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Individual emotional reactions towards music: Evolutionary-based universals?

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• **Abstract**

Music can elicit strong feelings and physiological arousal in listeners. However, it is still under debate as to whether these reactions are based on universal reaction patterns or are acquired during a process of individual acculturation. Here we present evidence for the latter hypothesis: Subjective ratings on the axes of valence and arousal as well as physiological measurements of skin conductance response of 38 participants were assessed. Data were recorded continuously over time while participants listened to seven different musical pieces as well as five to ten pieces which they selected individually. Individual reactions showed extreme heterogeneity and revealed no systematic reaction patterns for all participants. In an exploratory approach, reactions of female and male participants were compared in response to singing voices of different registers (basso, tenor, alto, and soprano). The comparison of genders showed no significant differences, either in subjective ratings or in physiological reactions. The data presented here suggests that individual differences in the subjectively felt reactions to music dominate possible universal patterns. We argue that the high diversity in individual affective responses to music suggests a high adaptability of the underlying reaction patterns. This response mechanism might be evolutionarily beneficial due to its potential for social differentiation.

Keywords: emotion, evolution, music, physiology, circumplex model.

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In the last decade there has been convincing evidence for the importance of making music and listening to music as a feature of humanity (Brown, Merker & Wallin, 2000; Cross, 1999). Blood and Zatorre (2001) found brain systems to be associated with euphoria and/or pleasant emotions, which are activated when listening to music. They found such structures as the nucleus accumbens, the ventral tegmental area, thalamus, insula, and anterior cingulate to be more active when participants reported strong emotional reactions. At the same time, activity in the amygdala and ventral medial prefrontal cortex was reduced. This pattern of activity has been observed typically in other brain studies concerning pleasant bodily experiences, such as eating or having sex (Breiter *et al.*, 1997). However, until now there has been no definite answer to the question as to why humans are able to experience strong emotions by listening to music or by making music. A convincing argument for the fascination of music in the sense of an "affective communication system" has evolved in the last years: Music seems to have the potential to initiate or reinforce the social bonding among individuals in a group by means of "emotional resonance" and shared emotional experiences.

McNeill (1995, p. viii) assumed that "moving our muscles rhythmically and giving voice consolidate group solidarity by altering human feelings." In other words, social cohesion is created by keeping together in time — a phenomenon which the author called "muscular bonding" (p. 2). However, from this standpoint the question remains open as to whether a unified pattern of emotional resonance (in the sense of a generalisable or "universal" reaction) or individual patterns with a high degree of diversity in emotional responses to music would be more beneficial from an evolutionary perspective. This perspective assumes that the reactions to music, whether universal or heterogeneous, are in some way relevant and beneficial traits for the evolutionary development.

Although the Darwinian concept of basic emotions in affective communication (which does not necessarily involve felt emotions) emphasizes the importance of similar patterns in acoustical utterances related to the same emotion (Darwin, 1965), it seems unlikely that aesthetic emotions, such as those experienced through music, are also characterized by this high degree of standardization. We also have to bear in mind that the categorizing of emotional reactions to music as "emotions" or as much weaker "aesthetic emotions" is still open to discussion (Scherer, 2005). The following short survey of studies will show that there are convincing arguments for the assumption of the central role of diversity in emotional reactions to music. The studies will be grouped according to the discrimination between "emotion perceived" and "emotion felt" (Gabrielsson, 2001-2002).

DIVERSITY IN EMOTIONS PERCEIVED

The perception of emotions in music seems to be limited to the general ability to distinguish between basic emotions of happiness, sadness and anger, for example. When the emotions expressed by a certain music involve more subtle shades of affective content, non-expert listeners as well as musicians fail to categorise the emotions correctly (Brown, 1981). Brown used stimuli which represented six grades of sadness — for example, "sadness tinged with romantic mystery". The consistency of categorisation was better for individuals who were highly familiar with the musical genre of the stimulus. In a very recent study, Kallinen and Ravaja (2006) found that listeners had difficulties rating music as "angry" which had been classified as such by another group of listeners in a pre-test. Two of the three "angry" pieces from this emotion category were rated by the second group of participants as representing "fear" and one piece as "joy". Results from studies in the decoding of speech prosody seem to contradict these results from music. Thompson and Balkwill (2006) recently found that English-speaking listeners were able to decode the emotive intent of utterances spoken by male and female speakers of English, German, Chinese, Japanese, and Tagalog.

When discussing the evolutionary roots of the perception of emotions in music, the findings of inter-cultural comparisons, the reactions of children to music, and the results of comparative studies (animal studies) are of great interest. The components of decoding emotions in music, which are based on our genetic inheritance and can thus be assumed to be evolutionarily relevant factors, should be found in other cultures and in early stages of human development. Abilities that are evolutionarily relevant for us may also be found in related species. The distinction between harmonic and disharmonic sounds, for example, may be a feature that we share with other species. The question of inter-cultural agreement of emotions coded in music was addressed by Gregory and Varney (1996). The authors compared the perceptions of Eastern (Indian) and Western classical music listeners. Judgements were given with a forced choice adjective list of emotions. The comparison of the groups revealed an overall similarity in the emotion judgements; however, specific pieces showed differences. Terwogt and van Grisven (1991) addressed the question as to how the perception of basic emotions in music changes during the lifetime development. They asked three age groups (5- and 10-year old children as well as adults) to link selected musical excerpts to facial expressions which represented basic emotions. In this study, excerpts exclusively from Western classical music were used as stimuli. Even the young children agreed considerably in their choices of expressed emotions. However, an increase of consensus in older listeners could be stated, indicating the relevance of learning processes in the decoding of emotional cues in music. Participants had more problems identifying negative emotions, such as fear and anger, compared to positive emotions.

When there is a general consensus even in young children about the emotional content of music, the perception of music may be based on some very basic principles that could be found even in the sensation of animals. McDermott and Hauser (2004) investigated whether cotton-top tamarin monkeys show preferences for consonant sounds. Cotton-top tamarins are often used for tests of perceptual abilities. McDermott and Hauser placed the tamarins in a v-shaped maze, which consisted of two arms with different auditory environments. Preference for one sound was measured by the time the tamarin spent in each arm of the maze. The animals differed in their preferences neither for consonant or dissonant sounds nor for screeching sounds compared to amplitude-matched white noise. Humans, in this experiment, showed clear preferences for consonant intervals over the amplitude-matched white noise. The authors concluded that the preferences that support our capacity for music could be music-specific adaptations.

Diversity in emotions felt

Results from studies on physiological effects of music also show a heterogeneous picture: On the one hand, we can find studies on felt emotions which show evidence for a generalisable pattern of bodily reactions to music of selected emotions. For example, the sensations of happiness, sadness, serenity, or agitation in music can result in different cardiorespiratory patterns (*e.g.*, respiratory rate, respiratory sinus arrhythmia, see Nyklicek, Thayer & van Doornen, 1997). Or, as Krumhansl (1997) found, sad music produced the largest changes in heart rate, blood pressure, skin conductance and temperature, while happy music excerpts produced the largest changes in the respiration rate. Particular structural features of the music can also influence emotional reactions: For example, Sloboda (1991) found evidence for an effect of unexpected harmonic changes or harmonic sequences which seem to function as triggers for the induction of so-called "chills". Schubert (2004) observed that changes in loudness and tempo, loudness being dominant, were associated positively with changes in self-reported arousal; melodic contour varied positively with valence.

On the other hand, there is support for the assumption of highly individualized reactions to music. In a very early study, Dogiel (1880) tested the influence of different timbre and melodies on heart rate and blood circulation. As a side-effect, he found an effect of a listener's cultural background on the experienced emotions: His Tartarian lab assistant showed the strongest changes in blood pressure when listening to a Tartarian melody. In the 20th century, Allesch (1981) was one of the first who investigated whether there is a generalisable influence of music on felt emotions. He presented a 21-minute piece of popular music ("Atom heart mother" by Pink Floyd) and measured changes in pulse rate and heart frequency in 25 participants. Results revealed that the pulse rate of a person was much more

influenced by his or her own base-line pulse level than by the music itself. Thus, he could not confirm the hypothesis of generalisable patterns of physiological reactions to music.

Finally, sensitivity for the emotional impact of music also seems to be influenced by the listener's personality. For example, persons with a high arousal threshold (so-called high sensation seekers) prefer rock music (Litle & Zuckerman, 1986) and show less activation after listening to heavy metal music (Nater, Krebs & Ehlert, 2005); extraverted listeners prefer music with exaggerated bass frequencies (McCown, Keiser & Mulhearn, 1997); persons with a tendency to seek novelty prefer techno music (Gerra *et al.*, 1998); and physiological responses to emotionally powerful music (heart rate changes, mean number of chills per minute) were positively correlated with extraversion as measured by the NEO-FFI inventory (Rickard, 2004).

Rationale of the study

The simple model presented in Figure 1 is intended to demonstrate the emotional reactions to which we are referring in this article. The question here is whether fixed reaction patterns in the subjective feeling or physiological domain can be found in response to music. Even if participants are not consciously aware of their reaction to a distinct pattern, the reaction should be revealed in the physiological domain. Certainly it is possible that learned reaction patterns and even consciously controlled reactions influence possible fixed reaction patterns. However, if music has any direct, manipulative influence on our emotions based on fixed reaction patterns, these patterns could be expected to exert influence on feelings or physiological reactions. For example, it was hypothesized that a high male voice in music may have a (sexually) arousing effect on females (Miller, 2000). This implies a very simple and basic affective impact of music which could be described by Figure 1 as a fixed reaction pattern. We were interested whether there are direct influences of music on felt emotions in addition to the discussed homologies in perceiving and recognizing emotions. However, this study only refers to simple cases with fixed reaction patterns and thus looks only at the direct impact of music on emotions.

As we began to study potential evolutionarily relevant triggers of emotions in music, we investigated a group of Western Europeans while they listened to different styles of Western music. If acoustical patterns that trigger emotions were to be found in an exploratory study, they could be controlled in further experiments with participants of different cultural backgrounds, young children, and even animals. In this study the circumplex model of affect as developed by Russell (1980) was used to measure subjective feelings in combination with physiological responses. We measured valence, arousal, and skin conductance response (SCR) on a second-per-second basis and asked in questionnaires after each piece whether the participant knew the piece, how much he or she liked it, and how pleasant it was. The main aim

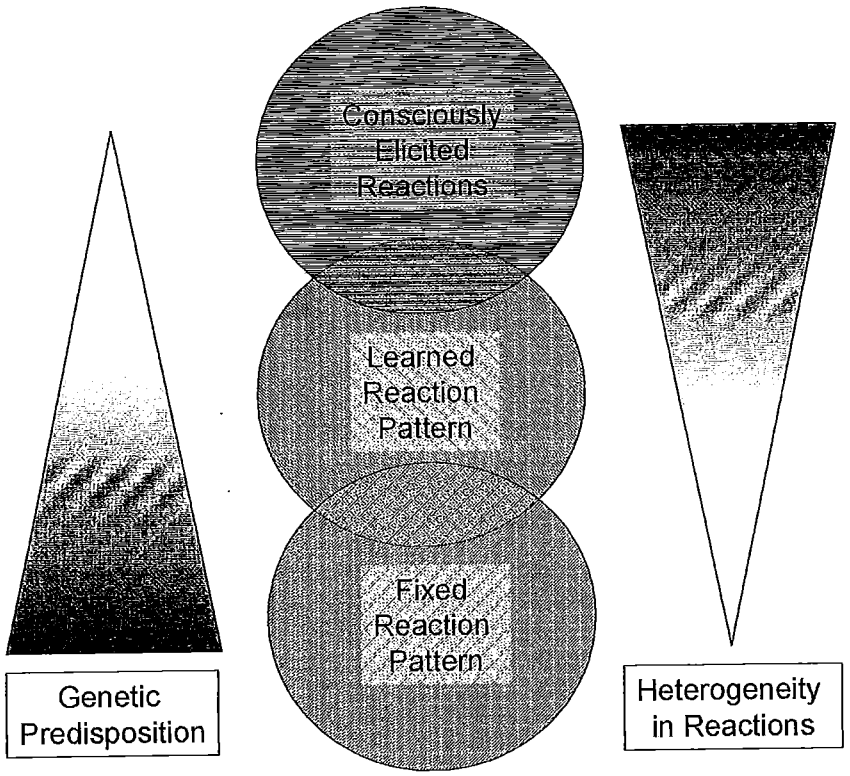

Figure 1.

Concept of different emotional reactions to music. This article refers only to possible fixed reaction patterns, which could be expected to be most conserved and highly homogeneous in a group of western listeners. All levels of reactions might influence each other (over-lappings). This model is not data based and should be understood as a heuristic illustration of the underlying concept of this approach to musically-induced emotional reactions.

of this study was to find first hints at evolutionarily conserved emotional reaction patterns in response to music. In a group of 38 Western European listeners we looked for response patterns in every individual. Furthermore, the reactions of one individual to the same pieces over seven days were compared. Additionally, in an exploratory approach we compared female and male responses to the different registers in the "Tuba Mirum" from Mozart's *Requiem*. This piece includes long solos of all registers from basso to soprano, and reactions could be compared within one piece. Some authors hypothesised that a high tenor voice may demonstrate biological fitness and thus be perceived as attractive (Miller, 2000). We also asked for "sexual arousal" as one possible reaction to music, especially in response to the pop song

"Making Love out of Nothing at All" by Air Supply, which is sung by a high tenor voice. We hypothesized that there would be differences between men and women in response to a singer of the opposite gender.

Method

Participants

We analyzed individual reactions selected from a group of 38 participants (mean age = 37.87 years, *SD* = 15.63 years, range = 11-72 years; 29 females and 9 males; 33 right-handed persons and 5 left-handed persons). Because we were interested in general reactions to music, we selected a heterogeneous group with regard to musical experience and preferences. Three participants even reported not being interested in music at all and that they only occasionally listened to music on the radio. The group was also heterogeneous pertaining to educational and social backgrounds. Students, professors, retirees, housewives, veterinarians, and labourers participated in the experiment. Volunteers were not paid for their participation. The group included 5 professional musicians or music students, 20 amateur musicians who still played or once played an instrument, and 13 participants who had never played an instrument.

Musical stimuli

Seven standard music pieces were used in the experiment in addition to five to ten personal pieces which were brought in by each individual participant. These seven pieces were chosen to cover as many musical styles as possible without overtaxing the participants: the "Soul Bossa Nova" by Quincy Jones as an example for dancing music; "Coma" by Apocalyptica as an example for rock music; "Skull full of Maggots" by Cannibal Corpse as an example for death metal music; and the main title from the soundtrack of the movie *Chocolat*, written by Rachel Portman, as an example of film music. Here we present the results of the three standard pieces which elicited the strongest affective responses: the "BWV" by J. S. Bach, the pop song "Making Love Out of Nothing at All" by Air Supply and the "Tuba Mirum" from the Requiem KV 626 by W. A. Mozart.

The "BWV" by J. S. Bach (duration 496 s) was used as an example of instrumental classical music. This organ piece consists of six structural segments, which are repeated and varied throughout the piece. In case of evolutionarily determined reaction patterns, similar responses to similar musical structures could be expected. The "Tuba Mirum" from the Requiem KV 626 by W. A. Mozart (duration 251 s) was chosen as an example of classical vocal music. In the "Tuba Mirum", all registers from basso to soprano sing a solo one after the other. In the end, all four voices sing together. The pop song "Making Love Out of Nothing at All" by Air Supply (duration 340 s) was found to elicit strong emotions in a former study (Panksepp,

1995). It has a simple structure and was chosen as an example of popular music. Classical music may mask basic emotional reaction patterns by overtaxing naïve listeners with its complexity. The 3 standard pieces were presented in randomised order, intermixed with the personal pieces (see also Grewe *et al.*, 2007a).

Questionnaires

Participants were asked to answer a researcher-developed questionnaire after each piece in which they stated how well they knew the piece, how much they liked it and how pleasant they would rate it. Answers were given on 7-point Likert scales ranging from "not at all" (= 1) to "very much/well" (= 7).

Retest experiment in one individual

In an exploratory attempt to test the homogeneity of responses in one individual, we repeated the experiment with one subject (24, female, right-handed, musician) seven times. The experiment was done on 7 days with a break of 2 days between days 5 and 6. We used the same pieces in the same order and began the experiment at the same time each day (10:30 am).

Apparatus and procedure

As a parameter for physiological arousal, we measured the Skin Conductance Responses (SCR). SCR is a well established measurement and has been used often in studies concerning emotional reactions to music (Krumhansl, 1997; Rickard, 2004; Witvliet & Vrana, 1995). For the physiological measurements, we used ARBO Ag/AgCl-electrodes with a diameter of 15 mm. SCRs were measured on the middle segments of the index and middle fingers of the nonactive hand. Signals were amplified 100 times with a biosignal amplifier developed by IED (Institut für Explorative Datenanalyse, Hamburg, Germany). SCRs are presented as arbitrary units with values between –2 and +4, adapted to the observed range. Valence and arousal ratings were recorded with the researcher-developed software "EMuJoy" for continuous measurement (Nagel, *et al.*, 2007), which is based on the two dimensional emotion space by Russell (1979; 1980). Participants were able to report their feelings on the axes of valence and arousal continuously while listening to the music. Auditory stimuli were presented using closed headphones (Beyerdynamic DT 770 Pro) in combination with a USB soundcard (Audiophile, M-Audio). Music, physiological data, and signals from valence/arousal ratings were synchronized by the researcher-developed software "EMuJoy" based on a D/A converter card (DT Measure Foundry by Data Translation). For evaluation and presentation of data, we used MatLab (Version 7.1).

For each participant an individual experimental session was processed. After welcoming the participant, the experimenter explained thoroughly the full process. Participants could ask questions to clarify the concepts of valence and arousal. High valence was explained as a positive feeling that the participant would like to continue,

whereas low valence was defined as a negative feeling the participant would like to avoid. The participants were explicitly asked to report the feelings they felt themselves and not the emotions expressed by the music. Participants chose which hand they preferred for operating the computer mouse. Then the electrodes for measuring the skin conductance response were set on the middle segments of the index and middle finger of the non active hand. The trial took place in a comfortable armchair in front of a computer display next to a small table on which the computer mouse could be moved. The computer display and mouse activated the EMuJoy software. A two dimensional valence (horizontal) and arousal (vertical) space was displayed, and participants could move a cursor continuously in the 2D-space. Before starting the experiment, a 30 second baseline was recorded. Additionally, participants could test the use of the EMuJoy software by rating 10 pictures from the International Affective Picture System, IAPS (Lang, Bradley & Cuthbert, 2001). Afterwards participants were asked whether they felt comfortable with the experimental setting and understood the use of the EMuJoy software. If everything was in order, then the experiment was initiated with the first piece of music. After each piece, participants filled in the questionnaire. Upon finishing the questionnaire, the participant gave a sign to the researcher, who sat in the same room behind a room divider and who then started the next piece of music and data recording. At the end of the experimental session, participants filled in short demographic questionnaires and were thanked for their participation. All participants were volunteers and were contacted during a public talk or by flyers. This experiment has also been involved in previous publications concentrating on other aspects (Grewe *et al.*, 2007b).

Results

In this study, we focused on individual responses to three different pieces. Assuming that evolutionary-based universals in response to music would be detectable, we expected that these responses would be more evident in a group of Western listeners. Possible general effects in all listeners of such a homogeneous group should then be tested with listeners of other cultures. Since music is not a static stimulus, the dynamics of responses are a crucial feature of any emotional response to music. We decided to present our data as a typical time-series because the change of subjective and physiological responses provides the most interesting information. For every piece described below, we have chosen six participants and will present them in order of their participation in the experiment.

Example 1: Toccata BWV 540 by J. S. Bach

Figure 2 shows the individual valence/arousal ratings as well as the skin conductance responses (SCR) of six participants while listening to the "Toccata" BWV 540 by J. S. Bach.

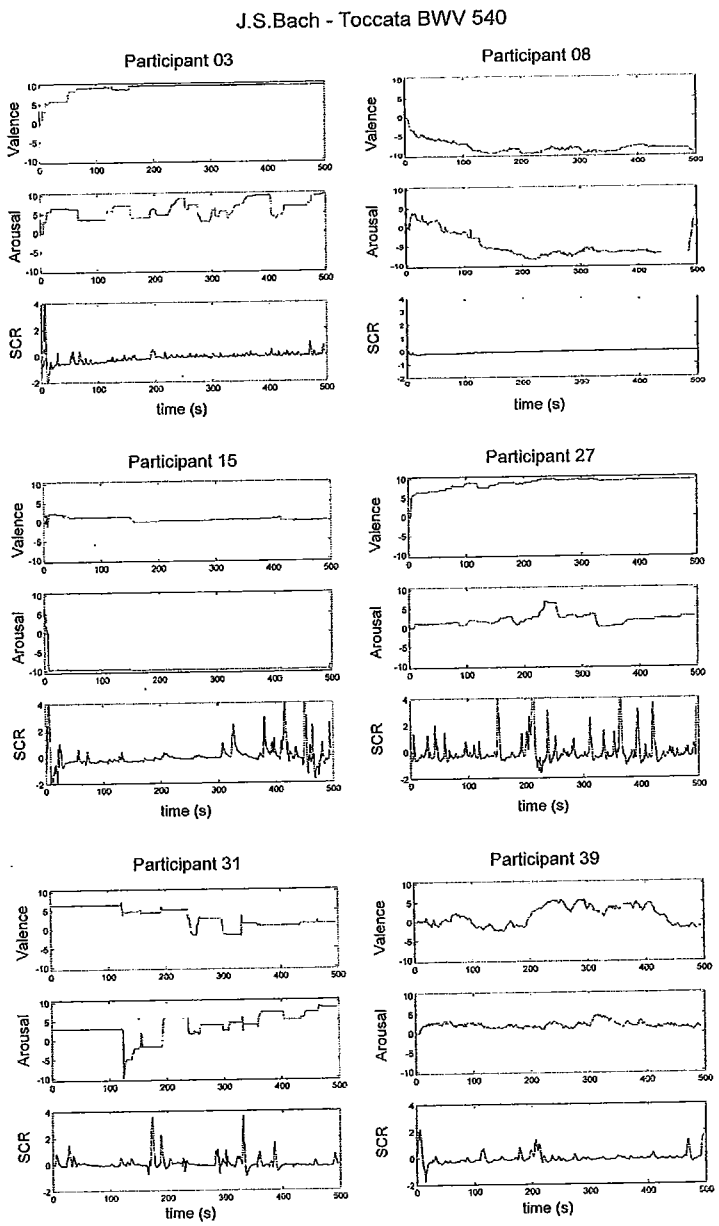

Figure 2.

Individual reactions of six participants to the "Toccata" BWV 540 by J. S. Bach (duration = 496 s). Valence and arousal were reported in a two-dimensional space ranging from –10 to 10. Skin conductance response (SCR) is presented in arbitrary units according to the observed range.

All participants showed different reaction patterns regarding the three parameters. Participant 03 reported an extremely high valence during the entire piece. His arousal ratings showed changes from medium arousal to high arousal at several points with a tendency to increase at the end of the Toccata. While skin conductance reacted strongly once at the beginning, changes in skin conductance during the rest of the piece remained small. Participant 03 reported on a 7-point Likert scale to not know the piece before listening to it. However, liking and pleasantness of the piece were both rated highest. Participant 08 showed complementary reactions to participant 03. Valence was reported as being extremely negative and arousal as very low. Knowing, liking, and pleasantness of the piece were rated very low (knowing = 1, liking = 1, pleasantness = 2). Surprisingly, participant 08 showed no SCR changes at all. While subjectively reported arousal and physiological arousal were consistent for this listener, participant 15 reported an extremely low arousal, while the SCR measurement revealed strong responses at the beginning and the last third of the piece. Valence was reported as neutral, as well as knowing, liking and pleasantness (all rated = 3). Participant 27 showed strong valence ratings and physiological reactions to the Toccata, while arousal was reported as medium. This listener rated the Toccata as being extremely pleasant (= 7). Participant 27 reported that he/she knew and liked the piece very much (both = 7). Participant 31 reported a medium valence with a tendency to decrease to the end of the piece and a medium arousal with a tendency to increase to the end of the piece. Two episodes of strong physiological arousal could be measured around t = 190 s and t = 300 s, which, however, were not reflected in the subjective ratings. Participant 31 reported knowing the piece (= 5), liking it (= 6) and perceiving it as pleasant (= 5). The last case, participant 39, showed medium valence, arousal, and SCR responses. After the first occurrence of the main theme at t = 200 s, valence was rated a bit higher. The entrance of the main theme was also marked by a peak in SCR as well as at the beginning of the piece. Participant 39 had heard the Toccata before (knowing = 4); ratings of liking and pleasantness were low (both = 3).

Example 2: "Making Love Out of Nothing at All" by Air Supply

An example for individual reactions to pop music is shown in Figure 3. Participant 03, who rated his/her knowledge, liking and the pleasantness of the piece as very low (knowing and liking = 1, pleasantness = 2), also reacted with negative valence. Subjective and physiological arousals, in contrast, were high. Between t = 50 s and t = 100 s participant 03 reported a strong increase in arousal and showed a strong SC response. A similar increase in subjective arousal was reported at t = 260 s. However, the physiological reaction at this point was much weaker. Participant 09 had a different opinion about this piece: He/she reported knowing and liking it very much (knowing = 6, liking and pleasantness = 7 each). Valence was reported as positive over the whole piece. A single strong peak was found at the beginning of the piece; however participant 09 reported experiencing this passage with extremely low

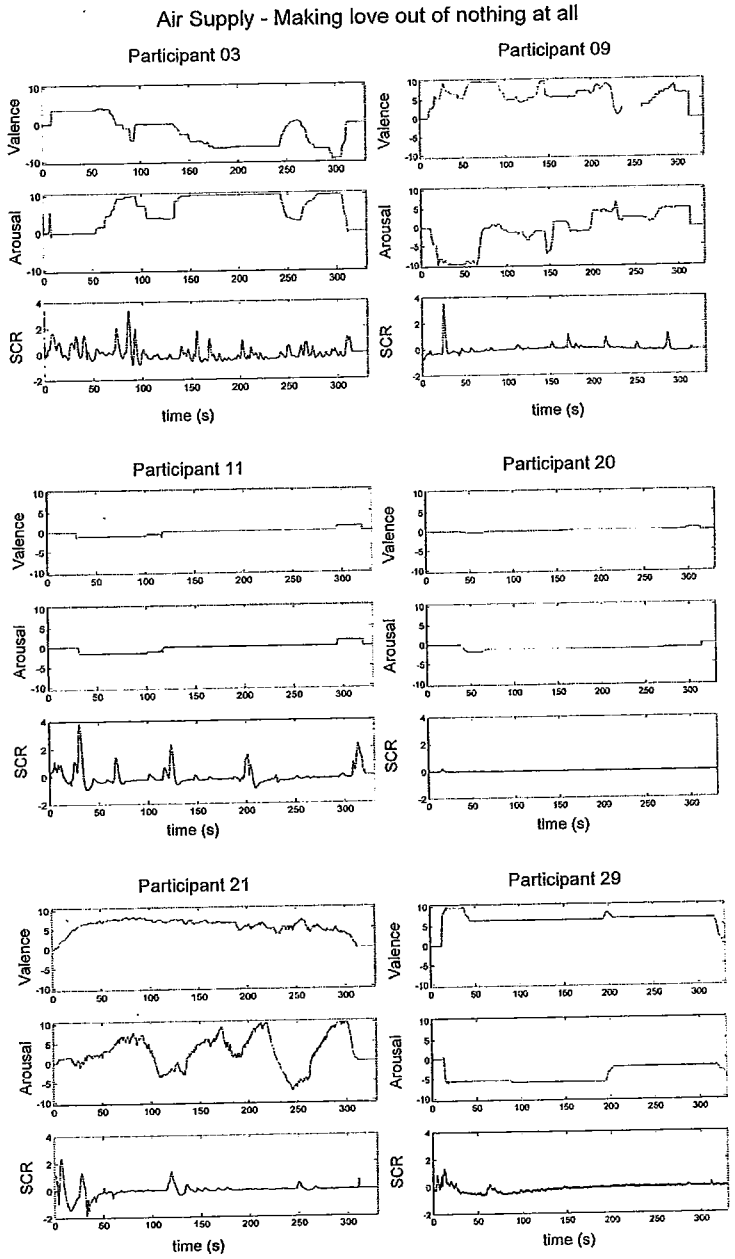

Figure 3.

Individual reactions (valence, arousal, SCR) of six participants to the pop song "Making Love Out of Nothing at All" performed by Air Supply (duration = 340 s).

arousal. Participant 11, who, similar to participant 03, disliked the piece (knowing = 1, liking 2, pleasantness = 2), reacted with neutral valence and arousal. However, several strong peaks in SCR could be found, the strongest at $t = 30$ s, similar to participant 09. Participant 20 reported neutral valence and arousal also, and in this case the SCR confirmed the neutral arousal. This participant did not know the piece (knowing = 1), and did not like it very much (liking = 3, pleasantness = 4). Participant 21 did not know the song (knowing = 1) and rated it as neutral on the liking and pleasantness scales (both = 4). However, this participant perceived high valence and several episodes of extremely high arousal. Surprisingly, the SCR showed peaks during episodes of reported neutral or low arousal. Finally, participant 29 reported high valence but did not like the piece very much, nor did he/she perceive it as being pleasant (knowing = 5, liking = 3, pleasantness = 3). Subjective arousal and physiological arousals were both low.

Example 3: "Tuba Mirum" from the Requiem KV 626 by W. A. Mozart

The next sound example, the "Tuba Mirum" by Mozart, is an example of classical vocal music (see Figure 4). Participant 06 reported a constant feeling of high valence for the "Tuba Mirum". In the questionnaire following the piece, this participant rated the piece as very pleasant (= 6), and liked it very much (= 6), even if he/she did not know the piece (= 2). Arousal was reported to increase from neutral to medium at the end of the piece. The SCR showed stronger responses at the end of the piece, too. Similarly, participant 12 reported high valence, liking (= 7), and pleasantness (= 7). This participant knew the piece (= 6). Subjective as well as physiological arousal was high for participant 12, being a bit stronger at the beginning. Participant 13 did not know (= 1) or like (= 2) the "Tuba Mirum" and did not perceive it as pleasant (= 2). The valence reported was neutral besides slight increases at the beginning and the end. Participant 13 showed a strong SC response at the beginning of the piece and several weaker peaks throughout the piece. Participant 19 showed consistent results regarding high valence, liking (both = 6), and pleasantness (= 5) — similar to participants 06 and 12. However, the subjectively perceived arousal differed from those of all other participants. It showed a tendency from medium to neutral, complementary to participant 06. From $t = 60$ s to $t = 90$ s, participant 19 reported a strong decrease in subjective arousal. The physiological response, however, was very strong in the beginning, but it showed almost no response later during the piece. Like the other participants, he/she showed a strong SC response at the beginning of the piece. The SCR pattern in response to the same piece was very different for participant 22. Besides the peak at the beginning of the piece, participant 22 showed only reactions after 170 s. The reported arousal also increased at the end of the piece. Valence was perceived as neutral, and knowing (= 1), liking (= 2) and pleasantness (= 3) of the piece was rated as low.

As a last example, participant 35 rated the "Tuba Mirum" high, regarding knowing (= 7), liking (= 7) and pleasantness (= 6). Valence was perceived as medium

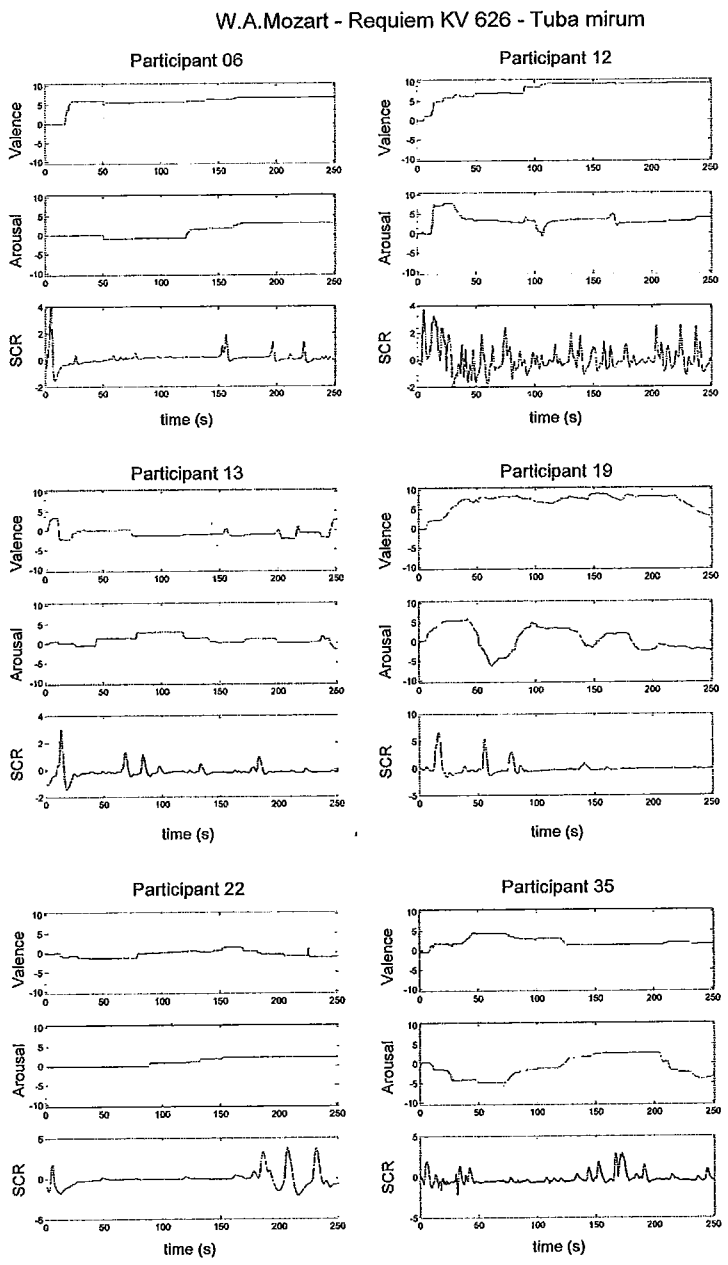

Figure 4.

Individual reactions (valence, arousal, SCR) of six participants to the "Tuba Mirum" from the Requiem KV 626 by W. A. Mozart (duration = 251 s).

high at the beginning and neutral at the end of the piece. Subjective arousal showed an increase in the middle of the piece, which in this case could be confirmed by the physiological data.

Summary

For each piece, responses were extremely inconsistent in terms of valence, arousal, knowing, liking, and pleasantness as well as SCR in different individuals; thus, almost all kinds of combinations between the parameters could be found. We did not find any underlying common pattern — neither for the subjective nor for the physiological responses on an individual basis. The only parameters that seemed to be related on an individual basis were ratings of knowing, liking, and pleasantness. These parameters did indeed correlate between all participants. For the "Toccata" BWV 540 knowing values correlated with liking (r = .47, p < .01) and with pleasantness (r = .49, p < .01). Liking and pleasantness correlated extremely high (r = .95, p < .001). The "Tuba Mirum" showed similar results. Knowing and liking are related (r = .49, p < .01), as well as knowing and pleasantness (r = .49, p < .01). As for the "Toccata", liking and pleasantness correlate strongly (r = .95, p < .001). For the pop song "Making Love Out of Nothing at All", only liking and pleasantness correlated significantly (r = .84, p < .001).

Responses of one individual for a repeated listening over seven days

In order to test for homogeneity in the responses of one individual, an additional experiment was conducted: one female participant listened to ten pieces for seven days. Here we present a representative example of one self-chosen piece (see Figure 5, "Oh, Röslein rot" [Oh, rose so red], by Gustav Mahler, 2nd Symphony, 4th movement, (Solti, 1996)). Valence ratings were generally highly positive on all days, increasing from the beginning to the end. Specifically, some differences between the seven days can be stated; changes occurred at different points in time. Arousal ratings were much more homogeneous compared with the ratings between individuals. Over all, the piece elicited low arousal. One major change at about 140 s could be found on six days out of seven. Physiological reactions, however, occurred at different points over time. Only in the time window between 20 s to 40 s could a response be found on five days. These responses show extremely different intensities. This reaction corresponds to a motive played in the brass instruments.

Comparison of valence/arousal reactions between different registers of voice

In the "Tuba Mirum" all registers enter one after the other with a vocal solo. At the end of the piece, the four soloists sing together (tutti). We compared the different registers of the "Tuba Mirum" regarding the mean valence and arousal ratings given by all participants using a Wilcoxon test (see Table 1).

This test revealed that the basso was felt with less positive valence compared to all other registers (see Figure 6). There was also a significant difference in the valence

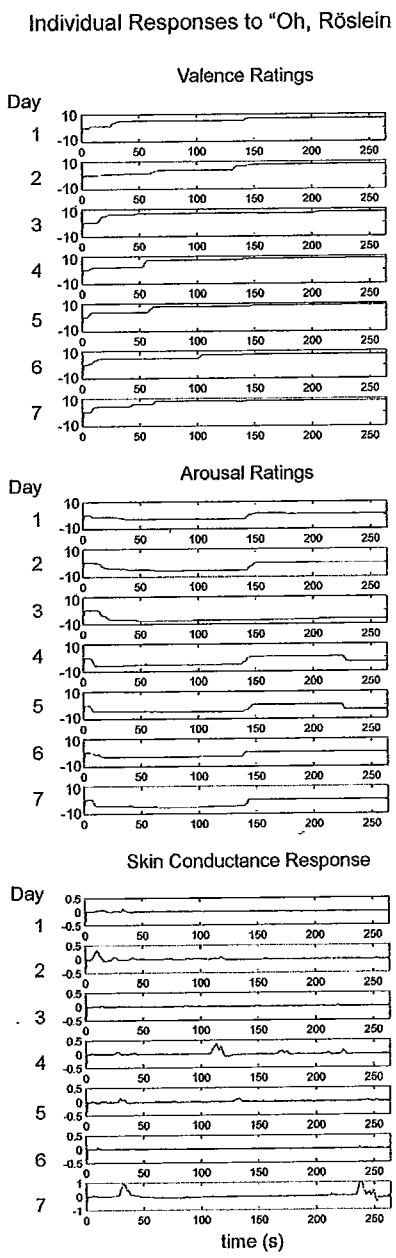

Figure 5.

Responses (valence, arousal, SCR) of one individual during repeated listening (tested seven days) to the 4th movement of Gustav Mahler's 2nd Symphony (duration = 246 s).

Table 1

Wilcoxon T values of valence/arousal ratings in response to selected registers and tutti (Mozart, "Tuba Mirum")

	Tenor (71-132 s)		**Alto** (132-156 s)		**Soprano** (156-199 s)		**Tutti** (199-251 s)	
	V	*A*	*V*	*A*	*V*	*A*	*V*	*A*
Basso (8-71 s)	186*	209	168*	283	171*	295	192*	248
Tenor (71-132 s)			147*	299	204	251	245	157**
Alto (132-156 s)					261	288	263	182*
Soprano (156-199 s)							298	161*

Note. V = Valence; A = Arousal. Wilcoxon test, $N = 35$; * $p < .05$, ** $p < .01$

ratings between tenor and alto (see Figure 7). The tenor, alto and soprano were felt as being more arousing compared with the tutti section, but there were no significant differences between the solo voices regarding arousal.

To test for gender differences in reactions to the four registers, we compared the valence and arousal ratings of female ($N = 26$, three missing values) and male ($N = 9$) listeners to the four solo passages of the "Tuba Mirum". We used the Mann-Whitney U-test to test for the Null hypothesis that female and male ratings were equal during the different passages.

The statistical results showed that the hypothesis could not be rejected for any of the registers (see Table 2). Furthermore, in a comparison of the SCR of males and females (see Figure 8), no significant differences could be found (see Table 2). In the questionnaire after each piece of music, we asked additionally for sexual arousal as one possible reaction to music. One piece out of all seven pieces ("Making Love Out of Nothing at All") elicited sexual arousal, but in only two participants.

In addition to the seven test pieces, participants brought in five to ten personal pieces, which frequently elicited strong emotional reactions in them. Sexual arousal was reported in three further cases out of a total of 480 pieces. Besides "Making love" two pieces of South American dance music and the 2nd piano concerto by Rachmaninov elicited sexual arousal. Only females reported sexual arousal, but none of them did so for more than one piece. In only one case the piece which elicited sexual arousal was not associated with a personal and positive recall (three positive, one missing value).

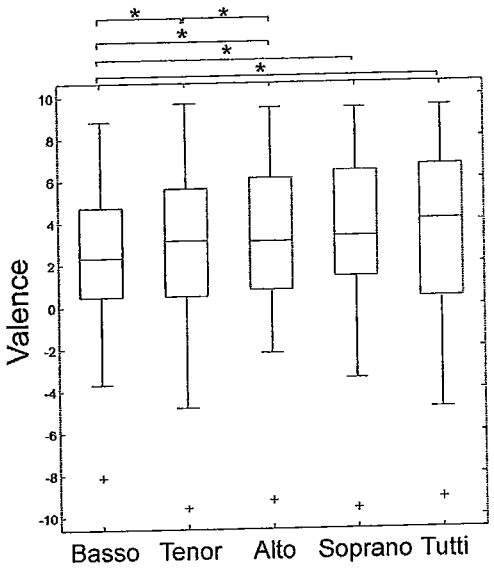

Figure 6.

*Comparison of the mean valence ratings of all participants (N = 35, 3 missing values) in response to the different registers in the "Tuba Mirum" (Wilcoxon test, * = p < .05).*

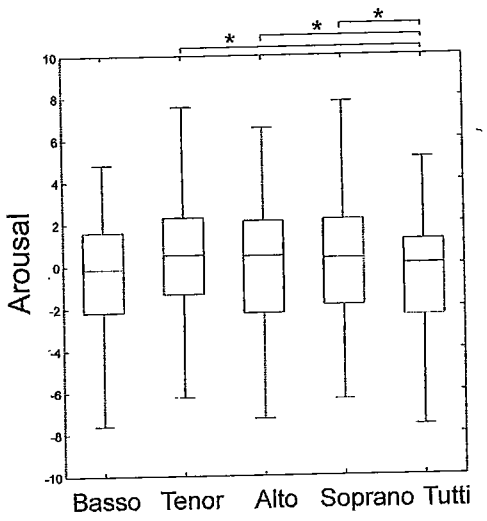

Figure 7.

*Comparison of the mean arousal ratings of all participants (N = 35, 3 missing values) in response to the different registers in the "Tuba Mirum" (Wilcoxon test, * = p < .05).*

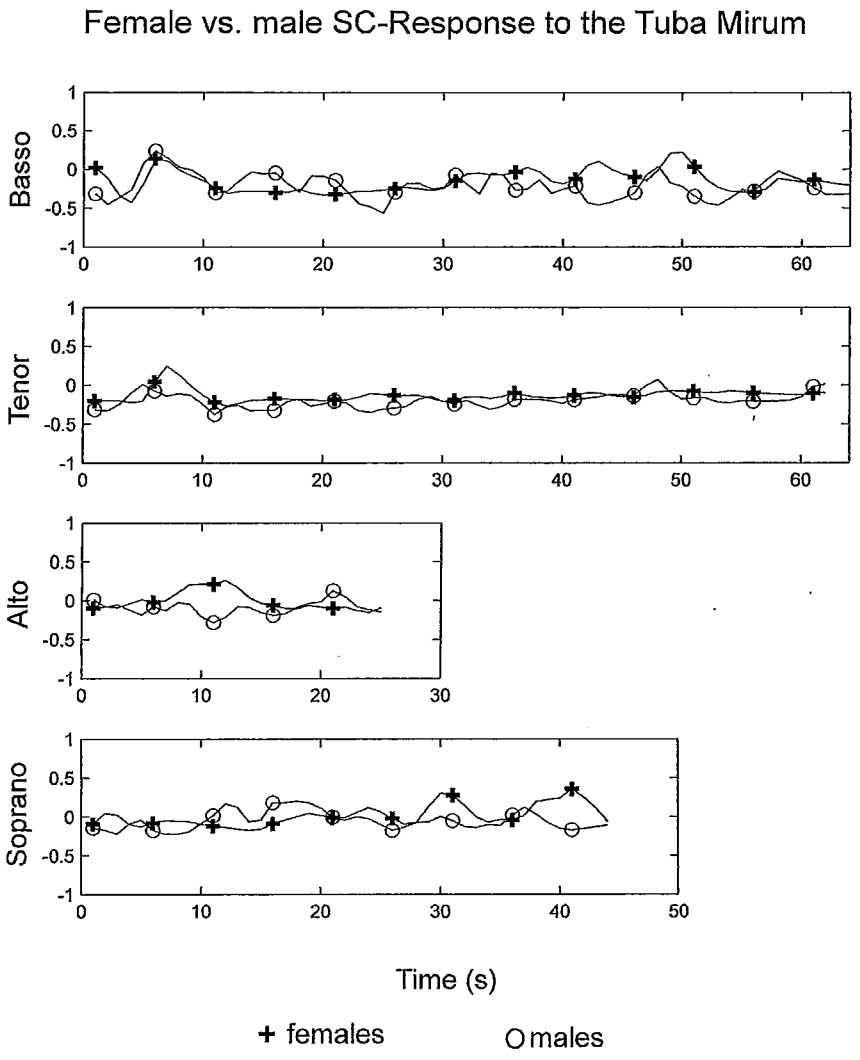

Figure 8.

Comparison of mean female (N = 26) vs. male (N = 9) SC response to the different registers of the "Tuba Mirum". SCR is presented as arbitrary units according to the observed range and the duration of the solo of each voice (basso, t = 64 s, tenor, t = 62 s, alto, t = 25 s, soprano, t = 44 s). The mean of female reactions is marked with crosses, the mean of male reactions with circles.

Table 2

Mann-Whitney U values for differences between female and male valence/arousal ratings and SCR responses to registers of soli (Mozart, "Tuba Mirum")

	ΔV (f/m)	ΔA (f/m)	ΔSCR (f/m)
Basso (8-71 s)	160 *n.s.*	113 *n.s.*	150 *n.s.*
Tenor (71-132 s)	147 *n.s.*	115 *n.s.*	127 *n.s.*
Alto (132-156 s)	147 *n.s.*	149 *n.s.*	150 *n.s.*
Soprano (156-199 s)	140 *n.s.*	141 *n.s.*	154 *n.s.*

Note. Mann-Whitney *U* test, $N = 35$ (26 females, 9 males); n.s. ... $p > .05$
ΔV (f/m) = difference between female and male valence ratings
ΔA (f/m) = difference between female and male arousal ratings
ΔSCR (f/m) = difference between female and male SCR level

Discussion

In this study we raised the question whether a unified pattern of emotional resonance (in the sense of a generalisable or "universal" reaction) or a high degree of diversity in emotional responses to music would be more beneficial from an evolutionary perspective. Since our participants came from a Western cultural background and were familiar with Western music, we expected clear reaction patterns in all individuals in the case of any underlying genetically conserved reaction pattern. Additionally, we compared the subjective as well as the physiological reactions of females and males to singing voices of the same and opposite gender in an exploratory approach. We concentrated on the reactions to music rather than the understanding of emotions coded in music. The perception and interpretation of music showed homologous responses in other studies, as was reported in the introduction. Thus, it is not the evolutionary benefit of music perception which is in the focus of this discussion. Here we concentrate on possible fixed reaction patterns toward music relevant for emotions. In contrast to the assumption of generalisable reactions patterns, we could not find a clear reaction pattern among all individuals. On the contrary, we have to state that individual responses to the selection of musical pieces used in this experiment were extremely diverse. Reactions ranged from extremely high valence ratings to extremely low ratings for the same piece. Some participants showed a strong SCR, while others had no physiological reaction during the entire piece. The analysis of continuous data revealed that reactions are diverse not only for entire musical pieces; they also differ over time and in reaction to distinct musical

sections. It should be mentioned that the methodology used (continuous measurement) tends to increase variability, and there might be some measurement errors rather than genuine differences in felt emotions. It is also possible that some of the participants rated their perception rather than emotional responses to the music, in spite of the conscientious instructions given to them. However, the individual reactions suggest that none of the musical sections of the different pieces could trigger a distinct emotion in a reflex-like manner, neither in an inter-individual, nor in an intra-individual comparison. In other words, we found no evidence for any unified pattern of "emotional resonance". Thus, our data suggest a high degree of diversity in emotional responses to music.

Some authors (Miller, 2000) have hypothesized that singing may be an expression of biological fitness and that thus the sexual attractiveness of singers may be raised when compared to non-singers. We found no evidence for this assumption, neither in men nor in women. While the basso was perceived a little lower in valence as a mean for all participants, no significant differences could be found between the other voices. Females and males did not react with different subjective ratings or physiological reactions to any of the registers. In the questionnaire after each piece, we additionally asked for sexual arousal as one possible reaction to music. The only researcher-chosen piece that induced sexual arousal in 2 out of 37 participants (one missing value) was "Making Love Out of Nothing at All". This piece is sung by a high tenor voice, and both reacting participants were females. However, also the pieces brought in by the participants elicited sexual arousal in only three cases. It would be interesting to investigate whether singing increases the attractiveness of a voice compared to speaking.

The correlations between knowing, liking, and pleasantness provide further evidence for the assumption that aesthetic emotions are strongly related to the familiarity with a stimulus and are thus likely to be learned (Panksepp, 1995). In this study, we concentrated on the feelings elicited by music, and the question as to whether music could be universally understood remains open. The selection of stimuli is, of course, a crucial factor, and we tried to consider as many musical styles as possible. However, it is not possible to test "music" in its immense and rich diversity in one experiment. The extreme variability in the individual reactions suggests that if there is any genetically conserved reaction pattern to music, it is at least strongly influenced and masked by individually learned patterns of emotional responses.

Finally, it remains to be asked what the meaning of the diversity in emotional reactions to music in an evolutionary perspective could be. Why do our aesthetic affective reactions rely so much on familiarity with a particular musical style? We would like to propose that this diversity may be the basis for the formation of social subgroups. Many social groups have *their* music and build their identity on musical preferences (MacDonald, Hargreaves and Miell, 2002). Rap, rock, classical music, grunge, electronic music, jazz — these are not only labels of musical styles; they are

also associated with social groups. Music belongs to a group's image as much as do specific clothing, haircuts, sets of behaviour, gestures, or sometimes even food. In other words, music is always a mean to emphasize social difference. As language differs between nations, music differs between social subgroups. Along these lines, music may provide emotional codes which must be learned and understood to be appreciated by every member of a group. Socialisation appears as one of the main evolutionary advantages of mankind, and music seems to be a crucial factor to build up the identity of a group. Our results suggest that an evolutionary perspective on the aesthetic reactions to music changes the idea of the *correct* or *good* music to a concept of the *appropriate* and *appreciated* music. This would change the idea of a musical *trigger* to a concept of musical *codes*. Besides socialisation, the adaptation of behaviour seems to be a great advantage of humanity in evolution. To adapt behaviour, we rely on our ability to build up expectations, to analyse situations and stimuli and to build up neuronal patterns about their relation to other stimuli. During our development, we play with stimuli to learn about the underlying patterns and their meaning. Music may be hypothesized as a game of sounds and voices that helps us to build up complex communicational patterns. For these reasons we would like to suggest that playing (with) music increases our ability to express our own emotions and to decode the feelings of other members of the social group we live in.

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• Reacciones emocionales individuales provocadas por la música: ¿universales basados en la evolución?

La música puede producir en sus oyentes sentimientos fuertes y excitación fisiológica. No obstante, aún se debate para saber si estas reacciones se basan en formas de reacción universales o si se adquieren durante un proceso de aculturación individual. Avanzamos aquí pruebas a favor de la segunda hipótesis. Hemos estudiado en 38 participantes las evaluaciones subjetivas sobre los ejes de valencia (placer-desagrado) y de excitación al mismo tiempo que las medidas fisiológicas de la respuesta electrodérmica. Los datos han sido recogidos de forma continua mientras los participantes escuchaban siete piezas musicales diferentes, así como entre cinco y diez piezas que ellos habían seleccionado de forma individual. Las reacciones individuales han mostrado una heterogeneidad importante y han revelado que no había modelos de reacción sistemática para el conjunto de participantes. En una aproximación exploratoria, se han comparado las reacciones de las mujeres y de los hombres en respuesta a voces de registros diferentes (bajo, tenor, contralto y soprano). Esta comparación no ha mostrado diferencias significativas, ni en las evaluaciones subjetivas ni en las reacciones fisiológicas. Los datos presentados aquí sugieren que, en estas reacciones a la música experimentadas de forma subjetiva, las diferencias individuales dominan posibles reacciones universales. Presentamos argumentos sobre el hecho de que la importante diversidad en las respuestas afectivas individuales a la música sugiere una gran facultad de adaptación de los modos de reacción subyacentes. Este mecanismo de respuesta podría ser beneficioso desde el punto de vista de la evolución, gracias a su potencial de diferenciación social.

• Reazioni emotive individuali dinanzi alla musica: universali basati sull evoluzione?

La musica può provocare forti sentimenti e una ecitazzione fisiologica negli ascoltatori. Ciononostante, non è ancora stato chiarito se queste reazioni siano basate su schemi universali ben distinti di risposta dipendenti dall'evoluzione o se la loro potenzialità si acquisisca durante un processo di educazione individuale. In questa sede porteremo prove a sostegno della seconda ipotesi: è stata effettuata una valutazione soggettiva sugli assi di valenza e di arousal, così come misurazioni fisiologiche della risposta di conduttanza cutanea di trentotto partecipanti. I dati sono stati acquisiti continuativamente nel tempo mentre i partecipanti ascoltavano sette diversi brani musicali e da cinque a dieci brani scelti da loro individualmente. Le reazioni individuali sono state caratterizzate da un'estrema eterogeneicità e hanno dimostrato che in nessun partecipante si è verificato uno schema di risposta sistematico. Con un approccio esplorativo, sono state comparate le risposte dei maschi e quelle delle femmine in seguito all'ascolto di canti effettuati da voci di vario registro (basso, tenore, alto e soprano). Il confronto tra i due gruppi non ha mostrato differenze significative, sia per quel che riguarda la valutazione soggettiva che le risposte psicologiche. I dati presentati suggeriscono che le differenze

individuali nelle reazioni alla musica percepite soggettivamente dominino possibili schemi universali. Riteniamo che l'elevata diversità nelle diverse risposte affettive individuali alla musica suggeriscano l'esistenza di una forte adattabilità degli schemi di risposta alla base. Tale meccanismo di risposta potrebbe essere evolutivamente vantaggioso in quanto garantirebbe un'alta possibilità di differenziazione sociale.

• Réactions émotionnelles individuelles provoquées par la musique : universaux basés sur l'évolution ?

La musique peut provoquer chez ses auditeurs des sentiments forts et une excitation physiologique. Cependant, on débat encore pour savoir si ces réactions sont basées sur des formes de réaction universelles ou si elles sont acquises durant un processus individuel d'acculturation. Nous avançons ici des preuves en faveur de la seconde hypothèse. On a étudié chez 38 participants les évaluations subjectives sur les axes de valence (plaisir-déplaisir) et d'excitation en même temps que les mesures physiologiques de la réponse électrodermale. Les données ont été enregistrées en continu pendant que les participants écoutaient sept pièces musicales différentes et cinq à dix pièces qu'ils avaient sélectionné individuellement. Les réactions individuelles ont montré une hétérogénéité importante et ont révélé qu'il n'y avait pas de modèles de réaction systématique pour l'ensemble des participants. Dans une approche exploratoire, on a comparé les réactions des femmes et des hommes en réponse à des voix de différents registres (basse, ténor, alto et soprano). Cette comparaison n'a pas montré de différences significatives, que ce soit dans les évaluations subjectives ou dans les réactions physiologiques. Les données présentées ici suggèrent que, dans ces réactions à la musique ressenties de façon subjective, les différences individuelles dominent un hypothétique mode de réaction universel. Nous argumentons sur le fait que l'importante diversité dans les réponses affectives individuelles à la musique suggère une grande faculté d'adaptation des modes de réaction sous-jacents. Ce mécanisme de réponse pourrait être bénéfique du point de vue de l'évolution, grâce à son potentiel de différenciation sociale.

• Individuelle emotionale Reaktionen auf Musik: Evolutionäre Universalien?

Musik kann starke Gefühle und physiologische Erregung in Hörern auslösen. Es ist jedoch bislang ungeklärt, inwieweit diese Reaktionen auf universalen Reaktionsmustern beruhen oder im Zuge einer individuellen Akkulturation erworben worden sind. Wir stellen im Folgenden Argumente für letztere Hypothese vor. Während 38 Versuchsteilnehmer sieben verschiedene Musikstücke anhörten sowie fünf bis zehn, die sie selbst ausgewählt hatten, wurden kontinuierlich subjektive Bewertungen von Valenz und Erregung sowie physiologische Messungen des Hautwiderstandes erfasst. Die gemessenen individuellen Reaktionen waren extrem heterogen und zeigten kein systematisches Muster über alle Probanden hinweg. In einem explorativen Ansatz wurden darüber hinaus die Reaktionen weiblicher und

männlicher Hörer auf Gesangsstimmen verschiedener Register (Bass, Tenor, Alt, Sopran) verglichen. Der Vergleich der Geschlechter ergab keinen signifikanten Unterschied, weder in den subjektiven Bewertungen, noch in den physiologischen Reaktionen. Die hier vorgestellten Ergebnisse sprechen dafür, dass subjektive Unterschiede in der Empfindung von Musik sich stärker ausprägen als dominante, universale Reaktionsmuster. Die hohe Diversifizierung individueller affektiver Reaktionen ist ein Hinweis auf die starke Adaption der zugrunde liegenden Reaktionsmuster. Diese Anpassungsfähigkeit könnte in Hinsicht auf die soziale Differenzierungsfähigkeit einen evolutionären Vorteil darstellen.