY POS MOD
Pride & Prejudice	4	00:02	00:33	105	5.84	5.90	5.67	VALENCE POS MOD
Road To Perdition	6	00:18	00:49	68	8.01	8.27	4.16	TENSION NEG MOD
Running Scared	15	01:44	02:16	86	2.51	6.03	8.01	VALENCE NEG HIGH
Shakespeare In Love	11	00:20	00:51	62	6.57	7.55	5.51	VALENCE POS MOD
Shakespeare In Love	21	00:00	00:29	57	4.28	3.88	5.84	ENERGY NEG HIGH
The Alien Trilogy	11	02:05	02:35	91	3.48	5.58	7.37	VALENCE NEG MOD
The English Patient	8	01:28	01:59	66	3.69	7.09	7.66	TENSION POS HIGH
The Fifth Element	13	00:16	00:48	92	2.58	6.85	8.16	VALENCE NEG HIGH
The Godfather Part III	5	01:11	01:41	107	2.99	6.99	8.12	TENSION POS HIGH
The Untouchables	6	01:38	02:08	71	7.09	4.21	2.75	TENSION NEG HIGH
Vertigo OST	6	02:02	02:33	58	7.45	7.64	4.27	ENERGY POS HIGH
Outbreak	6	00:15	00:45	60	6.03	3.82	4.31	VALENCE POS MOD

Table 2. Fixed effects and random effects for models with Valence, Energy and Task. For fixed effects, the beta estimate (b) with Standard error (SE) and 95% confidence intervals (CI) are reported, for random intercepts, the variance components and standard deviation (SD). For each model, two types of R^2GLMM are reported, marginal (m) and conditional (c) (see text for more information). Note that fixed effects are interpreted based on the *F*-tests reported in the text. Significance codes: 0 '***' 0.001 '**' 0.01 '*'.

Model	**Zygo ~ Valence + Task**	**Zygo ~ Energy + Task**	**Corr ~ Valence + Task**	**Corr ~ Energy + Task**	**SC ~ Valence + Task**	**SC ~ Energy + Task**	**HR ~ Valence + Task**	**HR ~ Energy + Task**	**RR ~ Valence + Task**	**RR ~ Energy + Task**
Fixed effects	*b* (SE) [95% CI]									
Intercept	-.072 (.043) [-.169, -.026]	.111 (.053) [.004, .218]	-.026 (.024) [-.073, .021]	-.112 (.033) [-.174, -.049]**	-.075 (.021) [-.590, -.441]	.058 (.215) [-.457, .574]	-.058 (.051) [-.176, .061]	.019 (.053) [-.101, .139]	-.052 (.012) [-.337, -.234]	.001 (.020) [-.285, .288]
Task (perceived)	.038 (.020) [-.002, .078]		.088 (.024) [-.041, .135]***		.036 (.019) [-.001, .072]		.050 (.018) [.015, .086]**		.033 (.010) [.016, .051]***	
Valence (negativ)	-.002 (.062) [-.117, .121]		.034 (.047) [-.056, .124]		.021 (.043) [-.064, .105]		.022 (.043) [-.062, .106]		-.013 (.030) [-.072, .047]	
Valence (positive)	.186 (.046) [.098, .274]***		-.089 (.034) [-.155, -.023]*		.116 (.032) [.054, .178]**		.057 (.032) [-.005, .119]		.053 (.022) [.010, .097]*	
Energy (low)		-.330 (.122) [-.567, -.093]*		.191 (.091) [.015, .366]*		-.262 (.074) [-.408, -.117]**		-.230 (.073) [-.372, -.087]**		-.168 (.055) [-.275, -.061]**
Energy (medium)		-.167 (.047) [-.259, -.075]**		.082 (.035) [.014, .150]*		-.124 (.029) [-.180, -.068]***		-.071 (.028) [-.126, -.015]*		-.048 (.021) [-.089, -.006]***
Random effects	Variance components (SD)									
Subject (Intercept)	.000 (.000)	.000 (.000)	.000 (.000)	.000 (.000)	.000 (.000)	.000 (.000)	.000 (.000)	.000 (.000)	.000 (.000)	.000 (.000)
Item (Intercept)	.009 (.097)	.010 (.10)	.003 (.051)	.003 (.053)	.003 (.058)	.002 (.046)	.004 (.060)	.002 (.047)	.002 (.049)	.002 (.045)
Interval (Intercept)	.002 (.047)	.002 (.047)	.0001 (.010)	.0001 (.010)	.091 (.671)	.091 (.301)	.004 (.066)	.004 (.066)	.028 (.167)	.028 (.167)
Residuals	.531 (.729)	.531 (.729)	.736 (.858)	.736 (.858)	.496 (.704)	.496 (.704)	.409 (.639)	.409 (.639)	.118 (.344)	.118 (.344)
R^2_{GLMM}										
marginal	.013	.012	.005	.005	.005	.007	.003	.006	.007	.009
conditional	.034	.034	.009	.009	.177	.177	.022	.022	.230	.230

7 Figure Captions

Figure 1. The mean activity of zygomaticus and corrugator muscles in response to Valence (left column) and from skin conductance, heart and respiration rate in response to Energy (right column). On the x-axis the respective categories are depicted and on the y-axis the standardized mean activity/response.

Figure 2. Scatterplots of felt-intensity ratings (z-score) during the felt task (x-axis) and perceived emotion ratings from 42 (y-axis) for all 32 musical pieces.

Figure S1. Plots for all measures and emotion dimensions. The mean activity/response of zygomaticus major muscle (row 1), corrugator supercilii muscle (row 2), skin conductance (SC, row 3), heart rate (HR, row 4), respiration rate (RR, row 5) in response to valence (column 1), energy (column 2) and tension (column 3). On the x-axis the respective categories are depicted and on the y-axis the standardized mean activity/response.

Figure 1

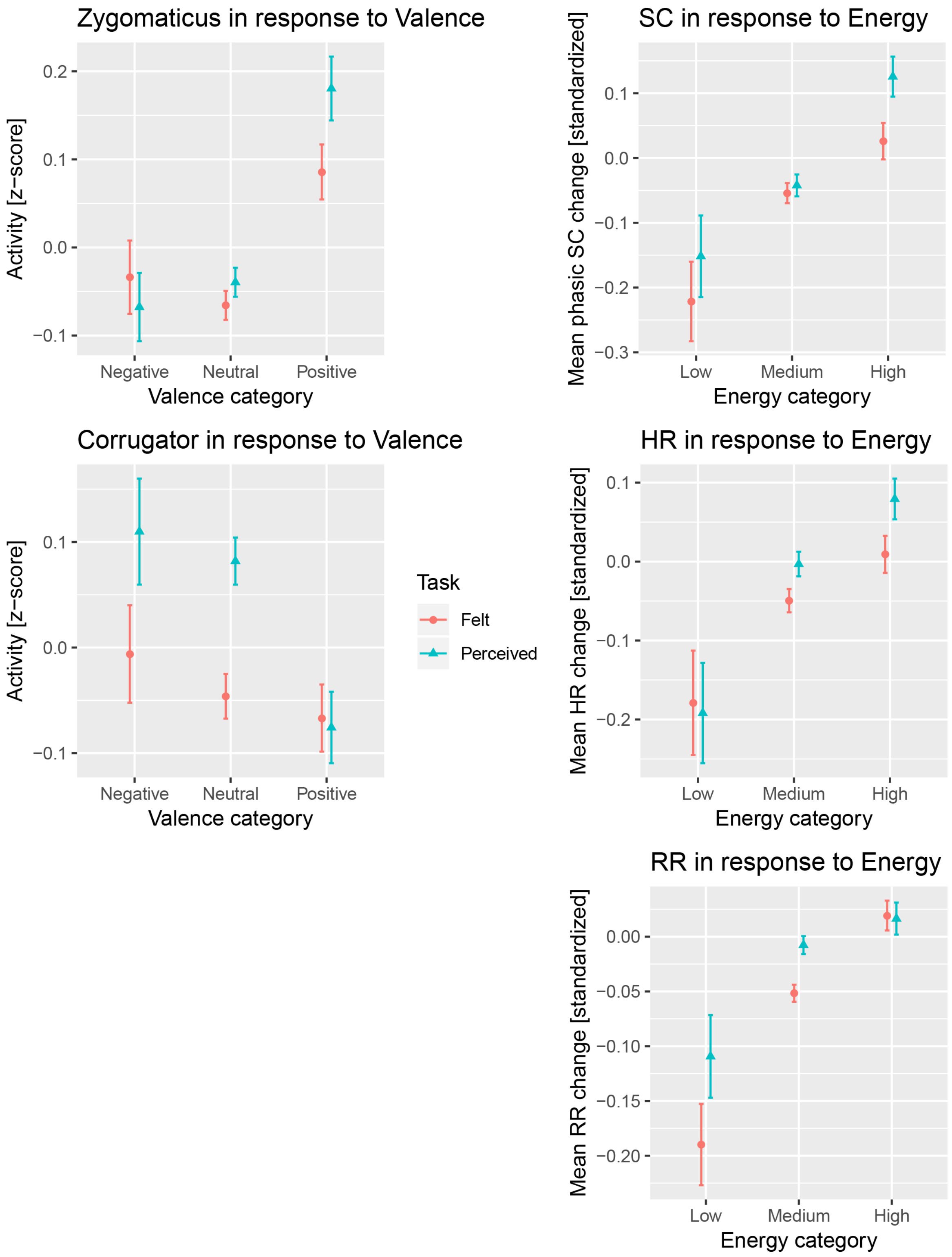
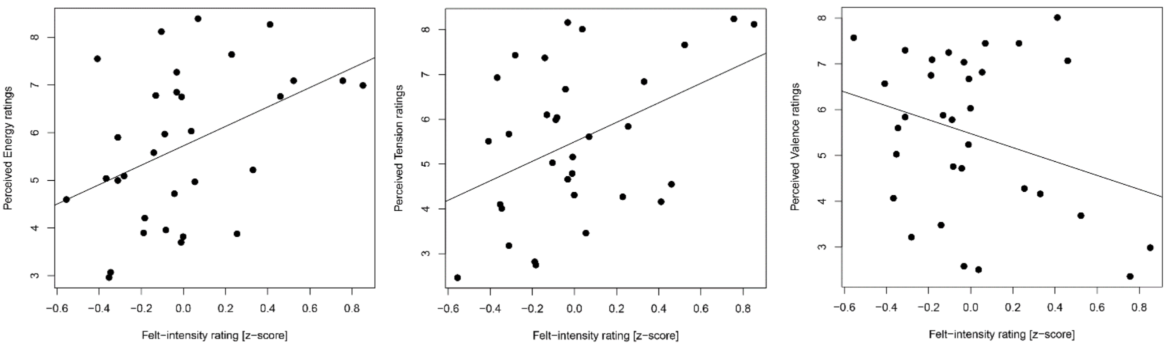

Zygomaticus in response to Valence
Activity [z−score]
0.2
0.1
0.0
−0.1
Negative
Neutral
Positive
Valence category
SC in response to Energy
Mean phasic SC change [standardized]
0.1
0.0
−0.1
−0.2
−0.3
Low
Medium
High
Energy category
Corrugator in response to Valence
Activity [z−score]
0.1
0.0
−0.1
Negative
Neutral
Positive
Valence category
Task
Felt
Perceived
HR in response to Energy
Mean HR change [standardized]
0.1
0.0
−0.1
−0.2
Low
Medium
High
Energy category
RR in response to Energy
Mean RR change [standardized]
0.00
−0.05
−0.10
−0.15
−0.20
Low
Medium
High
Energy category

Figure 2


Perceived Energy ratings
3
4
5
6
7
8
−0.6
−0.4
−0.2
0.0
0.2
0.4
0.6
0.8
Felt−intensity rating [z−score]
Perceived Tension ratings
3
4
5
6
7
8
−0.6
−0.4
−0.2
0.0
0.2
0.4
0.6
0.8
Felt−intensity rating [z−score]
Perceived Valence ratings
3
4
5
6
7
8
−0.6
−0.4
−0.2
0.0
0.2
0.4
0.6
0.8
Felt−intensity rating [z−score]