Deploying music characteristics for an affective music player

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Deploying music characteristics for an affective music player

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Abstract

This paper describes work toward an affective music player (AMP), which is able to direct affect to a goal state by selecting music. Repeatedly, music has been shown to modulate affect; however, precise guidelines for the use of music characteristics in an AMP have not been defined. To explore these, we investigated the influence of music characteristics on 32 participants who listened to 16 songs, testing effects of tempo (slow/high), mode (minor/major), and percussiveness (low/high). Subjective measures of affect (i.e., arousal, tension, and positive and negative valence) and physiology (i.e., skin conductance level, skin conductance responses, and heart rate variability) were measured during listening. Results show main and interaction effects of music characteristics on both subjective affect and physiology, implying that the characteristics are mutually dependent in modulating affect. Based on these results, guidelines are presented for AMPs, which can effectively direct affect through music.

1. Introduction

Music can stir us up and can make us sad. Music can make us wonder or can trigger memories. This is not only the case for you and us, but for everyone. As Leo Tolstoy (1828-1910) seems to have said: Music is the shorthand of emotion. In the present article, we deploy the influence of music on emotion and, consequently, work on guidelines for an affective music player (AMP). An AMP should be able to select music based on the desired affective state of the listener. With the development of an AMP, two aspects should be taken into consideration:

1. In general, a positive state is the goal since this has var-

ious advantages. The way we feel is interrelated with our cognitive functioning: in a positive state the capability to solve problems is improved, creativity thinking is increased, and optimistic feelings dominate [11]. However, identifying emotions and identifying their influence on our functioning is still a big challenge.

2. Music is known for its ability to change affect; it is able to make people feel comfortable and happy [12]. However, a problem arises with handling the enormous availability of music. In practice, it is even for a user himself difficult to select a song that suits his current state best. Hence, the development of a system like an AMP, which (helps the listener to more) easily select the desired music, is a huge challenge.

Despite the complexity of both emotions and the influence of music on them, music is often used in research on affective computing. As a result various applications in this field have already been developed. The various music players developed have different aims and abilities.

The affective DJ uses physiology to detect the affective state of the user [10]. Systems such as Pandora recommend music based on user profiles [34]. The PAPA music player includes physiological responses to music, to generate a playlist that suits the listener at a specific moment [21]. However, most of these systems do not have the explicit goal to direct affect. Moreover, the results reported are scarce and frequently shallow.

The research presented in this article aims to lift the functioning of current state-of-the-art AMPs to a higher level. We hypothesize that this can be realized through a better understanding of the relation between various music characteristics (e.g., mode and tempo) and experienced affect by its listeners. Then, music can be used to direct the listeners affective state.
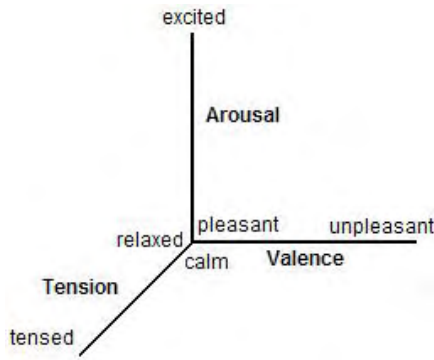
Figure 1. The 3 dimensional model of affect. Representing, the arousal, valence, and tension dimension.

Figure 2. The wireless Nexus-10 apparatus, as used for physiological measurements. The electrodes for the ECG measurements are shown on top. Below them the electrodes for skin conductance are displayed.

It is generally accepted that music characteristics can influence affect [13, 18, 27, 33]. Consequently, several algorithms were already introduced for content analysis of music [19,25,31,36]. They are also employed in music systems like last.fm [17]; although, for other purposes than to direct affect.

The influence of some music characteristics on affect as already described. For example, it has been found that major mode music is appraised as happy music and minor mode music is appraised as sad music [23, 33]. Additionally, fast tempo music has been shown to evoke higher amounts of arousal and positive feelings, and tension is found to increase during upbeat music [28].

Unfortunately, most of just mentioned research used settings that severely declined ecological validity. For instance, laboratory settings were applied instead of more realistic environments or artificially composed music was used, with its characteristics precisely controlled, instead of real songs. Furthermore, these studies did not incorporate physiology to validate the responses found but solely relied on subjective experiences of participants. There are studies incorporating physiological reactions to music, however non of them uses music characteristics select the songs [4, 15, 29].

To establish a thorough foundation for AMPs, we set out to investigate the relation between music characteristics and affect, using natural occurring music instead of abstract music stimuli. We focused on three music characteristics: tempo, mode, and percussiveness. These three characteristics are known to explain a large amount of musical variability [12]. To the authors knowledge, this research is the first in using real-world music, with these characteristics controlled. In this way, we expect to gain a better understanding on the relation between music and emotions in real world settings. As a result, we should be able to provide guidelines for the development of a robust, effective, real-world AMP.
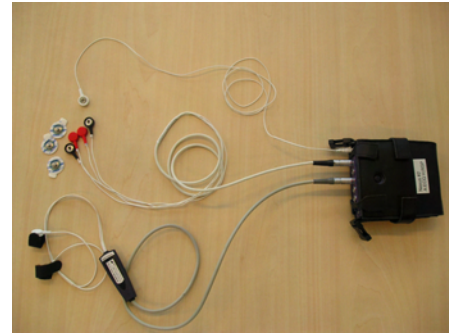
In the next section (Section 2), we present a study on the relation between the three music characteristics just introduced and the affect experienced by people. We end this article in Section 3 that denotes the conclusions derived from the study presented.

2. Relating music characteristics to affect

This section incorporates the studys methods, results, and a discussion in which we i) reflect on the study conducted and ii) present guidelines for the development of AMPs.

2.1. Methods

Participants Thirty-two employees of Philips Research, The Netherlands (16 men, mean age 25 years [range: 20-36] and 16 women, mean age 25 years [range: 20-28]) participated on a voluntary basis after they had given their written consent. The participants had no extensive musical knowledge, no hearing impairment, and no knowledge of a Slavic language which was needed to control for language.

Design The study used a counterbalanced, within subject design, where all participants conducted two blocks, each containing eight songs. In one block, there were silent episodes between the songs; in the other block, there were not silent periods. The presentation of the songs within the music blocks was counterbalanced among participants [9, 32].

To be able to capture the influence of music on affect we incorporate three affective dimensions: valence, arousal, and tension, as subjective measures of affect. See also Figure 1. This model is an extension of the valence-arousal model [24]. Note that this also increased the construct validity of this study. Furthermore, physiological measures are used to validate results on the subjective scales. Lastly, eco-
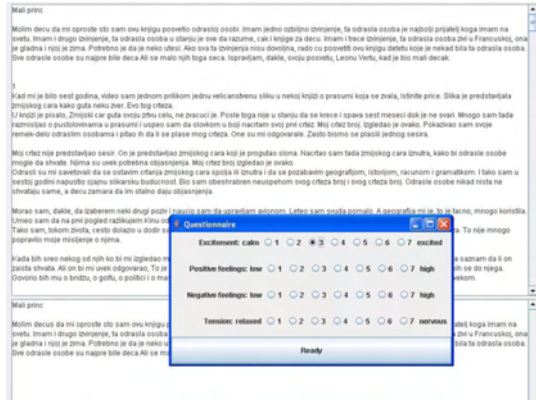
Figure 3. The experimenter window as used in the experiment. The text copying field is presented above, and the text entry field below. Centered on the screen the subjective questionnaire has popped up.

logical validity is maximized by presenting songs instead of excerpts in a setting mimicking an office situation.

The whole study was automated. Music was presented via a circum aural Sennheiser HD500 Fusion headphone and electroencephalogram (ECG) and electrodermal activity (EDA) were continuously measured throughout the whole study using the wireless NeXus-10 apparatus (Mind Media BV.) shown in Figure 2.

Music The songs, well known pop and rock songs, were selected from a database in which music characteristics were specified through automatic classification [25]. For each block, all combinations of tempo (slow: 74-83 bpm/fast: 128-155 bpm), mode (major/ minor), and percussiveness (low/ high) were selected, resulting in a total of eight songs per block.

Both silent periods and songs were adjusted to a duration of 2.5 minutes, using a fade out at the end of each song. The sound intensity level of the music was fixed by the experimenter.

Experimental task A text copying task, mimicking listening to music during a standard office job, was used as experimental task [22]. The task mimicked a daily life situation since attention would not be primary focused to the music, as is also the case in most situations when one is listening to music. The text was a Latin Serbian text, preventing the influence of the content of the text on the affective state of the participants.

The text field and the text editing field where presented horizontally aligned on the computer monitor. Figure 3 presents a screen-dump of this configuration.

Psychophysiological measurements The activity of the heart was measured via the standard Lead II placement (sample frequency 1024Hz) [30][24]. The negative and ground electrodes were placed respectively below the right and left collarbones. The positive electrode was placed lateral anterior the left chest between the lowest two ribs. To analyze the ECG signal, the raw signal was first cleaned for noise and aliasing, using a Butterworth bandpass filter (.5Hz - 40Hz) [20].

The R-peaks of the ECG signal were detected using the ANSLAB 4.0 software, above a fiducial point that was set manually [35]. R peaks that were not correctly assigned by the software were corrected and missing R peaks were interpolated by taking the mean distance between the surrounding R peaks.

The Inter Beat Interval (IBI) was derived successively. The Root Mean Square Standard Deviation (RMSSD) was calculated from the IBI as a time-domain Heart Rate Variability (HRV) measure, which is known to be the best predictor of short term HRV [2, 20].

EDA measurements were conducted, using dry Ag-AgCl finger electrodes attached with Velcro strips (sample frequency 32Hz). The electrodes were strapped around the upper phalax of the index- and middle fingers of the non-dominant hand. Small artifacts were minimized by a low pass Butterworth filter (0.5Hz), and large motion artifacts were removed by setting a maximum amplitude per participant [3, 6].

Skin Conductance Level (SCL) was calculated by taking the mean of the normalized signal over each song. Normalization was conducted per participant using

$$\frac{SCL - SCLmin}{SCLmax - SCLmin}$$

[3, 6]. In which SCLmin is the minimum and the SCLmax is the maximum SCL of the participant responses in the full trace.

The Skin Conductance Responses (SCR) were obtained after down sampling the signal (2Hz) and cubic spline interpolation of the raw signal. Subsequently, the SCRGauge algorithm of P. Kohlisch [3] was used to extract the SCRs.

Subjective measures The affective questions probed arousal (ranging from relaxed to excited), positive valence (ranging from low to high), negative valence (ranging from low to high), and tension (range from calm to nervous), all on 7 point scales. The separation of the originally bimodal valence scale into two unimodal scales enabled us to measure the presence of mixed feelings when listening to music [5, 7, 14, 16].

Procedure First, the sensors were attached. Next, instructions were given, the task was explained, and it was reiter-
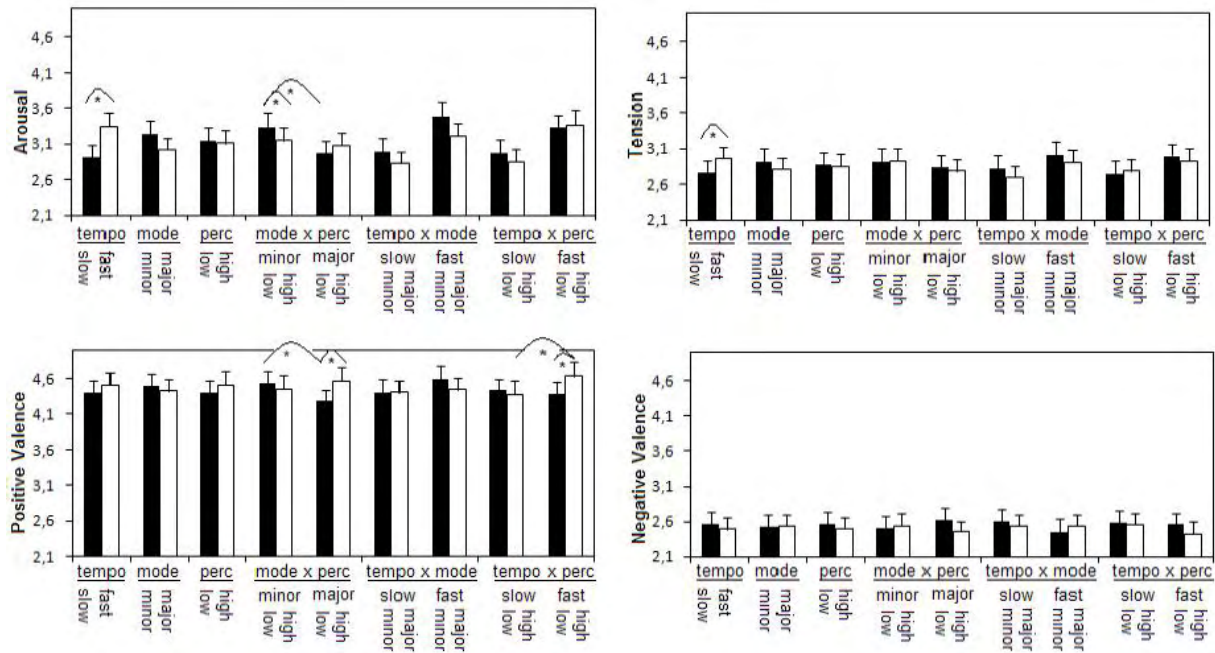
Figure 4. The means and standard errors of the influence of the music characteristics tempo, mode, and percussiveness on the subjective measures (i.e., arousal, tension, and positive and negative valence) are shown. Significant effects are indicated with a *. An abbreviation is used for percussiveness: perc.

ated that music would be present during parts of the experiment. Then, a baseline period of two minutes was recorded, during which the participant was requested to relax. Last, the first block started. During each silent period and song, the affective questionnaire was presented after two minutes of music listening, such that the response time would never interfere with the next stimulus or break.

Between the two blocks, a five-minute break was presented in which the experimenter had a little chat with the participants. After finishing the second block, the physiological sensors were detached and the participants were thanked for their participation.

2.2. Results

Missing responses on the subjective data occurred for two songs of two participants. The missing values and outliers were excluded from all analysis; i.e., values that deviated more than 2.5 standard deviations from the group mean [1, 8].

Two participants were omitted from further ECG analysis because of abnormalities in their ECG; i.e., frequently occurring ectopic beats [20]. From the EDA data, two participants were omitted from further analysis since their EDA was almost completely stable, having little to no SCR.

In the following analyses Bonferroni corrections were used for post hoc testing. For the correlations, two-tailed Pearsons product moment correlations (r) were determined.

For brevity, non-significant effects will not be mentioned.

2.2.1 The effect of music characteristics

First, no differences were found between the block of continuous music presentation and the block including silent periods between the songs.

To show the effects of music characteristics on the subjective and physiological measures, a repeated measures MANOVA was conducted with the music characteristics tempo (fast/ slow), mode (minor/ major), and percussiveness (low/ high) as within- participant factor. Separate analysis for the subjective (arousal / positive valence / negative valence / tension), the ECG (HRV), and the EDA (SCL / SCR) data were conducted. The results of these analyses are described next, and are visualized in Figure 4 and Figure 5 for the subjective and the physiological results.

2.2.2 The effect of music characteristics on the subjective measures

A multivariate effect of the subjective measures is significant for tempo ($F_{(4,28)}= 7.22$, $p<.001$, $eta^2=.508$). Univariate tests show that tempo shows a main effect on both arousal ($F_{(1,31)}=29.11$, $p=.001$, $eta^2=.484$) and tension ($F_{(1,31)}=13.93$, $p=.001$, $eta^2=.310$). Fast tempo music revealed greater amounts of arousal and tension compared to
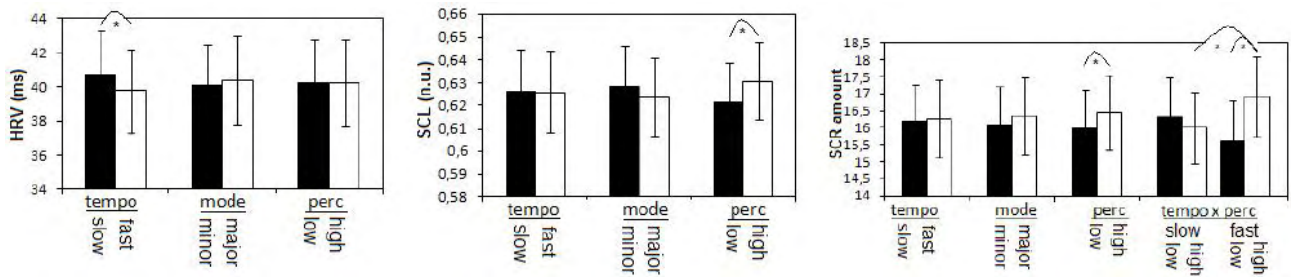
Figure 5. The means and standard errors of the influence of the music characteristics tempo, mode, and percussiveness on the HRV, SCL, and SCR are shown. Significant effects are indicated with a *. An abbreviation is used for percussiveness: perc.

slow tempo music. Greater amounts of arousal were also felt during minor mode music than during major mode music $(F(1,31)=8.04, p<.001, eta^2=.206)$.

A two-way tempo with percussiveness interaction was found on the amount of positive valence $(F(1,31)=5.98, p=.020, eta^2=.162)$. During fast tempo music, more positive valence were indicated during high than during low percussiveness $(p=.009)$. The amount of percussiveness does not change the amount of positive feelings during slow tempo music. Additionally, the amount of positive valence is significantly greater with high percussive fast tempo than with high percussive slow tempo music $(p=.014)$, see also Figure 4(c).

A two-way mode with percussiveness interaction was found for arousal $(F(1,31)=6.25, p=.020, eta^2=.168)$ and positive feelings $(F(1,31)=6,86, p=.020, eta^2=181)$. Subsequent post hoc tests showed that minor mode low percussive music yields lower arousal $(p=.037)$ than minor mode high percussive music. Major mode evoked higher positive feelings in combination with high compared to low percussive music $(p=.003)$. In addition, the amount of arousal $(p=.001)$ and positive feelings $(p=.025)$ were higher during low percussive minor than during low percussive major mode music. See also Figure 4(a) and Figure 4(c).

2.2.3 The effect of music characteristics on the physiological measures

The results show solely a significant main effect of tempo on the HRV, $F(1,29)= 4.26, p=.048, eta^2=.128$. HRV is higher during slow than during fast tempo music see also, Figure: 5(a).

A significant multivariate effect of percussiveness was found on the EDA measures $(F(2,28)=4,151, p=.026, eta^2=.229)$. Both the amount of SCRs $(F(1,29)=4.36, p=.046, eta^2=.131)$ and the SCL $(F(1,19)=5.54, p=.026, eta^2=.160)$ was higher during high percussive music compared to low percussive music.

The tempo with percussiveness interaction showed a multivariate effect $(F(2,28)=3.75, p=.036, eta^2=.211)$. This

two way interaction between tempo and percussiveness was found on the SCR frequency $(F(1,29)=7.77, p=.009, eta^2=.211)$ as can be seen in Figure 5(b) and 5(c). During fast tempo, a greater amount of SCRs appeared during high than during low percussive music $(p=.008)$. Furthermore, during high percussive music, a greater amount of SCRs occurred during fast than during slow tempo music $(p=.048)$.

2.2.4 Correlations between subjective and physiological values

Correlations between the subjective measures and the physiological measures were calculated to provide further support of the affective terms that should be present in the AMP to indicate a goal affective state. Figure 6 shows that arousal is strongly positively correlated with tension and positive Figure 6. The significant correlations between the subjective and physiological measures are shown. Abbreviations are used for Pos Val= positive valence and Neg Val = negative valence.

Although arousal is strongly correlated with the amount of tension, their relation with positive valence is different. During greater amounts of arousal the positive valence will also be higher, while during greater tension the amounts of positive valence will be lower. Furthermore, the amount of negative feelings shows a positive correlation with the amount of tension. This is inline with the negative correlation between positive valence and negative valence.

The amount of SCRs is positively related with the amounts of arousal and tension. As expected, the SCL is positively related with arousal, implying that the SCL is higher during higher levels of arousal. Furthermore, the HRV measure is negatively related with the arousal, the amount of negative feelings, and the amount of tension. This is in accordance with literature that the heart rhythm is stricter when one is in negative situations [6].

2.3. Discussion

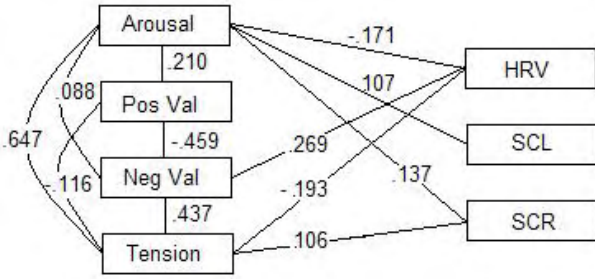Results show that the three music characteristics influence both subjectively indicated and physiological affect.

Figure 6. The significant correlations between the subjective and physiological measures are shown. Abbreviations are used for 'Pos Val'= positive valence and 'Neg Val' = negative valence.

	Tempo	Mode	Percussiveness
Arousal	Fast		
		Minor	Low
Positive valence	Fast		High
		Major	High
Tension	Slow		

Table 1. Design guidelines to use music characteristics to direct to a higher aroused, higher positive valence, or lower tension level.

The results are convincing since, the affective influence of music on emotion was found even when the participants did not primary focus their attention to the music but to the task. This supports the view that musics influences affect in daily life situations. A faster tempo increases arousal, tension and the three physiological measures. This implies that tempo influences the sympathetic activity of the nervous system which is more active during higher arousal states [2]. This finding is validated through the decline in HRV during fast tempo music, since it is known that the heart rate follows a stricter pattern during higher tension and arousal (i.e., its variability decreases) [6].

Although minor mode music is known to be linked with low levels of valence [12] we found that minor key music is associated with higher amounts of arousal than major key music. A possible explanation for this result is that studies reporting these results often use generated composed music excerpts in where music characteristics that are normally present in music were omitted. Since our study uses real songs, no music aspects were omitted which results in increased reliability and external validity.

Greater levels of percussiveness do not influence subjective measures but do evoke higher amounts of SCL and SCR. Higher EDA levels reflect autonomic arousal. This suggests that the physiology is more sensitive to the higher levels of percussiveness than the subjective feelings. In addition, higher levels of percussiveness show higher amounts of positive feelings in combination with fast than with slow tempo music, and show higher amounts of arousal in combination with minor mode music. This indicates that these music characters together influence subjective affect.

The various two-way interactions, illustrate the mutually dependency of the music characteristics in modulating affect. Several and not just one or two music characteristics should be taken into account in choosing a song with a predicted influence on affect. Future research should use advanced analysis techniques (e.g., machine learning / pattern recognition techniques) to find a full overview of combinations of music characteristics that elicit or lead to particular affective states measured from physiology. They can additionally focus on the composition of combinations of music characteristics to form new characteristics that influence affect.

The correlations between the affect measures support the use of arousal, positive valence, and tension as input for the desired affective state from the user of an AMP. Consequently, we suggest to replace the valence-arousal model [24].

If the user of an AMP aspires to be more aroused, the AMP should select fast tempo music, or minor mod low percussive music. Higher positive valence will be evoked when fast tempo high percussive music, or major mode high percussive music is selected. This is summarized in Table 1, which provides concrete design guidelines for the use of music characteristics in an AMP. Songs in music databases can be tagged with music characteristics by employing one of the algorithms proposed by [19, 26, 31, 36]. Then, using the guidelines provided, an AMP can be implemented directly.

3. Conclusion

This study unraveled the relation between the music characteristics tempo, mode, and percussion and experienced affect. For this purpose, real world music was employed, which was not yet done before. Moreover, in parallel, subjective and psychophysiological measures were applied, which is seldom done for this purpose. Consequently, a set of unique the results are presented. They can serve as a set of guidelines that can be used for the development of a robust, effective, real world AMP.

We found that music characteristics can modulate affect, which was reflected in both the subjective and the physiological affect measures. Moreover, the effects of the music characteristics interact; hence, the affective impact of music cannot simply be derived from the sum of its individual music characteristics. This emphasizes the importance of the use of real songs instead of using music reflecting only specific music characteristics in music affect research concerning applications.

In time this research could prove to be ground breaking in providing a first step toward a thorough foundation

for music-induced affective applications, such as AMPs. In parallel, this research illustrated the complexity of the relation between (highly interactive) music characteristics and emotions. Taken it all together, a crucial directive is provided toward robust, effective, real world AMPs.

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