The Time Course of Emotional Responses to Music

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ABSTRACT: Two empirical studies investigate the time course of emotional responses to music. In the first one, musically trained and untrained listeners were required to listen to 27 musical excerpts and to group those that conveyed a similar emotional meaning. In one condition, the excerpts were 25 seconds long on average. In the other condition, excerpts were as short as 1 second. The groupings were then transformed into a matrix of emotional dissimilarity that was analyzed with multidimensional scaling methods (MDS). We compared the outcome of these analyses for the 25-s and 1-s duration conditions. In the second study, we presented musical excerpts of increasing duration, varying from 250 to 20 seconds. Participants were requested to evaluate on a subjective scale how "moving" each excerpt was. On the basis of the responses given for the longer duration, excerpts were then sorted into two groups: highly moving and weakly (or less) moving. The main purpose of the analysis was to identify the point in time where these two categories of excerpts started to be differentiated by participants. Both studies provide consistent findings that less than 1 s of music is enough to instill elaborated emotional responses in listeners.

KEYWORDS: emotional responses; Mozart; acoustic structure; cultural stimuli

INTRODUCTION

Music is a complex acoustic and temporal structure that induces a large variety of emotional responses in listeners. The adaptative value of these emotional responses to music remains a matter of debate,[1] and several arguments support the idea that emotional responses to music rest on a complex psychological and neurophysiological architecture that could be specifically devoted to music processing. If music was a simple by-product of evolution (some kind of "cheesecake" as suggested by Pinker[2]), emotional responses to music would certainly not be as elaborated as they are in human communities. Understanding the psychological and neurophysiological foundation of these responses is an issue of importance for the cognitive neurosciences, as is shown by the increasing number of studies investigating emotional responses to music at both the behavioral level[3–8] and neurophysiological level.[9–11]

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FOUR ISSUES FOR THE PSYCHOLOGICAL STUDY OF MUSICAL EMOTION

Psychological approaches should contribute to, at least, four main issues. First of all, the nature of emotions induced by music should be described in detail. Preliminary empirical investigations have demonstrated that basic emotions, such as happiness, anger, fear, and sadness, can be recognized in, and induced by, musical stimuli in adults and in young children. These studies converge to demonstrate a strong consistency among participants, as long as musical excerpts are chosen to convey very basic emotions.

The conclusion that music induces three or four basic emotions is, however, far from compelling for music theorists, composers, and music lovers. Indeed, they are likely to underestimate the richness of the emotional reactions to music that may be experienced in real life. An alternative approach is to stipulate that musical emotions evolve in a continuous way along two or three major psychological dimensions. A lot of previous research has established a bidimensional structure of emotion for facial expressions,[12,13] voice perception,[14] and affect words.[15,16] In the music domain, an attempt to model the perception of expressive content of Western music in multidimensional space has been developed,[16–21] and specific neurophysiological reactions associated with the arousal and valence dimensions have also been reported.[22,23] In Wedin[24–26] musical excerpts were rated on a number of semantic scales defined by emotionally colored adjectives. Factor analysis was then used to extract the dimensions accounting for the evaluation.

More recently, Canazza, De Poli, Vidolin, and Zanon[27] presented participants with an excerpt from Mozart's Concerto for Clarinet, K622, that was interpreted and recorded with different levels of expressiveness. Participants were asked to use a set of sensorial adjectives (e.g., light, soft, dark, hard) to express the emotion they felt the excerpt possessed. Using multidimensional and factorial analyses, they obtained a semantic bidimensional space of musical expressiveness in which two dimensions appeared: one called *kinematics* that corresponded to the tempo parameter, and another called *energy* related to the intensity parameter. Such a kinematics–energy space provides useful information on how expressiveness is organized in the listener's mind. Interestingly, this study indicates that kinematics aspects could be a main determinant of participant judgments on musical expressiveness.

A common feature of these studies was to investigate emotional responses to music using linguistic labels. The use of verbal labels is potentially problematic since it can encourage participants to simplify what they actually experience.[28] Some philosophers even argued that musical emotions are definitely ineffable.[29,30] As nicely coined by the composer Felix Mendelssohn, the emotion induced by music may be so rich that even language may not be able to account for it. If this is the case, using linguistic labels in empirical research could result in missing important aspects of musical emotion. We will report below a method to investigate the emotions conveyed by musical pieces without using linguistic responses.

A second important issue of the psychological approach is to characterize the factors that contribute to musical emotion. A broad distinction of extra- and intramusical factors has been proposed. Extramusical factors designate the features inherent to both the inner state of the subject and the social context in which he/she stands that contribute to emotional responses. Listening to music alone, with partners, or within an experimental setting, for example, may have considerable influence on the perceived emotion. Similarly, being in a positive or in a negative mood when going to a concert may drastically change the emotional experience. By contrast, inner musical factors designate the features in the auditory signal that induce emotions. Some psychoacoustical parameters, such as loudness or roughness, obviously have an quasi-immediate impact on the nature of perceived emotion (with negative valence of emotion being generally correlated with higher roughness). Other more cultural factors linked to the compositional processes also play an important role in modulating the variety of emotions we may experience. These factors deal with harmonic processes (modulation, ornamentation, tonal tension, and relaxation), or rhetoric processes (theme elaboration and variations, violation of expectancies).[31,32] It is likely that emotions induced by a given piece are derived from the way both type of factors (psychoacoustics and cultural factors) are combined in the performance. That is to say, a sudden change in loudness (or in timbre) per se is not crucial for emotion: the way this change occurs in the musical process is, however, of central importance.

A third important issue for the psychological approach would be to describe the timing of emotional response to music. Emotion is a dynamic process that evolves through musical time. Tracking these changes would illuminate how sophisticated the processes governing emotions are. Recently, provocative findings relative to this issue have been reported by authors showing that emotional responses to music may occur very fast. A previous study by Watt and Ash[33] showed that 3- to 5-second extracts of orchestral interludes from Wagner operas were quite sufficient to generate consistent, and emotionally relevant, categorizations in listeners. Peretz *et al.*[32] went one step further by showing that emotional responses rest on very fast-acting mechanisms, so that 250 ms of music may be enough to distinguish happy from sad excerpts. This suggests that some basic emotions may function without cortical mediation. Independence between the affective and cognitive systems has been demonstrated in the visual domain.[34] Cerebral lesions have been found to alter the recognition of facial expressions while the ability to identify faces was spared. In the field of music, I.R., a brain-damaged patient who suffers from considerable deficits in music cognition, was shown to be able to discriminate between happy and sad excerpts while being unable to determine whether the music was familiar or not (Peretz *et al.*[32]) Moreover, I.R. performed similarly to controls when differentiating sad from happy excerpts of extremely short duration (500 ms). This suggests that severe deficits in the cognitive processing of music may leave emotional responses unimpaired.

Finally, the fourth issue of the psychological approach to musical emotion is to delineate the potential influence of musical expertise. There is no doubt that emotion is the core of musical experience, and it is what motivates people to listen to music and to produce it. As such, it is of crucial importance to investigate how emotional experience may change with musical expertise. Surprisingly, there is no clear *a priori* predication about this issue. On the one hand, we may assume that musical expertise results in a greater ability for musically trained listeners to process very subtle changes in auditory musical signals that may be highly relevant for emotion. Research on auditory plasticity in musicians provided a lot of empirical arguments showing that musicians' brains differ from the brains of nonmusicians and that this difference reveals the greater ability of the former group to process subtle changes in pitch or timbre (see papers on plasticity, this volume). Accordingly, important differences in the emotional experience to music should be reported. On the other hand, several studies pointed out that musicians and nonmusicians do not differ a lot when processing musical structures of critical importance for Western music.[35–37] According to these studies, musically untrained listeners implicitly process subtle changes in musical structure, as trained listeners do. This finding challenges the idea that the emotional experience of both groups should differ importantly. Moreover, if we accept the possibility that music serves important evolutionary functions, such as regulating emotion in human communities, then we should also assume that musical competence is largely shared by human beings and does not require a complex explicit training. Ethnomusicological studies provide a large set of evidence along this line.

TRACKING THE TIME COURSE OF EMOTIONAL RESPONSES TO MUSIC

Our two studies focus more specifically on the timing of emotional experience in music but also deal more or less directly with the other issues. The first study involved the multidimensional scaling of emotional responses to musical excerpts that were 25 seconds and 1 second long. A complete account of this study will appear in Bigand *et al.*[38] The second study adapts a gating paradigm to the study of musical emotion.[39]

In the former study, participants were encouraged to focus entirely on their emotional experience of the musical excerpts. A sample of 27 musical excerpts of serious nonvocal music was selected by music theorists and psychologists according to several constraints.[a] All excerpts were expected to convey a strong emotional experience. They were chosen to illustrate a large variety of emotions and to be representative of key musical periods of Western classical music (baroque, classic, romantic, and modern) as well as of the most important instrumental groups (solo, chamber music, orchestra). This final constraint is of methodological importance, since it helps to neutralize any confounding effect between the structural surface similarity and the emotional similarity of excerpts.

Participants were presented with a random visual pattern of 27 loudspeakers, representing the 27 excerpts. They were first required to listen to all the excerpts and to focus their attention on their emotional experience. They were then asked to look for excerpts that induced similar emotional experiences (whatever they might be) and to drag the corresponding icons to group these excerpts. This task encouraged participants to focus on induced emotions and not to recognize the emotional information encoded in the music. They were allowed to listen to the excerpts as many times as they wished, and to group together as many excerpts as they wished. A simple rule then transformed the partition obtained into a dissimilarity matrix: stimuli grouped together were set with a dissimilarity of 0, while everything else was set to 1. The multidimensional scaling (MDS) method was then used to analyze the psychological dimensions underlying this matrix. The critical point of this study was to

[a]Musical stimuli are available at http://www.u-bourgogne.fr/LEAD/people/bigand.html.

compare two experimental conditions: in one condition, excerpts lasted 25 seconds on average. In the other condition, excerpts lasted 1 second. We expected that this drastic length change would have a profound impact on the outcome of the MDS. Moreover, the experiment was run with musically trained and untrained listeners in order to assess the potential influence of training on emotional experience.

Here are the main important outcomes. First, emotional response was found to be very consistent within participants, as well as between participants. Second, we found that a three-dimensional solution accounted for a substantial part of the emotional responses: the vertical axis separates musical excerpts that vary by their arousal level. The horizontal axis presumably separates musical excerpts that differ by their emotional valence. The third axis tends to separate pieces with broad and regular melodic contours from those that proceed harmonically or by broken arpeggios. A possible interpretation is that this dimension expresses the influence body gestures evoked by musical excerpts might have on perceived emotions. The link between music and movement is well established, and several authors have emphasized that musical affects arise in large part from their relationship to physical patterns of posture and gesture.[40] Given that a considerable amount of emotional experience is presumably embedded in cortical sensory motor maps,[41] the evocation of gestures by music could have relevant influence on listeners' emotional experiences.

The geometrical solution found for musicians and nonmusicians was not distinguishable. Both groups of musicians and nonmusicians produced an equal number of clusters, and their matrices of emotional similarity were highly correlated. This weak difference is all the more surprising given the complexity of the musical stimuli used. For the present purpose, the critical point of the study was to find that the outcome of the MDS is weakly influenced by the duration of the excepts: that is to say, the structure of the emotional experience, as revealed by MDS, did not apparently differ between the 1-s and the 25-s conditions. Reducing considerably the length of the musical excerpts (25 seconds to 1 second) only had a weak effect on emotional responses. The present data thus extends the findings of Peretz *et al.*[42] to a larger set of complex musical stimuli. At first glance this finding may sound extremely surprising. In half of the cases, the first second of our excerpts contained a single chord or pitch interval (excerpts 1, 3, 4, 7, 8, 9, 10, 17, 21) and sometimes even a single tone (excerpts 5, 6, 19). What factors may contribute to the emotional experience in this case? A cautious analysis of these one-tone excerpts suggests that performance cues are enough to induce emotions in Western listeners, even at this extremely short duration. The importance of performance for musical expressiveness is well established.[8,18] The way the first tone of a piece of a given expression should be played is highly constrained. Expert performers shape the amplitude and the spectral envelope of the first tone of a piece in a way that prefigures the main mood of the piece. Acculturated listeners have probably internalized these regularities of Western performances (implicitly for nonmusicians). Thanks to this knowledge, they may experience an emotion as soon as the first tone of a piece is played (at least when the performer is highly skilled). In short, we suggest that cognitive appraisal occurs with these extremely short excerpts and that it immediately induces emotional feelings in listeners.

It may be argued that participants in our experiments may have identified the musical expression of the piece without being really moved by the piece. Our experimental paradigm encouraged them to focus on what they experienced, but this did not insure that their response actually reflected this instruction, notably for very short excerpts. Several control experiments were done to address this issue. In one of them, we slightly modified the task and asked participants to evaluate on a subjective scale how much they were moved by the musical excerpts. The critical manipulation consisted of presenting musical excerpts by slices of increasing duration. That is to say, participants started the experiment by listening to 250-ms excerpts and then continued the task with excerpts of 500 ms, 1 s, 2 s, 5 s, and 20 s (on average). One group of musically trained and untrained participants worked with excerpts from classical (serious) music, another group with a sample of excerpts for pop/rock music. Excerpts were initially chosen so that half of them were likely to be perceived as strongly moving and the other half as being less moving. In addition, half of the musical excerpts had high dynamic contrast, and the other half had low dynamic contrast. In order to explain the task to participants, we encouraged them to imagine that they were looking for moving (emotional) music on a radio. Shifting from one radio station to another would be an ecological situation that was similar to the experiment. The critical question of the experiment was to specify how many milliseconds they needed to decide whether the excerpts they were listening to were highly moving.

To analyze the data, we first considered the responses given to the longest excerpts. On the basis of these responses, we sorted the excerpts into two groups: those that were perceived as highly moving by the participants, and the other with those that were perceived as less moving. The critical point was to assess the point in time when participants became able to differentiate significantly between these two groups of excerpts. We were wondering whether this minimum time to feel an emotion would vary as a function of musical style (classic versus pop/rock), as function of dynamics (low versus high), or as a function of musical expertise (musically trained versus untrained listeners). The outcome was highly consistent for all groups of listeners and for both styles: statistically significant differences between these two groups of excerpts were found by 250 ms and notably for the pieces with a low dynamic contrast. However, there was neither an effect for musical style nor for musical expertise. This finding suggests that 250 ms of music may be enough to induce strong or weak feelings of emotion in listeners, whatever the musical style being played.

CONCLUSION

The present data lead to several conclusions. First, they demonstrated that refined emotional responses to music occur from the very beginning of music listening. This finding is consistent with a number of others in the domain of emotion: it has been shown that responses to emotional stimuli such as human faces, human body gestures, or other stimuli of biological importance occur extremely fast. It is remarkable, however, that a highly cultural stimulus such as music, which seems to have no clear adaptive value (at least for some authors), can trigger emotions in such a fast-acting way. Further research is needed to settle the issue of whether the speed of emotional responses is a general characteristic of human emotions that could be confirmed irrespective of the type of stimuli used, or whether it is restricted to stimuli of evolutionary importance for human species.

Second, the present findings suggest that emotional responses to very short musical stimuli presumably involved cortical mediation. An analysis of the musical and psychoacoustical structures of very short excerpts (in both experiments) suggests that emotions are likely to be governed by features in both compositional structure (harmony) and performances that all are highly cultural. Musical emotions induced by very short excerpts are too refined to be simply derived from basic emotional properties of sound. We argue that these responses required a cognitive appraisal. From this point of view, our conclusion differs from Peretz *et al.*,[43] who considered that fast emotional responses to music may be viewed as the product of some subcortical reflexes.

Taken in combination with other findings reported on music cognition that show that cognitive processing of subtle musical structure occurs extremely fast,[44] the present findings provide evidence that both cognitive and emotional processes are very fast-acting processes that seem to occur automatically in acculturated listeners. The fact that these findings were obtained for the musically trained as well as for the musically untrained provided further evidence that music is a highly relevant sound structure of the environment, and that processing it does not require an intensive explicit training.

Finally, our data suggest that emotional responses are quasi-immediate as soon as music is played. Of course this does not mean that musical emotion does not change as music goes by. On the contrary, it is likely that emotional experiences accumulated from the very beginning of the piece contribute to color and to intensify the emotions experienced later.

[Competing interests: The authors declare that they have no competing financial interests.]

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