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Continuous Measurement of Musically-Induced Emotion: A Web Experiment

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Abstract: The aim of this study was to determine the validity of the Internet-based *ESeRNet* software for the measurement of emotional music experiences by comparing the data of this study with those previously collected in a lab experiment. Participants (N = 83) listened to different music pieces online. At the same time they gave a continuous self-report about their emotional state by moving their computer-mouse in a two-dimensional emotion space and indicating chills (strong emotions accompanied by shivers down the spine or goose pimples) by clicking the mouse button. The emotional dimensions assessed were arousal and valence. Participants reported that the music pieces caused different emotional reactions that were not significantly different from the lab study using the same stimuli. Thus, the validity of this Internet-based method could be confirmed. In general, nearly all participants evaluated positively most aspects of the study – with the exception of the participation time. None of the technical parameters investigated at the participants' computers significantly affected the emotional self-report, but an influence of the self-rated concentration on arousal and chill ratings was observed. The results also show that experiments in the Web offer a promising way for emotion research and provide insights on emotions experienced when listening to music in every day life.

Keywords: Emotion, music, Web experiment, continuous rating, Internet

Continuous measurement of musically-induced emotion: A Web experiment

Music surrounds us everywhere: at home, at work, in cars, at shopping centers – or when making music ourselves. Juslin, Liljeström, Västfjäll, Barradas, and Silva (2008) confirmed the omnipresence of music in everyday life by using the experience sampling method: In 37% of all examined episodes, participants listened to music. One of the most important reasons for listening to music is its effect on emotions (Sloboda & O'Neil, 2001). In 64% of the music episodes investigated by Juslin et al., participants reported that the music influenced how they felt. Past studies were only conducted in the laboratory. In the present study we wanted to use a new and innovative Internet-based set-up to find out if those emotional effects of music can be measured online.

In our study, *emotion* is used according to the *component process model* presented by Scherer (2004, 2005). According to this model, an emotion episode consists of synchronized changes in four major reaction components: physiological arousal, motor expression, behavior and subjective feelings. Furthermore, Scherer distinguishes between *utilitarian* and *aesthetic emotions*, which differ in appraisal concerning goal relevance. The absence of direct personal relevance in aesthetic emotions leads to rather diffuse, reactive physiological and behavioral changes in contrast to distinct and proactive changes in the case of utilitarian emotions, including so-called *basic emotions* (Ekman & Davidson, 1994). Since aesthetic emotions are not always accompanied by physiological and behavioral synchronizations, it is adequate to record only the subjective feeling component for measuring emotional responses to music.

Measuring emotion: The dimensionality of the emotion space

To measure the subjective feeling component of emotion, different approaches were developed. Beside adjective lists and categorical emotion models, dimensional emotion models have been used for emotion research. Already in 1897 Wundt maintained that the different states of feeling consist of three bipolar partial feelings (Sloboda & Juslin, 2001; Sokolowski, 2002). The feeling dimensions arousal and valence were derived by Russell (1980) employing factor analyses and multidimensional scalings for different emotional terms. All terms examined by Russell could be projected onto a circle structure model with two orthogonal axes. The bipolar dimension *valence* was placed along the horizontal axis, from negative (on the left) to positive (on the right), the dimension *arousal* vertically from low (on the bottom) to high (on the top). This two-dimensional structure was confirmed in many other studies (Sloboda & Juslin, 2005) also using musical stimuli (Krumhansl, 1997; Bigand, Vieillard, Madurell, Marozeau, & Dacquet, 2005). It was applied in our study, because it easily captures the general quality of many different affective feelings using only two dimensions.

Measurement of affective experiences of music perception

According to Gabrielsson (2002), there is a difference between perceived and felt emotions in music. Music is able to express a certain emotional expression, but this expression is not always induced in every listener automatically. Some researchers found empirical support for this distinction (Evans & Schubert, 2006; Kallinen & Ravaja, 2006). Music is also able to induce strong emotions, such as *chills* or *thrills* when accompanied by goose pimples or shivers down the spine (Goldstein, 1980; Panksepp, 1995; Sloboda, 1991). Since one of the most important reasons to listen to music is its effect on emotions (Sloboda and O'Neil, 2001), the study presented here investigated felt and not perceived emotion.

In addition to other emotion components, the subjective experience while listening to music or the emotional expression in music has been the object of many studies. Ratings of subjective feelings during music listening can be provided continuously during music listening or retrospectively after music listening. Continuous ratings have the advantage that the dynamics of emotions in music listening can be measured, because for every point in the time course of the stimulus, ratings are recorded. Additionally, this method requires less memory from the participants because emotions felt during listening don't have to be memorized and afterwards reported. Due to the fact that the dynamic time course of whole music pieces was of interest, continuous self-report was recorded in our study.

Already in 1936 Hevner examined discretely the time course of the emotional effect by manipulating certain compositional structures (e.g. major vs. minor) while participants listened to selected pieces. Other music researchers used newly developed computer methods that allowed simultaneous and continuous report of the dynamics of emotional processes during music listening. For example, Schubert (1999, 2001) used the two-dimensional emotion space which is based on the dimensional emotion model of Russell (1980). The participants had to indicate the emotions expressed in the music by mouse movements on the arousal and valence dimensions simultaneously in the emotion space. Schubert wanted to investigate the temporal-dynamic processes of musically emotional events. With different re-test studies and the fulfillment of various criteria, Schubert (1999) showed that the emotion space is a reliable and valid instrument.

In 2007, Nagel, Kopiez, Grewe, and Altenmüller proposed a new method for recording and measuring continuously self-reported emotions. In order to grasp the subjective experience of emotions, they used the *EMuJoy* software to measure the two-dimensional emotion space based on Schubert (1999). But with the mouse movements in Nagels et al.'s study, the participants were not to indicate the affect expressed in the music, but rather the dynamics of their own emotional state. Additionally, they could indicate chills by clicking the mouse button. Because of the many advantages of Web methods, the online version of the same software was used in the study presented in this paper.

Web experimenting

A *Web experiment* is defined here as a psychological experiment collecting data from participants with the help of the World Wide Web (WWW). Web experiments might be a promising way to advance the method of measuring musically-induced emotion continuously. According to Reips (2002b), Web experiments have many useful advantages over lab studies:

- A high number of participants can be reached because of easy access to the experiment (i.e., by bringing the experiment to the participants instead of the other way around). A large sample meets requirements of rating the very subjective and individually varying emotional feelings during music listening (Grewe, Nagel, Kopiez, & Altenmüller, 2007a).
- There are no time constraints for participation.
- They permit the implementation of a high standardization.

- There are no direct social interactions and because of this there is less researcher bias affecting participants. For instance, it could be that due to demand effects (e. g. the researcher's expectations to have emotions), participants in a lab setting rate intensity of emotions higher than they would in a Web-based setting.
- Participation takes place in a more natural environment (thus enabling a bigger external validity). A familiar, non-artificial setting could be important for measuring subjective experiences of emotions.
- They allow an open research process in which external people can control others' methods.

Reips also mentioned some disadvantages of Web experiments:
- A number of participants can drop out during participation.
- They offer less control than do lab experiments.
- Technical problems may arise on the participant's end.

However, Reips (2002b) gave some hints as to how to eliminate these potential problems. For instance, he suggested using the *high hurdle technique* to control the dropout rate and motivational problems. This can be accomplished by including motivationally adverse factors in the beginning, which participants have to pass in order to reach the main section (in this study, it is the self report of musically-induced emotions). Thus, insufficiently motivated participants will drop out at the beginning of the study, leaving only motivated participants in the dataset.

According to Musch and Reips (2000), the first published Web experiment is the study on auditory perception conducted by Welch and Krantz (1996). Marcell and Falls (2001b) did a study on auditory memory with a special population: children with Down and Williams Syndrome. Patel and Iversen (2003) also conducted a Web experiment on speech and drum sound perception, but they used the Web experiment to just demonstrate the procedure and not to collect data. Salganik, Dodds and Watts (2006b) investigated the unpredictability of an artificial cultural market and had more than 15,000 participants. They investigated social influences on music preferences and found out that their music listeners' choices were based on preceding participants' behavior. Honing (2006b) found evidence for tempo-specific timing in music using a Web-based experimental setup, and the "Music Universals Study" of Farbood, McDermott and Pressbrey (2006) studied universal aspects of music perception. Schönberger (2006) conducted a survey study on strong experiences with music based on the concept of Gabrielsson and Lindström Wik (2003) without using auditory stimulation. To our knowledge, up to now only three studies have been published in journals (Honing, 2006a; Marcell & Falls, 2001a; Salganik, Dodds, & Watts, 2006a). The small number of studies shows that the method of the Web experimenting has not been fully established in music psychology and related disciplines up to now, even though modern computer users are equipped with broadband Internet access and high-quality sound cards. These technical prerequisites generate many interesting applications of this new method. The following citation by Musch and Reips (2000) illustrates the considerable potential of Internet research: "Although computerized experiments have become the method of choice in conducting psychological research, there are many signs that another revolution is now beginning. It is associated with the recent exponential growth of the Internet" (p. 62).

We could find only one critical discussion of the method in the whole scientific discourse (Honing & Ladinig, 2008; Honing & Reips, 2008; Kendall, 2008). Here Kendall presents many pseudo-arguments against Web-based research that can all be disproved by Honing and Ladinig as well as by Honing and Reips. The advocates of Web based research cite as an advantage of this method the bigger external validity due to a higher realistic variance in many parameters on the side of the participants, which in turn can lead to a greater generalizability of the results. Thus, they have proposed that the Internet might be more suited for applied research, and a controlled lab experiment would be the better choice for basic theory-guided research (i.e., on psychophysical perception processes). Web experiments to investigate auditory perception processes have been mostly left out of the methodological discussion of psychological experiments in the WWW: Krantz wrote (2001) a very interesting article about stimulus presentation in the Internet without addressing the issue of auditory stimuli in detail. Furthermore, in many other publications about psychological experiments on the Internet, auditory stimuli are also not discussed (Birnbaum, 2000; Janetzko, Hildebrandt, & Meyer, 2002; Krantz & Dalal, 2000; Musch & Reips, 2000; Reips, 2000, 2002a, 2002b, 2002c). Our study is the first to test validity and reliability of auditory Web experiments filling this gap.

Aims

The purpose of this study was to explore whether the self-developed *ESerRNet* software for continuous measurement of emotions while participants listen to music is valid by means of the Internet. This was the first attempt to conduct a study related to emotional effects of music over the Internet. Regarding the reliability and validity of the new method, we addressed the following issues: the comparison of the Web data with the lab data using the same method (the similar offline software *EMuJoy,* Nagel et al., 2007), the influence of different

technical and situational parameters on the emotion ratings, the dropout-problem, the participant's evaluation of the study, and possible technical problems.

Method

Participants

Participants were recruited by personal invitation based on various mailing lists. For copyright purposes, all participants were given a personal account to use for the study. At the same time, personalization presented the first high hurdle Reips (2002b). Participants could take part after logging in on the Web page http://www.musik-emotion.de. All participants completing the experiment could take part in a lottery and win one of three 10 € Amazon-vouchers. Of all participants 48 were male and 41 female. Their mean age was 32 years (range = 14–66 years, *SD* = 13 years). Most of them were highly educated: 58% with a university degree and 36% with the German "Abitur" (university-entrance diploma). Many participants were musically skilled: Only 18% were non-musicians, whereas 52% were amateur and 30% professional musicians. The mother tongue was German for 93% of the participants.

Procedure

The online questionnaire comprised four sections (see Figure 1) that altogether took approximately 45 to 60 minutes to complete (depending on the number of musical pieces listened to). It was in German and programmed using PHP (version 4.4.2) that produced HTML-pages.

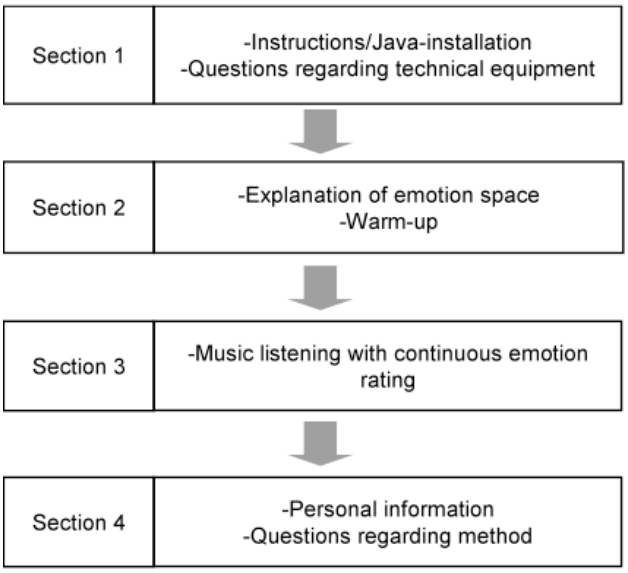

Figure 1. Flowchart of online questionnaire.

Instructions. This section provided information on the background of the study and the time needed to participate. In addition, participants had to enter their login data on the first page. It was then determined whether or not the necessary Java-Runtime was installed (the second high hurdle). If needed, a hyperlink to a free Java download could be used. The participants also had to give a self-assessment concerning the seriousness of their participation (the third high hurdle). At the end of this first section, the participants were able to test the playback capacity of their computer equipment using a test tone (the fourth high hurdle). They were asked to use headphones for playback and set the volume to a comfortable sound level. Information about their technical equipment and the location of their participation was also collected.

Warm-Up. The emotion space was explained after section one. The participants were instructed to rate continuously the emotions they felt in the dimensions of valence and arousal by moving the computer cursor in the emotion space; chills had to be expressed by pressing the mouse button. High arousal was defined as being exciting and low arousal as being calming. Positive valence was defined as pleasant and negative valence as unpleasant. After the instructions, a warm-up section was started to familiarize the participants with the rating system within the emotion space. All participants had to view five different pictures and simultaneously rate their emotions in the emotion space. Mouse movements and clicks were recorded by the Java-Applet *ESeRNet*, which was presented in a pop-up window. The pictures were presented in the emotion space. After the warm-up,

participants were asked whether they had fully understood the instructions. If their answer was *no*, they were sent back to the instruction section; if it was *yes*, they were sent on to the music listening section.

Ratings of Emotions Induced by Music. In part three, participants listened to musical pieces and reported the emotions they felt in the same manner as in the warm-up. After every piece, participants filled in a questionnaire related to the piece they had just listened to. On a 5-point scale they had to rate how much they focused their attention on the music. Additionally, the questionnaire asked about different bodily reactions to the music piece. The answers were taken from the most often reported reactions in Sloboda's survey (1991).

Personal Information. In this final section, personal information was collected from the participants. For example, they were asked about their socio-demographic background (e.g., age, sex, or profession) and about their musical training. Finally, all participants evaluated different aspects of the study and had the opportunity to give feedback on the experiment. The evaluation was given by rating one's agreement to eight different statements about the study. The addressed topics were:

– The sound quality
– The honesty of answering
– The ability to express one's emotions in the emotion space
– The comprehension of the instructions for the emotion space
– The duration of downloading
– The duration of participation in the entire study
– Problems with the installation of Java
– The naturalness of the listening situation

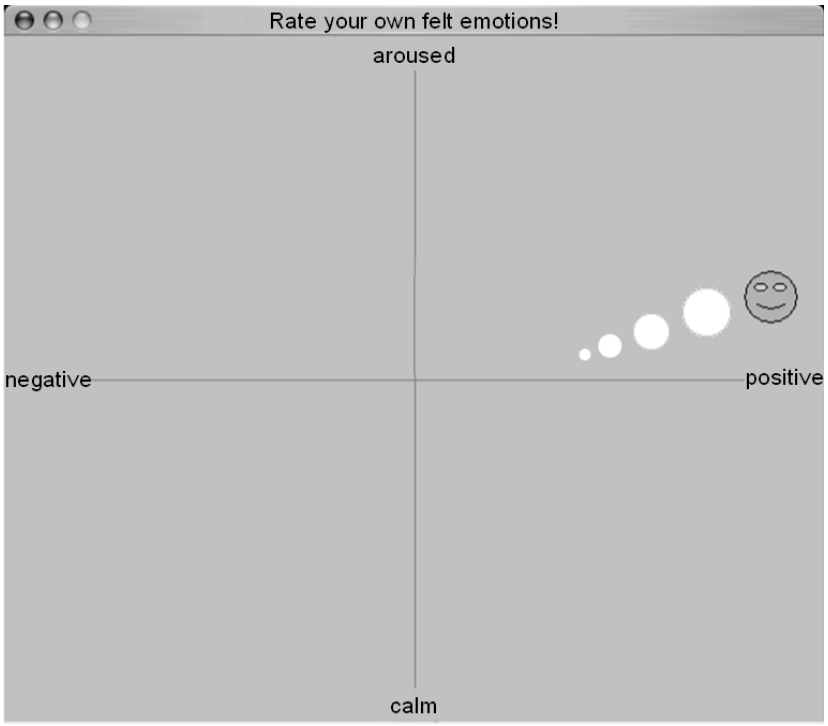

Figure 2. *ESeRNet*-Applet with emotion space: Valence is on the horizontal and arousal on the vertical axis for continuous measurement of musically-induced emotions.

The Java-Applet ESeRNet. Because EMuJoy was based on the computing platform independent programming language Java (version 5.0), it could be easily transferred into a Java applet for running it in a browser. The Java applet was used to present the stimuli and to allow continuous rating of felt emotions in the two-dimensional space (Russell, 1980; Schubert, 1999).[1] The popup window was 600 pixels wide, 500 pixels high and not resizable (see Figure 2). The emotion space consisted of a co-ordinate system whose axes corresponded to the two bipolar emotion dimensions. Within this emotion space the participants could indicate their emotional experience continuously by moving the mouse. The window was entitled, "Rate your own felt emotions!" Every position in the emotion space corresponded to a certain emotional state. If a participant moved the cursor into the emotion space, the cursor changed its shape to a face. To give the participants an intuitive feedback about the state indicated by them, this face changed its emotional expression depending on the position in the space. The

[1]A demonstration of the applet is available at: http://musicweb.hmt-hannover.de/emujoy/

pointer had the shape of a worm with a tail and a face, which made the handling very intuitive and uncomplicated. To illustrate the dynamics of the movement, a tail covered the trajectory of the last points in the emotion space. The International Affective Picture System (IAPS) (Lang, Bradley, & Cuthbert, 2001) also uses facial icons for the *Self Assessment Manikin* (SAM), and Schubert (2004) used faces to display reported emotions. In our study the facial icon consisted of two eyes and a mouth. The eyes opened and closed along the vertical dimension arousal, and the corners of the mouth were raised or lowered on the horizontal axis of valence. Pressing the left mouse button indicated the experience of a chill. Every movement of the cursor and every mouse click were transferred to a Web server. The music's mp3-files were copied completely into the RAM of the participant's PC before they were presented, so that even participants with slow Internet connections could take part. If the applet had played the pieces immediately, the reproduction in slow connections would have been interrupted because parts of the mp3-file were missing. In an extensive pretest, the correct functioning and recording of the applet under different operating systems and browsers was assured.

Stimuli

As a warm-up, four pictures were chosen from the IAPS (Lang et al., 2001) to cover all four quadrants of the emotion space. Additionally, one neutral picture was used. Pictures were presented in a fixed order for ten seconds each (see Table 1). It is sometimes hard to induce all kinds of emotion with music, e.g. an unpleasant low arousal state. Thus, we decided to take pictures like Nagel et al. (2007) for learning how to indicate all possible emotions.

Table 1
Pictures Used as Stimuli for the Warm-Up (From the IAPS, Lang et al., 2001)

Position of presentation	Name/Content	Expected arousal	Expected valence	IAPS no.
1	Gun	High	Negative	3530
2	Water rafting	High	Positive	8370
3	Rabbit	Low	Positive	1610
4	Graveyard scene	Low	Negative	9220
5	Teaspoon	Neutral	Neutral	7004

In the music listening section, participants listened to a maximum of seven musical pieces (see Table 2) in randomized order. Pieces were taken from Nagel's et al. (2007) lab study in order to compare their emotional effects with the Web-based results. The authors chose them to cover all quadrants of the emotion space. All participants were asked to listen to at least four pieces, but it was up to the participants to decide how many pieces they actually listened to.

Table 2
Music Pieces Used as Stimuli

Name of piece	Name of composer	Performer	Style	Length (min:sec)
"Main Titles" – Soundtrack from the movie "Chocolat"	Rachel Portman	Portman, 2000	Film music	3:11
"Coma"	Apocalyptica	Apocalyptica, 2004	Rock music on classical instruments	6:58
"Skull Full of Maggots"	Chris Barnes	Cannibal Corpse, 2002	Death metal	2:06
"Making Love out of Nothing at All"	Air Supply	Air Supply, 1997	Pop music	5:44
"Tuba mirum"- Requiem KV 628	Wolfgang Amadeus Mozart	Karajan, 1989	Classical with vocal soloists	4:15
"Soul Bossa Nova"	Quincy Jones	Jones, 1997	Dance music	2:46
"Toccata" BWV 540	Johann Sebastian Bach	Walcha, 1997	Classical instrumental (organ)	8:21

Data recording and data analysis

The data related to the questionnaire were stored in a MySQL database (version 5.0). The participants' self-reported emotions while looking at the pictures or listening to the music were transmitted and recorded in separate data files in real-time. For each distinct mouse-movement and mouse-click, the absolute position of the user's mouse in the emotion space and the corresponding time point were registered. For comparison of the

emotional time-series of different participants, data had to be interpolated in post-processing. A sample rate of 1 Hz was chosen for interpolation. Therefore, only complete datasets from self-rated serious participants were used when they rated their concentration for each song with three, four or five on the 5-point scale. For the chill analysis, every mouse-click was validated. Thus, for every chill to be counted, participants had to additionally respond after each piece that they had experienced a shiver down the spine or goose bumps. Some chill-events had to be excluded because a few participants wrote a comment that they had pressed the mouse button inadvertently, although no chills had occurred.

To find out, whether different technical and situational factors influenced participants' ratings, multiple dependent measures were computed per music listener: First, for the arousal and valence dimension the median and standard deviations were calculated over time for each piece and then averaged over all pieces listened to. Additionally, the number of chills per piece and the self-rated concentration were computed for every participant as individual means over all pieces listened to. The software used by the participants (type of operating system, type of browser, and Java-Runtime version installed) was technically measured and also stored in the MySQL database.

Results

The result section is divided into two parts. The first part presents the results that refer to Web-based experiments. The second part shows the results related to emotion measurement.

Methodological results

The Dropout Problem. In the online questionnaire, the dropout rate was low. From 107 participants who made an initial effort to participate, 89 completed the questionnaire. The other 18 participants may have had technical problems or lost interest. Most of them dropped out when they had to pass the warm-up. Following the instructions, 77% of the participants listened to at least four complete music pieces. For further data analysis, the participants listening to less than four pieces were also included. This was done because the exclusion of participants listening to less than four complete pieces would have excluded complete and valid data sets. Table 3 presents the ratio of the completed vs. uncompleted music rating datasets separated by music pieces. It can be seen that for the piece "Toccata" the discontinuation rate was the highest. Twenty percent of the participants who listened to it abandoned the rating of this piece.

Table 3
Frequency of Data Sets Completed or Uncompleted Separated by Music Pieces

Music piece	Completed (percent of total)	Uncompleted (percent of total)	Total
"Main Titles"	92	8	66
"Coma"	84	16	73
"Skull Full of Maggots"	91	9	65
"Making Love out of Nothing at All"	92	8	64
"Tuba mirum"	90	10	67
"Soul Bossa Nova"	94	6	54
"Toccata"	80	20	61
Total	86	14	464

Situational and Technical Attributes of Participants. The participants' self-assessment of their seriousness resulted in 99% answering 4 or answering 5 on the 5-point scale from 1 = *not serious* to 5 = *serious* (see Figure 3a). Thus, no participant refused to indicate her/his seriousness. The distribution of the individual mean of the self-rated concentration can be seen in see Figure 3b. On average the self-rated concentration was very high, only a few participants (10%) scored lower than 3.

The location of participation was home for 76% of the participants, work for 10%, an university for 9%, and other places for 5%. Most of the participants (74%) were connected to the Internet via broadband and 54% listened to the music via headphones (as requested) or an external stereo (10%). Sixty-six percent used a computer mouse for the emotion ratings. The most frequently used browser was the MS Internet Explorer (58%), followed by Mozilla Firefox (30%), Netscape (7%), and Safari (5%). Windows XP was used by 79% of participants, older Windows versions by 15% and OS X by 7%. Only 12% of all participants had to download and install the Java-Runtime. For those participants equipped with the Java-Runtime, the by that time newest Version 1.5 was detected (60%), the older version 1.4 was installed by 40% of participants.

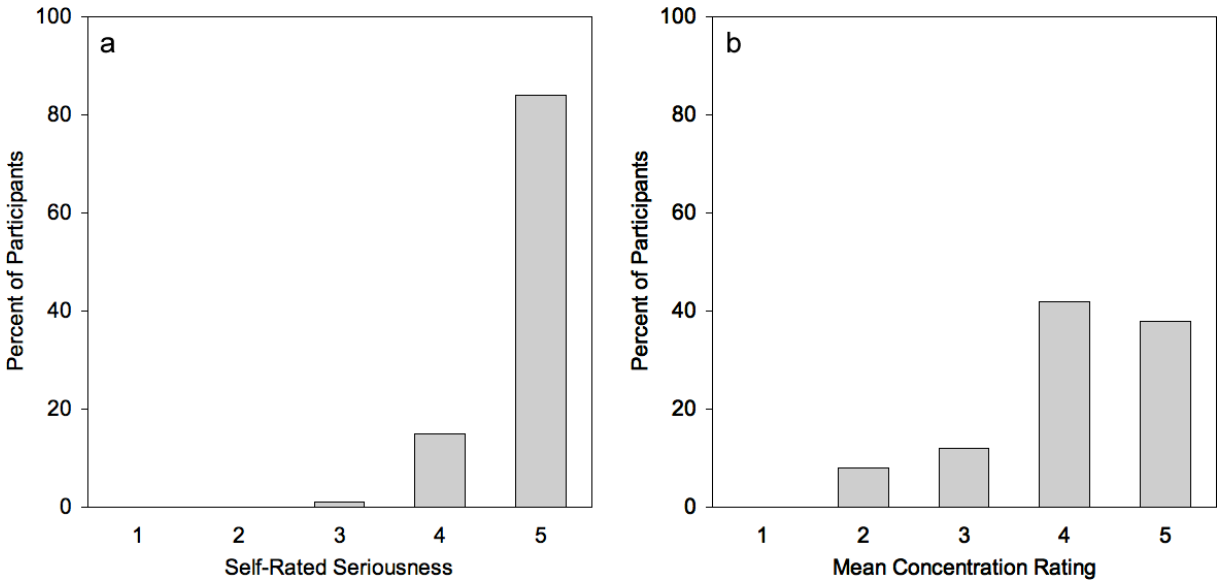

Figure 3. a) Bar chart showing the distribution of the self-rated seriousness at the beginning of the study (N = 107, M = 4.8, SD = 0.4). b) Bar chart showing the distribution of the self-rated concentration ratings (individually averaged over all pieces listened to, N = 90, M = 4.0, SD = 0.8). Answers were given on a 5-point scale (1 = *not serious*, 5 = *serious*) for seriousness and on a 5-point scale (1 = *low concentrated*, 5 = *high concentrated*) for concentration.

The Participants' Evaluation of the Study. Participants were asked for a subjective evaluation of the study. The results of the 83 valid participants who answered these questions are displayed in Figure 4. Sound quality was rated as good by the majority of participants. Also, many participants indicated having answered all questions honestly. Nearly all participants agreed that they were able to indicate their emotions in the emotion space reasonably well. Almost no one had difficulties understanding the functionality of the emotion space, had technical problems, or mentioned that downloading some of the pages took too long. Furthermore, hardly any participant had difficulties installing the Java-Runtime. Most people agreed that the music listening experience was similar to a normal listening situation. Only the item "participation time" was negatively evaluated: One third of the participants indicated that the experiment took too long to complete.

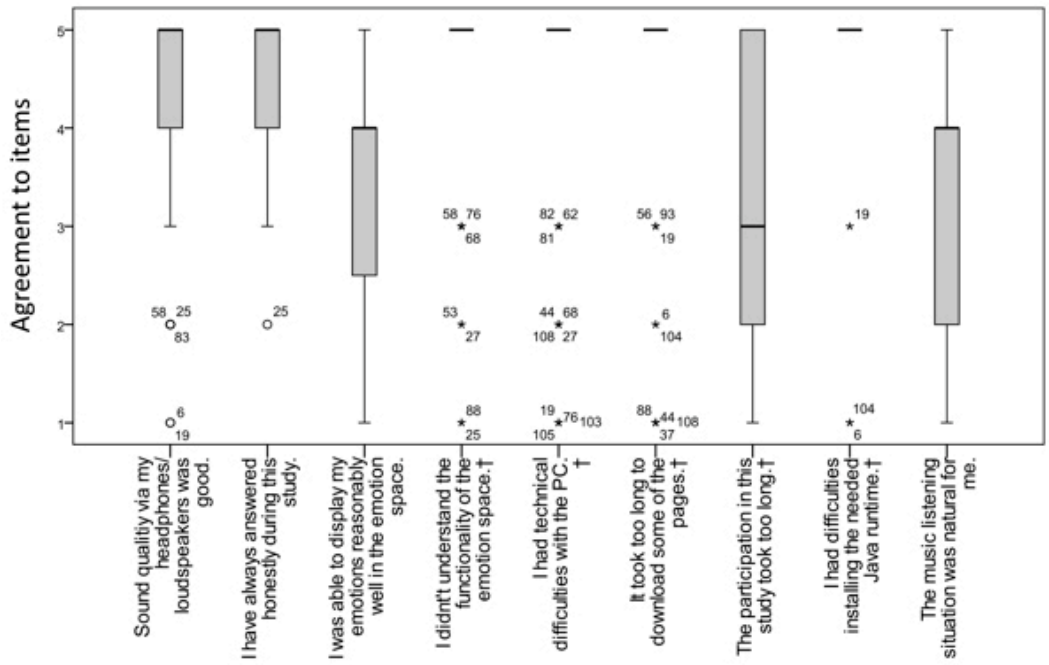

Figure 4. Box plot of mean agreement to certain aspects of the study. Answers were given on a 5-point scale (1 = *I do not agree*, 5 = *I do highly agree*). Values more than three Interquartile range (IQR) from the end of a box are labeled as extreme (*). Values more than 1.5 IQR but less than 3 IQR's from the end of the box are labeled as outliers (°). †Values were recoded for better comparability with the other items: 1 = 5, 2 = 4, 4 = 2, 5 = 1.

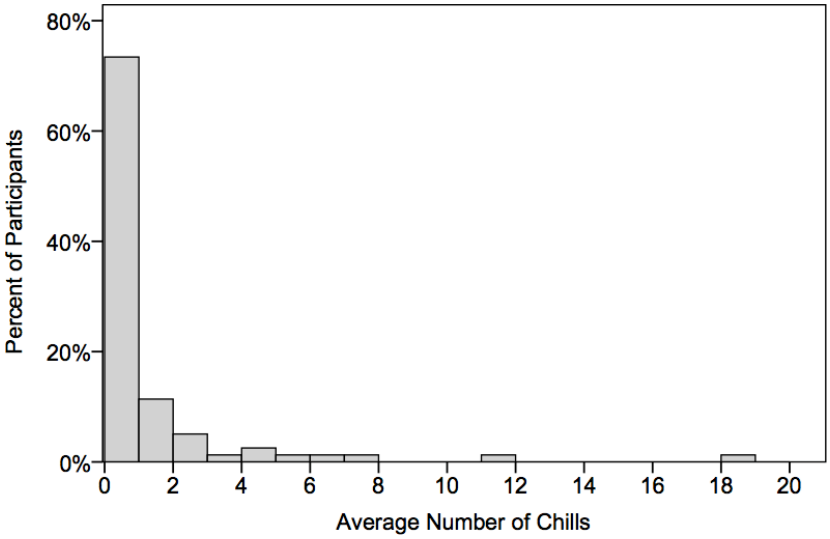

Figure 5. Histogram showing the average number of validated chills per person and piece ($N = 79$).

Emotion-measurement results

Chills. After excluding the chill events that were not reported in the questionnaire after each music piece (78 from a total of 356 chill events), the mean chill frequency for each participant was 1.14 per piece ($SD = 2.7$, $N = 79$). The frequency distribution can be seen in Figure 5. Table 4 presents the mean chill frequency separated by the different music pieces. As can be seen, "Making Love Out of Nothing at All" elicited the highest number of chills across participants, followed by "Toccata." The lowest chill frequency occurred for the soundtrack piece "Main Titles" and the death metal piece "Skull Full of Maggots". The frequencies' ranges indicate that a high individual variability existed. For instance, "Making Love Out of Nothing at All" induced in some participants no chills at all, but in one participant more than 40 chills.

Table 4
Frequency of Chills per Participant Separated by Music Pieces

Music piece	Maximum frequency[a]	Mean over participants (SD)
"Main Titles"	6	0.45 (1.18)
"Coma"	11	1.43 (2.74)
"Skull Full of Maggots"	6	0.55 (1.48)
"Making Love out of Nothing at All"	48	1.97 (7.85)
"Tuba mirum"	12	1.04 (2.60)
"Soul Bossa Nova"	18	0.83 (3.32)
"Toccata"	25	1.69 (5.31)

[a]Minimum frequency was 0 in all conditions.

To find out whether differences in the individual number of chills per piece between the different participants existed, we computed an ANOVA with age, sex, profession, education, and music skills as independent variables. None of the five factors significantly influenced the mean number of chills, nor were there interactions.

Influences of Technical and Situational Parameters on Emotion Ratings. To find out if different technical and situational parameters influenced the arousal and valence ratings of participants, we computed two MANOVAs: (1) The first tested as fixed factors the effects of different technical equipment (Internet connection speed, input device used for rating, type of loudspeaker), location of participation and, as a covariate, the individually averaged concentration ratings; (2) The second tested as fixed factors the effects of different software parameters (browser type, operating system, and version of Java-Runtime). For both MANOVAs the four individual rating means were dependent measures: for arousal and valence the medians and standard deviations over time. In the first MANOVA a significant influence of concentration on the median over time of arousal ratings was observed, $F(1, 67) = 4.12$, $p < .05$. The higher the concentration was, the higher the arousal ratings were (Figure 6a). The regression line shows that this was a very weak correlation. The second MANOVA failed to find any significant factor influencing one of the four dependent measures.

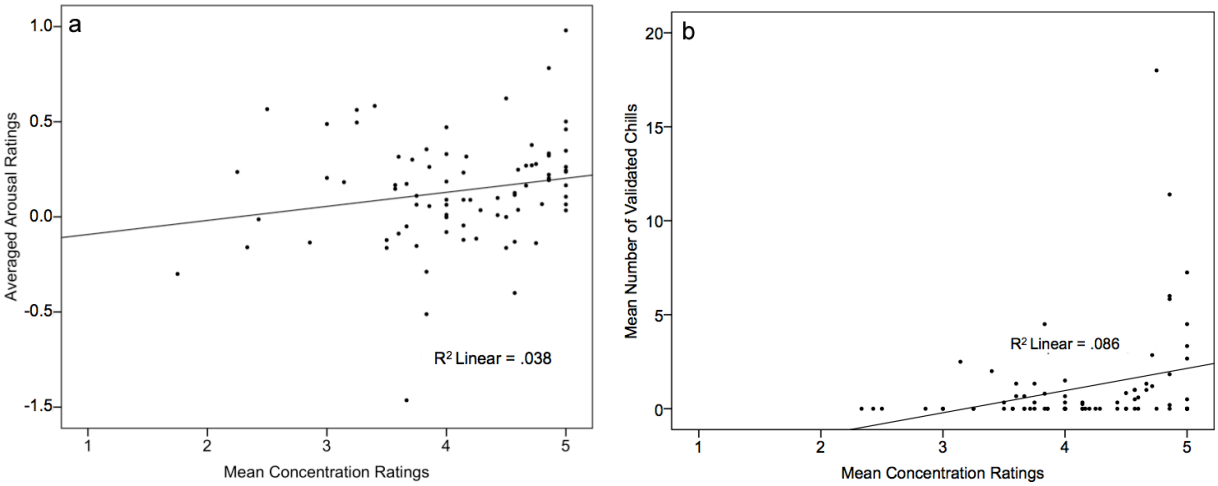

Figure 6. a) Scatter plot of self-rated concentration ratings and the time averaged arousal ratings with regression line (both ratings were individually averaged over all pieces listened to, $N = 82$). b) Scatter plot of self-rated concentration ratings and the individually averaged number of chills with regression line (both were individually averaged over all pieces listened to, $N = 79$).
Note. Answers for concentration were given on a 5-point scale: from 1 = "low concentrated" to 5 = "high concentrated."

Two ANOVAs were computed for chill events, using the same independent variables that were used for the MANOVAS (1) and (2). But here the dependent variable was the averaged number of validated chills per participant. Results also showed that for the first ANOVA the averaged concentration rating significantly influenced again the averaged number of chills, $F(1, 65) = 5.14$, $p < .05$. The higher the concentration was, the more chills were experienced (Figure 6b). The second ANOVA failed to find any significant influence of the different software parameters on the averaged number of chills reported.

Comparison of the Lab Data With the Web Data. The pieces of music used were the same as those used as standard pieces by Nagel et al. (2007) in a lab study. In the online study, it was of interest whether other emotional effects of music could be observed via the data collection method in the Internet. Figure 7 shows the median values of both groups across time for the seven pieces projected onto the emotion space. The participants who took part in the study via the Internet made up the first group; those who took part in the lab study made up the second group. There were a total of 38 participants in the lab study (mean age 38 years, $SD = 16$ years, range = 11–72 years; 29 females and 9 males). The procedure in the lab was similar to the procedure of the online study. Participants in the lab also rated music continuously using the two-dimensional emotion space. For this comparison, the values from the lab group had to be transformed for the two dimensions ranging from −10 to 10 to the new scale from −1 to 1.

For the Internet group this figure shows the following general emotional effects of the pieces of music on the subjective self-report: While listening to "Skull Full of Maggots," the Internet test persons indicated having felt an exciting and negatively valenced affect. Excited and positively valenced emotions were indicated by the participants for three pieces: "Toccata," "Making Love out of Nothing at All," and most effectively for "Soul Bossa Nova." The cello piece "Coma," seemed to cause no clear effect on arousal and valence. The median shows that this piece was described in general neither as exciting nor as calming, nor did it cause positive or negative emotions in participants. Finally, the pieces "Main Titles" and "Tuba mirum," elicited neutrally aroused positive emotions in the participants. Using the Bonferroni-Correction method, the Mann-Whitney U-Tests with a corrected significance level of $p \leq .004$ for 14 tests, revealed that the subjective self-report did not differ significantly between the groups for any of the pieces and dimensions.

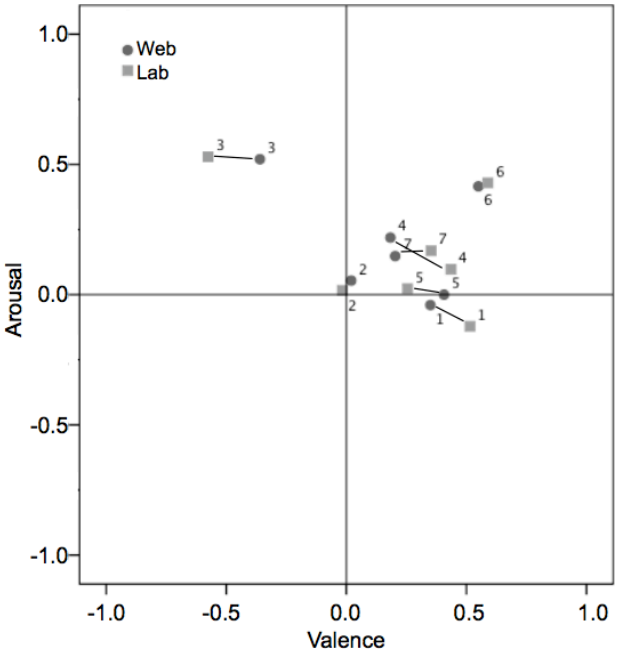

Figure 7. Emotion space with medians of all music pieces divided by method group (averaged over time and participants, Web n = 41 to n = 56 vs. lab n = 38). 1 = "Main Titles", 2 = "Coma", 3 = "Skull Full of Maggots", 4 = "Making Love Out of Nothing at All", 5 = "Tuba mirum", 6 = "Soul Bossa Nova", 7 = "Toccata."

Discussion

The initial question of this study was whether it is possible to validly and continuously measure music-induced emotions over the Internet. The results presented might offer much potential for investigating emotions during music listening and other music psychological questions. The following discussion focuses first on methodological issues and, second, on emotion rating issues.

Methodological issues

The Dropout Problem. In the present study, the dropout rate often observed with Web experiments (Reips, 2002b) was no major problem. In spite of the high technical requirements, 78% of those that logged in at least once in the study took part until the end. The implemented hurdles (see Reips' high-hurdle technique) were the personalization, the seriousness check, the installation of the Java-Runtime, and the sound check. An analysis of the different sections of the questionnaire revealed a point at which the dropout rate was at its highest. The biggest hurdle was the warm-up, were most dropouts occurred. Thus, it could be assured that only those participants took part who were so motivated that they installed additional software if needed, had a functioning sound system, and went through the test-phase. Nevertheless, there might have been some participants who were motivated enough but had technical problems, for example with the Java-software-installation or the warm-up, and thus dropped out of the study early on. But the dropout of a few participants seems to be justified in light of insufficient motivation. If one compares the dropout rate of the present study with those dropout rates presented by Musch and Reips (2000), one can see that in the present study an exceptional number of participants took part up until the end. Musch and Reips reported that the median completion rate for the studies in their survey (N = 20) was 66%. Of course, it has to be considered that in our study the greater number of participants might have been motivated above average since the sampling method addressed people with a certain affinity for music or empirical research. The high completion rate can also be explained by the necessary personal registration functioning as a hurdle before beginning the questionnaire. The completion rate for "Toccata" was the smallest compared to the other pieces, maybe due to the fact that it was too long. Some participants might not have been motivated enough to listen to it for more than eight minutes and aborted the rating by closing the pop-up window before the piece was finished.

The Internet Sample. The sample of the present study contained participants who had an above-average education (59% had a university degree) and who were musically very active (80% indicated being a musician). These above-average values (compared with the whole population, see Deutscher Musikrat, 2003) are presumably caused by the sampling method. Most of those that were invited to the study were members of the DGM (German Society for Music Psychology), singers in a choir, or students. However, regarding the age of the participants, a rather heterogeneous sample from about 20 to 60 years of age was achieved. Thus, it can still be

assumed that this investigation presents a higher external validity than do many other lab investigations (Krantz & Dalal, 2000; Marcell & Falls, 2001a), which often rely on the very homogeneous subgroup of psychology students as participants. Furthermore, participation in this study took place in a more natural environment, as compared with conventional experiments. More than three quarters of the participants listened to the music at home, the location where music is most often listened to in everyday life (Juslin, et al., 2008).

Technical Results. As mentioned in the introduction, a potential problem in studies conducted online is that different technical equipment, such as the software and hardware available to the test persons, can prevent some from participating. Therefore, we tested our software on many different computers prior to the data-collection. Thus, we were assured that the online questionnaire and the applet would run on the most used operating systems and browsers. Analyzing the different software configurations of participants revealed that all used the pretested systems. Nearly two thirds employed earphones or a stereo for the playback of the music, guaranteeing the best sound quality for them, also reflected in the rating of this aspect in evaluation of the study. Also, the majority of music listeners in our study were connected via broadband to the Internet (75% of the participants), enabling a short download time of the applet including the music stimuli as mp3 files. Thus, in each aspect a large portion of the test participants was equipped optimally for the study.

The Control of the Experimental Setting. An essential problem of Web experiments is the lack of control over the data collection. The study conductors cannot observe, for instance, what a participant really does during participation. Also, it is not possible to check directly whether the instructions are understood and followed by the participants properly. Obviously, an important pre-requisite for understanding the instructions given is the language used. In our study this was no problem: Most participants (93%) indicated German as their native language. The language aspect has repercussions for the repetition of this study in different cultural contexts. In the study of Farbood et al. (2006), the researchers used an innovative function to control the linguistic competence of the participants: Every non-native English speaker had to pass a linguistic test to take part in the study. Words in connection with the tasks of the study were tested to reveal the participants' comprehension.

In our study two instructions gave information as to how strongly participants followed the requirements of the study: First, listeners were instructed to use earphones. About half of the participants (44%) followed this instruction, and the remaining used other loudspeakers. The recommendation of earphones was given in order to mask other external sound sources that might have existed nearby. But presumably not all participants had access to earphones. The second instruction was to listen to at least four pieces of music. It was carried out by 77% of the participants. That all instructions were clear was also confirmed by conducting a pretest as Reips (2002b) suggested.

To counteract the lack of control over the experimental participants, a precise data analysis procedure was prescribed for all records included in the statistical analysis. Thus, we could be certain that only records by participants that participated in a concentrated and serious manner were used. No record had to be excluded from the evaluation because a participant indicated not taking the experiment seriously. The self-approximated concentration averaged for all participants and pieces was very high. Therefore, it could be presumed that the task was carried out in a concentrated manner. Of course, it could also be possible that participants consciously answered the question in the survey untruthfully. But it remains doubtful as to what would motivate a participant to deceive the experimenters (Honing & Reips, 2008). Also, because of the size of the sample, a few wrong or untruthful answers by some participants would not influence the data set systematically. Thus, this potential problem is most probably of minor importance. In a conventional lab experiment, there is also a risk that participants give wrong answers, though this might be reduced by the presence of the conductor. The risk of participants' answering based on social desirability exists in both lab and Web settings. But in the Web the distance between researcher and participants might minimize this.

Participants' Evaluation of the Study. The participants had the chance to evaluate the study at the end of the online questionnaire. Almost all aspects were positively evaluated; only the duration of participation was too extensive for some test persons. This could be due to the length of some music examples. Asked about the comprehensibility of the function of the emotion space, almost all test persons claimed to be satisfied with the explanations. In spite of the unusual task of observing one's own emotions continuously, almost all participants described the listening situation as natural. This could be explained by the fact that three fourths of all test persons took part in the study at home. In this age of multimedia, it has become more and more normal for many people to listen to music in the mp3-format using a computer.

Emotion-measurement issues

Comparison of Internet vs. Lab Data. The most important result of this investigation is that in comparing the two groups (median values over time and participants), for none of the pieces a significant difference was revealed.

The fact that data sets relate so strongly presents a clear argument for the method of continuous measurement of the emotional experience via the Internet. Thus, the participants of both studies seemed to have obeyed the instructions concerning the rating dimensions similarly. Although it might be a risky challenge to explain abstract concepts such as valence and arousal in the Internet, our attempt seems to have succeeded. The data of the lab study were used here as an external criterion of validity for our Internet investigation. In addition, the results of Nagel et al. (2007) describing the emotional effects of the seven music pieces could be replicated.

Chills. In this study 22% of the chill events reported had to be excluded, because the mouse-clicks were not accompanied by an indication of the experience of goose pimples or shivers down the spine in the questionnaire following the corresponding pieces (validation of chill events). Hence it might be that for some participants, the instruction to press the mouse button only for these two sensations was not really followed. Perhaps instructions should have been more explicit as to when a chill had to be reported, and when not. After this validation of chill events, chills were very rare. Moreover, many participants didn't experience them at all. The chill rate in Grewe, Nagel, Kopiez, and Altenmüller (2007b) was also very small, similar to Goldstein's (1980) experiment. Thus, precisely defined chills might be used in future studies as indicators of strong emotions, but additional measures should always be included to measure emotional reactions to music.

Influences of Technical and Situational Parameters on Emotion Ratings. Using various statistics, we investigated in quasi-experimental designs the influences of different technical and situational parameters on the emotional self-report. None of the different hardware and software parameters influenced significantly the emotion ratings or the number of chills reported. Interestingly, no significant effect of the participation location could be observed, possibly due to the fact that most participants listed home as their location. The only influential factor was the averaged self-rated concentration. Those who indicated a high concentration also reported more chills and claimed that the music was more arousing than did those who were less concentrated. This result has two implications: first for emotion research related to music in general, and second for applying online research for this purpose. On the one hand, it emphasizes the role of attention in the genesis of emotion. Emotions related to music are not deterministic responses to musical structures, but rather the result of attentive cognitive appraisals regarding the musical stimuli (Grewe et al., 2007b). On the other hand, this finding shows how important it is to control for concentration, when online methods are employed. This can be done by excluding non-concentrated datasets, similar to the study presented.

Conclusions and Further Perspectives. The main question of this paper concerned the feasibility of a music-psychological study of the emotional effects of music on the Internet. Considering all results generated within the scope of the present study, it becomes clear that this question has to be answered affirmatively. An enormous number of participants finished all tasks and had few technical problems in spite of all the requirements in comparison with other lab studies. Almost all participants described the emotional self-rating as a suitable method to capture their emotional experiences.

Perhaps the emotion-psychological theory building has not progressed enough, especially in relation to music (Juslin & Västfjäll, 2008). Thus, there arise different research possibilities and goals for future studies. For example, it remains questionable which emotion model can be transferred to a measuring instrument to capture emotions experienced while listening to music. The two-dimensional model of Russell (1980) seems to be able to map participants' main traits of the affective phenomena. But a differentiated description of the qualities of all emotions cannot be achieved – for example, those pertaining to anger, fear, or sadness. Some researchers could show that the bipolarity of the valence and arousal dimension might be questionable, because in their investigations some music pieces with contradicting emotional cues induced mixed feelings of happiness and sadness at the same time (Hunter, Schellenberg, & Schimmack, 2008). In our study participants were asked how well the two-dimensional bipolar model captured their emotional feelings, and most participants indicated that they were able to express their emotions within this model. Additionally, in contrast to retrospective ratings, using continuous methods enables one to express fast changing contrary emotions at different time points.

With the help of the Internet, this problem (using the right emotion model) and others could be solved empirically. Many different studies could be enriched by the advantages of this innovative research instrument. For example, a study without personal login accounts would enable the recruitment of larger samples on the Internet, which meet the subjective and interpersonal varying character of musical emotions. This would then allow a better generalization of the results. It would also be possible to insert a test to indicate one's understanding of the instructions, similar to the one in the study of Farbood et al. (2006). This could permit participation only when instructions are fully understood. Moreover, the participation time would have to be reduced, because the participants criticized this aspect in their evaluation of our study. Perhaps it would be more user friendly to use the Flash technology that is more widespread in Web browsers than is the Java technology. Another interesting option for a replication of this study would be to insert a function allowing the participants to upload their own pieces of music as mp3-files to the server of the study. Thus, a stronger relation between the

participants and their music could be achieved which might, in turn, lead to more intense emotional experiences. This would also allow examining the files uploaded by different parameters and relating them to the emotion ratings. Relevant parameters would be, for example, psychoacoustic measures or music-structural qualities. Intensifying the relationship between the music listeners and the music could also be achieved by recruiting only special subgroups of music listeners. For instance, one could link the study to a Web site of a certain band, thereby attracting mainly their fans. In such an investigation, people from all over the world could participate at the same time. They could take part in their natural environments and contexts, minimizing demand characteristics on answering. Thus, emotional responses could be intensified due to participation in a familiar, natural setting, although in the quasi-experimental comparisons of our study no effects of location could be found. At the same time, emotional responses could be reported as being less intense because the participants are not socially influenced by the presence of a researcher. As could be shown, music-induced emotions are affected by social feedback (Egermann, Grewe, Kopiez & Altenmüller, 2009), and it might be plausible to conclude that in the social situation of conducting a lab experiment, those influences also occur sometimes. The participant is instructed to report his/her emotions and chills, but maybe because of the demands of the conductor being present, music listeners report an unnaturally high intensity of emotions. Here, Web experimenting might offer a solution, because social influences are decreased due to the distance between experimenter and participant (see for example social impact theory, Latané, 1981). The data presented in this paper failed to find any significant differences between the lab and Web results, emphasizing the validity of arousal and valence ratings, but using different emotion measurements (e.g. intensity ratings) might have had led to the differences described between the two methods.

To summarize, Web experiments seem to offer a promising tool for emotion research related to music and music perception research in general. Data from the Web do not differ significantly from the lab, confirming the validity of Web experimenting. Most of the participants indicated having had no technical problems and having participated seriously. Although technical parameters varied for participants, none of them systematically influenced the participants' ratings. The results of these analyses emphasize the importance of controlling for concentration, which systematically influenced ratings. Additionally, chills were very rare events and some of them had to be excluded because they were not properly reported. Participants understood the two-dimensional emotion model, and they indicated that they were able to express their emotions within the model. With these positive results, the Web experiment could take its place among other methods used in music psychology. This might then lead to an increased understanding of the emotions experienced while listening to music in everyday life.

Author Note

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