Music directs your mood

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Music is the shorthand of emotion
Leo Tolstoy

Contents

Chapter 1

Introduction

Music is in some way efficacious to humans, central to human life. Yet it has no concepts, makes no propositions; it lacks images, symbols, the stuff of language. It has no power of representation. It has no necessary relation to the world. ...But, for virtually all of us, music has great power. ... it lies so deep in human nature that one is tempted to think of it as innate. ... it reproduces all the emotions of our innermost being, but entirely without reality and remote from its pain.

Musicophilia, Sacks (2007)

1.1 Introduction

Sacks (2007) illustrates people's awe and wonder at the mystery of music. This amazement originates from the fact that music does not have an adaptive use, like birdsong, for example. Rather, it is sometimes argued that music is a by-product of our evolution (James, 1884; Sacks, 2007). As Sacks (2007) also points out, music is extremely important to people. The importance of music may emanate from the fact that it influences our mood. Yet it is unknown what lies behind the powerful influence that music has on mood (Juslin & Sloboda, 2010). It is also unclear how we can use music to direct our mood to feel content and perform at our best (Isen, 2000). Automated mood enhancement may be possible by integrating music with modern technology which can monitor mood. A first step towards making these technologies feasible has been taken in that scientists now recognise that affect plays a central role in our everyday life, and hence, affect needs to be incorporated in system design to make systems truly intelligent (Picard, 1997). To make these systems unobtrusive and acceptable to users Picard (1997) proposes deriving users' affective state from unobtrusive mood measurements such as physiological responses. Devices which are capable of making such unobtrusive measurements are increasingly available (Ouwerkerk, 2011; Picard, 2010), and as technologies increasingly become part of our everyday life the potential for technologies that recognise and act upon the affective state of a user will also grow (Petta, Pelachaud, & Cowie, 2011).

The aim of this thesis is to build an experimental basis for an affective music player. An affective music player is a music player that automatically selects and plays songs to direct mood towards a desired state. To be able to build the experimental basis more insight into the relationship between music, mood and physiological response is required. Once this relationship is better understood it may be possible to design and properly validate an affective music player. The design of the music player will be guided by the assumption that changes in mood relate to changes in the physiological state (e.g., skin conductance or temperature). Based on previous physiological responses to a song, the music player can make a prediction of how that song will influence the physiological state the next time it is played. The affective music player then selects songs that direct the physiology, and mood, of the user towards a desired state. In this first chapter the concepts of affect, psychophysiology and music listening will be explained. A description of the affective music player will also be given together with research showing its potential to direct mood. Finally, the main aims of the other chapters will be set out.

1.2 Research scope

1.2.1 Affective phenomena

Emotions and moods pervade our everyday lives, yet everything indicates that they are complex phenomena. The complexity derives from the fact that hundreds of different words are used to describe affective phenomena (i.e., the collective term for emotions, moods and related phenomena). There is also not a single model that can fully describe all aspects of moods or emotions, let alone how these phenomena relate to one another (Davidson, Scherer, & Goldsmith, 2003; M. Lewis, Haviland-Jones, & Feldman Barrett, 2008). As a result, the affective terms used in scientific literature do not always denote what the authors wish to focus on which can cause confusion. To gain an overview of how affective phenomena are represented in the literature, it is necessary to have an understanding of the different affective features. For this purpose, Scherer and Peper (2001) and Scherer (2005) attempted to classify and identify different affective phenomena using a matrix of 'design features'. By taking this approach various affective phenomena can be distinguished on the basis of design features. These design features relate to aspects such as the intensity, duration, event focus, rapidity of change and behavioural impact of the affective phenomena. Table 1.1 shows the extent to which four different affective phenomena exhibit some of these design features. These design features could be fine-tuned in the future, however they also show that the affective terminology needs to be specified. This will help to clarify scientific communication and enable advances to be made in the theoretical modelling of affective phenomena.

Table 1.1 – Several features of affect that allow differentiation of affective phenomena. This Table is an adapted version from Scherer (2005), Scherer (2004), and Scherer and Peper (2001), and reflects to what extent affective phenomena (in rows) are characterised by the various features (in columns)

	Intensity	**Duration**	**Event focus**	**Rapidity of change**	**Behavioral impact**
Emotion	H	L	VH	VH	VH
Mood	M	H	L	H	H
Attitudes	M	H	VL	L	L
Personality	L	VH	VL	VL	L

VL = very low; L = low; M = medium; H = high; VH = very high.

To differentiate between affective phenomena, a definition of the most widely used affective phenomena has been taken based on Davidson et al. (2003), Ekman and Davidson (1994), Frijda (1999), M. Lewis et al. (2008), and Scherer (2005). *Feelings* are the subjective experience of affective states. As such, they constitute only a small part of affective phenomena and should not be confused with the phenomena themselves. *Emotions* are very short (seconds to minutes) affective phenomena and comprise intense reactions to internal or external events that are of major importance for survival (e.g., anger, fear, elation). Because emotions and their behavioural impact are highly important, as reflected in the rapid synchronisation of all bodily systems (e.g., physiology, muscle tension), they enable a quick response to an emotional event. The intensity and resource mobilisation of emotions, both positive and negative, can be very demanding on the body. *Moods*, however, are diffuse and longer-lasting (minutes to hours) affective phenomena (e.g., joy, depression) with a medium level of intensity. The origin of moods may have a clear cause but the cause is not always apparent. Moods do not trigger an urge to immediate action in the same way as emotions do. Rather, they subtly change subjective feelings, behaviour and cognitions. We are generally often unaware of our moods until we focus attention on them. This attention shift can happen when the intensity of a mood passes a certain threshold or when the mood increases in salience (Gendolla, 2000; Wilhelm & Schoebi, 2007). Apart from severe mood states such as prolonged depression, moods do not necessarily place such great demands on the body as emotions do. *Attitudes* are relatively long-lasting beliefs about objects or people (e.g., love, desire). *Personality* is a stable characteristic typical of an individual (e.g., extrovert, nervous). Personality traits vary only slightly over a lifetime.

In this thesis we will focus on moods because they influence various behaviours and cognitions, causing optimistic feelings to dominate (Gendolla, 2000). Moods can also have health benefits in the way that they affect physiological and immune processes (M. Lewis et al., 2008). Long-lasting positive moods, for example, do not require as much energy as long-lasting negative moods (e.g., depression) (Cacioppo, Tassinary, & Berntson, 2007). Moods can furthermore be changed gradually for a period of minutes to hours with no apparent cause for the change (Scherer, 2005; Thayer, 1996), which implies that moods could be induced in the background to other activities. The possibility of background mood induction may be beneficial as there are mood induction procedures, such as listening to music, that can be done in the background to most activities.

An exact definition of mood induction is difficult to find in the current literature. Even some meta-reviews about mood induction procedures do not give a definition of mood induction (Westermann, Spies, & Stahl, 1996). Originally, the term mood induction is very frequently used to indicate that a specific, absolute mood is induced (Gendolla & Krüsken, 2001, 2002), but very frequently it indicates no more than that a change in mood in the direction of a target mood is induced (Gomez, Zimmermann, Guttormsen-Schär, & Danuser, 2009). Currently, both definitions are used interchangeably, but the literature is dominated by the former. A problem with the absolute mood induction definition is that it is very hard to assess with the current methodology what absolute mood was induced. Gendolla and Krüsken (2002), for example, used music to induce absolute negative and positive moods. In the second experiment that is described in this paper, they calculate mood difference scores by subtracting the valence values obtained after the baseline from the valence values obtained after the induction (valence scale of 0-40, positive baseline $M = 33.42, SE = 9.17$, negative baseline $M = 32.08, SE = 2.23$). After mood induction they found significantly higher valence difference values in the positive mood induction group ($M = 5.33, SE = 1.60$) compared to the negative mood induction group ($M = -4.39, SE = 1.99$), and concluded that positive and negative mood manipulation was successful. In the rest of the paper, they further call the induced moods 'positive' and 'negative' moods, instead of 'more positive' and 'more negative' mood states, which were actually induced. This way to interpret mood induction data is generally used in the field and probably results from the fact that the effectiveness of mood manipulations is often checked via self-ratings using Likert scales (R. L. C. Mitchell & Phillips, 2007). These scales should by definition be interpreted in relative terms and not in absolute terms. In sum, successful mood induction reflects significantly higher valence values for positive compared to negative mood inductions. This implies that relatively more positive or relatively more negative mood states are found (indicating a direction). It does not mean that absolute negative or positive states are induced. We comply with this and therefore, in this thesis mood induction should be read as the direction of moods towards a mood state.

To be able to asses someone's mood in a way which is fairly simple and brief, methods have been proposed for subdividing and classifying moods into a couple of bipolar dimensions (Wilhelm & Schoebi, 2007). This dimensional approach places little demand on the user, even when moods need to be assessed several times, or when moods have to be assessed in ambulatory settings. Another advantage of the dimensional approach is its convenience for the computational modelling of moods (Petta et al., 2011). Simple models have proven to be more useful representations of moods for the purpose of affective computing because they avoid ambiguity.

Several slightly varying methods have been proposed to operationalize the subdivision of mood into dimensions. Russell (1980) proposed that a mix of valence and arousal is the base of affect, which he called the affective grid. Watson and Tellegen (1985) proposed that positive and negative affect are two orthogonal dimensions. They introduce the positive and negative affect scale (PANAS) which measures the positive and negative valence of moods with ten unipolar questions. Both these grids were criticised by Matthews, Jones, and Chamberlain (1990) who described and statistically demonstrated that moods should be conceptualised according to three dimensions only: valence (ranging from positive to negative), energetic arousal (ranging from energetic to calm), and tensed arousal (ranging from relaxed via restless to under tension). Although the two arousal scales are correlated, they cannot be reduced to one single arousal dimension. Several mood measurement scales have been proposed to assess these three mood dimensions (Matthews et al., 1990; Schimmack & Grob, 2000; Steyer, Schwenkmezger, Notz, & Eid, 1997). The existence of the three dimensions was also verified in an assessment of moods in everyday life using ambulatory measurements (Wilhelm & Schoebi, 2007).

Moods can also be detected with physiological measurements. In contrast to claims that moods do not have a clear link to survival (i.e., the rapid synchronisation of bodily systems) in the way that emotions do, they are not disembodied either. Accordingly, some physiological changes have been shown to relate to moods (Cacioppo et al., 2007). Although it is not precisely known to what extent moods relate to changes in physiological responses. Therefore, affective computing systems have not yet used physiological signals to measure mood in everyday life.

Affective computing is concerned with studying how systems recognise, interpret, and process affective information in the environment (Picard, 1997). Work in this area includes the field of cognitive science in which computer science and psychology play important roles, indicating that affective computing is a multidisciplinary field (Petta et al., 2011; Picard, 1997; Van den Broek, Janssen, Van der Zwaag, Westerink, & Healey, 2012). Affective computing began after it became clear that affect plays a crucial role in intelligent and social behaviour (Picard, 1997). Hence, systems need to incorporate affect to be able to behave intelligently. Affective computing systems do not necessarily need to deal with affect at the same level as humans do. Rather, it depends on the application under consideration which affective phenomena or affective state has to be recognised or acted upon to appear intelligent. Affective systems may incorporate unobtrusive measurements of affect via physiological responses (Picard, 2000). To be able to recognise affect from physiological measurements, the relationship between physiology and affective phenomena needs to be understood. Physiological measurements also have to be pre-processed appropriately to be able to derive the appropriate features from which affect can be detected (Petta et al., 2011; Van den Broek et al., 2012). Hence, as already pointed out in Section 1.2.1, a better understanding of how moods relate to physiological responses, as well as improvements in ambulatory measurements of physiology, will be necessary before affective computing systems can incorporate physiology to assess mood in everyday life and and react appropriately.

1.2.2 Music influences mood in everyday life

Listening to music is a very popular activity in everyday life (Sloboda & Juslin, 2010). Music is listened to in many places, preferably while alone at home, in a car or while travelling, for example. In such places people prefer to listen to music of their own choice, and the music personally selected is often music that has the greatest affective influence (North & Hargreaves, 2004). The fact that music influences mood, (e.g., relaxing, enjoying, energising) has been found to be among the top five reasons why people listen to music in everyday life (Eerola & Vuoskoski, 2010; Juslin & Laukka, 2004). Music is also one of the most effective methods of mood regulation in everyday life, along with activities such as reading a book, eating, watching TV and exercising (Thayer, Newman, & McClain, 1994). Another advantage of music as a mood regulator is that it can be used almost anywhere and at anytime. All in all, music greatly influences mood in daily life. However, as music databases increase in size, it is becoming increasingly difficult to select the music that you prefer or to direct your mood. To overcome this difficulty in music selection, affective computing technologies, such as an affective music player (see Section 1.2.3) may help in automatically selecting music that will direct your mood towards the desired state.

Only recently music psychology researchers have started to realise that research findings need to be applied to everyday life situations (Juslin & Sloboda, 2010; North & Hargreaves, 2008). As a result, the research objectives in music psychology have increasingly shifted towards real life situations. To give some examples, Sloboda and Juslin (2010) suggest that the influence of music on mood should be investigated through self-reports in experience sampling method (ESM) studies to investigate the true influence of music on mood. This method can take into account wide differences in music preferences between individuals. Music in everyday life today goes beyond classical music and it is, therefore, difficult to justify the amount of research that is still based on listening to classical music only (North & Hargreaves, 2008). Another aspect in music research that has adapted to real-life situations is that music is listened to almost everywhere and at anytime nowadays

(Bull, 2000). Some researchers have therefore started to investigate the extent to which concurrent activities affect the influence of music on mood. Despite these efforts to increase ecological validity in the field of music and emotion research, by far the most studies are still conducted in laboratory situations. In these studies, the experimenter selects music and tests its effect without understanding how these results can be generalised to everyday music listening. Therefore little is known about the relative success of music mood induction in everyday life. The research field of music and emotion is nevertheless rapidly advancing and with the greater recognition of the methodological issues, it will not be long before the study of music and emotion increases our understanding of how and when music affects moods.

Listening to music is not just an auditory activity, it not only influences mood but it impacts our psychophysiological responses as well (Hodges, 2010). Research on the influence of music on physiological measurements has shown generally mixed results (Hodges, 2010; Krumhansl, 1997; Nyklíček, Thayer, & Van Doornen, 1997; Rickard, 2004). These varying results can largely be explained by the research methods used. To start with, the music is very often selected by the experimenter, hence music is used which does not take into account individual differences in music preference. The music presentation time varies in duration from seconds to minutes which is also likely to influence the results. The adaptation to the stimuli occurs in the first few seconds which is different from the longer lasting influence of songs on mood. A clear definition of methodological and affective concepts is needed for this research. Another way to investigate the influence of music on physiological responses is through music characteristics. It is well-known that some dominant music characteristics, such as tempo or mode, result in certain predictable patterns of physiological responses to music (Van der Zwaag, Westerink, & Van den Broek, 2011). Several music recommendation techniques (i.e., information filtering systems that attempt to recommend music) are applied based on music characteristics, thereby providing a general predictor of how a song could influence mood and the physiological response (Skowronek, McKinney, & Van de Par, 2006, 2007). However, these recommendation techniques do not take into account individual differences in music preference. All in all, the effects of music on physiology are still unclear. The use of self-selected music may help to bring greater clarity, as this will increase the probability that the music influences mood in the intended way.

1.2.3 An affective music player

Several music players aim to influence the mood of a user. Some of these music players use music recommendation techniques to suggest songs (Cunningham, Jones, & Jones, 2004; Seyerlehner, Knees, Schnitzer, & Widmer, 2009; Van De Par, McKinney, & Redert, 2006; Yang, Lin, Su, & Chen, 2007), and some incorporate the use of physiological responses to make song selections to suit the users (Kim & André, 2008; Oliver & Kreger-Stickles, 2006; Picard & Healey, 1997). These systems, however, derive their suggestions from the responses of groups of users and do not take into account individual preferences and reactions to the music, even though it is known that individuals differ greatly in their responses to music. To our knowledge, the affective music player (AMP, by Janssen, Van den Broek, and Westerink (2012)) is the only music player among the set of players developed that takes into account individual physiological responses to songs, as opposed to the reactions of groups of listeners, and is able to learn to select music that suits a particular user.

The affective music player is a music player that selects a song to be played based on previous physiological responses while listening to that song (Janssen et al., 2012). The user can select a desired state in terms of valence or energy, and the AMP rephrases the desired state to a goal state in terms of physiological response. The affective music player thus assumes a certain relationship between the mood dimensions and physiological response. For example, it could be assumed that changes in skin conductance are positively correlated to the energy dimension of mood (Boucsein, 1992). Based on this relationship between physiology and mood, the affective music player tries to direct the physiological state of the user to the desired level. It does so by keeping track of the user's previous physiological responses to a song. A probability function is then used to predict how a particular song will influence the physiological state the next time it is played. Thus, if the user wants to become more energised, the music player can select songs with the greatest probability of increasing skin conductance and thus the energy or mood of the user. The more the AMP is used, the better the prediction will be of how a song will affect the physiology. An estimated prediction could be used for songs that are new to the user based on the music recommender system output.

The affective music player is a sophisticated and relatively complex music player that aims to influence mood. Some basic questions with regard to this affective music player remain unanswered. Firstly, it is unknown what physiological measurements provide the most reliable prediction of a mood's valence and energy dimensions. Secondly, it is unknown to what extent music can influence mood in different everyday settings, for example, when music is listened to as a primary activity or in the background of a concurrent activity. Thirdly, it is unknown how music can best be selected to direct mood most effectively towards a target mood. For example, music can be offered to guide the user's mood gradually to the desired state, or music of the desired state can be presented immediately. Lastly, it is unknown whether an affective music player can be used to direct mood towards a desired state during everyday activities. This thesis aims to answer these questions. These answers will lead to a better understanding of how music can be used to influence moods and physiological states in everyday life and will support the further development of the affective music player.

1.3 Outline

This thesis investigates how music influences mood and the psychophysiological state and looks for evidence to support the feasibility of an affective music player. Because music preferences as well as physiological responses are highly personal, it is expected that there will be wide variability between individuals in the experiments to be conducted. Our aim therefore, is to minimise the possible impact of this variability on the research results. Firstly, to overcome the differences in music preferences, the impact of music on mood was investigated in individuals listening to self-selected music rather than the effects of music listening on a group of people. Secondly, to reduce the variability in physiological responses we chose to investigate the influence of music on mood on a seated person either performing office work or driving. A brief outline of the research objectives of the individual studies conducted is then described.

Chapters 2 to 4 set out to investigate the extent to which music impacts mood and psychophysiological state when it is listened to as a main activity or heard in the background of office work activities. These fundamental steps provide a basic understanding of how music, mood and psychophysiological responses relate to one another. Chapters 5 till 7 investigate the influence of music on mood and psychophysiological state in several applied car driving scenarios. These chapters provide answers to more specific design issues of the affective music player. Next, Chapter 8 gives a validation of the affective music player in an everyday office setting. Finally, Chapter 9 includes a general discussion that brings together the implications of the research conducted and its significance in relation to what is currently known in the field.

We will now provide a brief overview of the research objectives of the individual chapters. Chapter 2 describes an experiment which aims to show the extent to which happy and sad music influences mood and a variety of physiological responses. The temporal patterns of music mood induction were also investigated to gain a better understanding of how long it takes before musically-induced moods are seen in physiological responses. This analysis also showed the time it takes for physiological responses to stabilise at levels that were induced by the music.

In Chapter 3 we investigate whether induced moods and physiological responses persist when music listening continues in the background to a task. This study also extends the first study in that it aimed to show the specific range of moods that can be induced with individually selected music. Therefore, high and low energy as well as positive and negative moods were induced. Finally, we introduced a more sophisticated method of selecting music per individual that targets a specific mood. In this way we were able to take into account the wide differences in music preference, and mood and physiological responses between individuals.

Chapter 4 describes an experiment intended to investigate whether mood can be induced with background music. We investigated the similarities and differences between physiological responses and mood to this more ecologically-valid music mood induction technique compared to traditional mood induction methods in which listening to music is the primary activity. For the purposes of the affective music player, it is crucial that music can induce moods and physiological responses when it is played in the background to an activity. In this way, a listener's activities can be continued when the music player is started without first having to interrupt the user for a couple of minutes to induce a mood.

Chapter 5 presents the first study that aims to show the impact of music on mood and physiological state under different driving scenarios. The study investigated whether positive and negative moods can be induced with music during high and low demand driving tasks. It also looked at how music affects physiological state and driving performance during low and high demand driving scenarios.

Chapter 6 considered how music can be selected to most efficiently regulate mood during high demand driving tasks. People often listen to their favourite music while driving. However, this music may be too demanding during high concentration driving. This study tested whether it is best to select calm music abruptly, or whether gradually increasing calmness to calm drivers works better. The impact of these mood regulation strategies on driving performance was also investigated.

Chapter 7 investigates the influence of music on mood during anger-inducing driving. The aim was to show whether music can be used to reduce the amount of anger that would normally be induced during anger-inducing drives. Anger is one of the most frequently felt negative emotions while driving (Underwood, Chapman, Wright, & Crundall, 1999), which can potentially influence driving behaviour negatively and cause long term health risks (Cacioppo et al., 2007). Therefore, the influence of music from each of the four quadrants of the valence-energy model on preventing anger induction was investigated and compared to the impact of hearing no music.

Chapter 8 describes an extensive validation of the affective music player in an ecologically-valid setting. Participants listened to music while carrying out their regular office tasks. The experiment was therefore conducted at the participants' desks. First of all, in a training phase, it was investigated whether music can be selected to decrease, maintain or increase skin conductance level. Next, in an evaluation phase, it was tested whether this music can be used to direct skin conductance and mood energy to a desired state, either up or down. This second phase provided an indication of the feasibility of directing mood to a desired state with the affective music player in an ecologically-valid setting.

Finally, Chapter 9 briefly reviews and consolidates the conclusions of all the chapters. Future challenges in relation to the affective music player are also discussed together with the ethical implications. Lastly, the overall conclusions are drawn.

Sumbitted as: Van der Zwaag, M. D. & Westerink, J. H. D. M.. Physiological patterns during musical mood induction.

Chapter 2

Physiological patterns during music mood induction

Little is known about the occurrence and the temporal patterns of physiological responses to musically-induced moods. This study investigated physiological response patterns during musical mood induction. In two sessions moods were induced in two opposite directions, towards happy and sad moods, in 36 participants using eight minutes of music in a within-subject design. Subjectively reported moods and various physiological response patterns were measured: facial muscle tone, cardiac rates, respiration, electrodermal activity and skin temperature. The results show that from four minutes onwards moods can be differentiated in a large subset of the recorded measurements. Various physiological measures changed from their baseline level during music mood induction and stabilised at new mood-dependent levels in three to five minutes. This study shows the sensitivity and temporal patterns for a broad range of physiological responses in relation to musically-induced moods. The impact of this study on methodological considerations related to mood induction is also discussed.

2.1 Introduction

Mood is important for normal functioning as it influences various cognitive functions. A positive mood state increases problem solving abilities, for example, enhances creative thinking ability, and memory consolidation (Isen, 2000). Music is known to be a very strong mood inducer. It can regulate mood in everyday settings (Juslin & Sloboda, 2010; Thayer, 1996) and in the laboratory (Etzel, Johnsen, Dickerson, Tranel, & Adolphs, 2006; Gerrards-Hesse, Spies, & Hesse, 1994; Westermann et al., 1996). Music is also listened to in many everyday situations and for many different purposes (Sloboda & Juslin, 2010). It is used to regulate affect in various settings, for example, to reduce boredom while waiting for public transport (DeNora, 2000), for enjoyment while driving (Dibben & Williamson, 2007), or to reduce anxiety and stress in hospital environments (MacDonald et al., 2003). These beneficial effects of music are so self-evident that the ability to induce moods has been described as the most important function of music (Saarikallio & Erkkilä, 2007).

Several studies have specifically demonstrated that music influences affect in autonomic activity (Etzel et al., 2006; Gomez & Danuser, 2007; Hodges, 2010; Khalfa, Roy, Rainville, Dalla, & Peretz, 2008; Krumhansl, 1997; Nykliček et al., 1997; Witvliet & Vrana, 2007). These studies show that there are various bodily responses to listening to short pieces of music. Nonetheless, it is not yet precisely known whether or not musically-induced moods change physiological baseline measures and hence the accompanying time-related properties are also unknown. To examine this, this study investigates the physiological responses to and timing of musically-induced happy and sad moods with a broad range of physiological measures.

2.1.1 Subjective and physiological correlates of mood

Mood can be described as a base-line body state (Ekman & Davidson, 1994; Gendolla, 2000; Thayer, 1989; Wilhelm & Schoebi, 2007). As such, moods are tonic in how they vary i.e., slow and gradual, over time. Mood is further a diffuse and long-lasting affective state, lasting minutes to days, while a person may have no clear idea of its origin (Cowie et al., 2001; Morris & Reilly, 1989; Thayer, 1989). On average, moods have moderate to low intensity levels, and mood awareness is absent until attention is drawn to changes in mood. Emotions, by contrast, are short-term processes related to a specific internal or external event, which result in an action tendency to that event (Ekman & Davidson, 1994; Frijda, 1999; Scherer, 2005). Thus, emotions can be seen as phasic, i.e. short and rapid, processes which occur on top of tonic stabilised moods. Current research on physiological responses in the affective domain focuses mainly on the emotions. As a result, short duration stimuli are often used to evoke emotions while the influence of longer affective stimuli (lasting several minutes or more) on physiological responses is not yet well understood.

The results of the shorter affective stimuli on physiology show that the most consistent physiological responses appear in facial expression and skin conductance responses. Facial muscle tension has been found to vary with valence; Lang, Greenwald, Bradley, and Hamm (1993) describe that the musculus zygomaticus major contracts during the positive emotion of happiness, whereas the musculus corrugator supercilii contracts during negative emotions such as stress and anger. Witvliet and Vrana (2007) showed similar results; more musculus zygomaticus major reactions were found during happy compared to sad music pieces that were presented for 26 seconds.

Electrodermal activity is directly influenced by the sympathetic nervous system, and has consistently been found to be positively correlated to arousal (Boucsein, 1992). Lang et al. (1993) showed that skin conductance responses increased with arousal when participants had to look at affective pictures. In line with this, Khalfa, Isabelle, Jean-Pierre, and Manon (2002), showed more skin conductance responses during high (compared to low) stimulative music excerpts with a duration of seven seconds.

No consistent results have been found in heart rate responses to affective stimuli (Cacioppo et al., 2007; Gendolla & Krüsken, 2001; Nater, Abbruzzese, Krebs, & Ehlert, 2006). This may be explained by the fact that heart rate is affected by both the sympathetic and parasympathetic branches of the autonomous nervous system. A second cardiac measurement, respiration sinus arrhythmia (RSA), could be considered a measure of the parasympathetic nervous system only (Berntson et al., 1997; Butler, Wilhelm, & Gross, 2006; Grossman & Taylor, 2007; Ritz, 2009). RSA shows the periodic fluctuations in heart rate linked to breathing and has been shown to vary with emotions. Butler et al. (2006), for example, showed that higher RSA values are related to more negative emotions and Nykliček et al. (1997) attribute higher RSA values more to sad than to happy music excerpts.

Respiration is mainly innervated by the parasympathetic nervous system, however it can also be controlled voluntarily (Wientjes, 1992). Faster respiration rates, shorter inhalation and exhalation times are found during higher levels of activation (Boiten, Frijda, & Wientjes, 1994; Homma & Masaoka, 2008; Ritz, 2004). Decreases in respiration rate have also been found in relation to sedative music (Iwanaga, Ikeda, & Iwaki, 1996).

Skin temperature is indirectly innervated by the sympathetic nervous system; increased sympathetic nervous system activity causes vasoconstriction of the blood vessels near the skin which after some time results in a drop in the skin temperature (Kistler, Mariauzouls, & Von Berlepsch, 1998; Marieb & Hoehn, 2007). As described by Mittelmann and Wolff (1943) higher skin temperature was found during unpleasant emotions compared to pleasant emotions which indicates less sympathetic nervous system activation in negative feelings.

In contrast to emotions, considerably less is known about physiological responses to mood changes. Because moods do not have an action tendency coupled to them, their ability to evoke changes in the autonomic nervous system is under discussion. Gendolla and Krüsken (2001) did not find any difference in several cardiac responses during eight minutes of positive and negative music mood induction. Nater et al. (2006), on the other hand, did find differences in skin temperature, skin conductance and heart rate during ten minutes of listening to heavy metal compared to renaissance music. Further evidence for the influence of mood on autonomic activation can be found in research on mood disorders. In depressed people, lower skin conductance levels (SCL) and fewer skin conductance responses (SCR) were found compared to normal persons, for example (Dawson, Schell, & Filion, 2000). Furthermore, clinically anxious people have further been shown to have reduced parasympathetic nervous system activity and increased sympathetic nervous system activity (Friedman, 2007). This same relationship has been found for hostility (Sloan et al., 1994). Clearly, mood disorders can change physiological baseline levels. Nevertheless, there is still little research available on the impact of mood on autonomic activity and physiological baseline levels.

2.1.2 This study

Neither the physiological features that discriminate musically-induced mood nor their temporal patterns are fully described in the literature. There are several advantages to understanding the physiological differentiation of moods as well as the related temporal patterns. Firstly, this may help to increase understanding of the relationship between mood and mental state disorders (e.g., depression or anxiety), specifically as reflected in physiological markers. Secondly, the temporal characteristics of physiological differentiation between moods could be applied in mood induction methodology, such as the time needed to induce mood. Knowing which physiological responses best reflect certain moods can help guide decisions about including physiological measurements to reflect mood changes. This is beneficial for both off-line and real-time processing of physiological response measurements (Fairclough, 2009).

Accordingly, the aim of this study was to examine the physiological characteristics of mood induction: their ability to differentiate between moods, their alteration of baseline levels, and their temporal properties. As a consequence, this study comprises a broad spectrum of bodily responses: the activity of facial muscles, cardiac measurements, respiration, electrodermal activity and skin temperature, as these at least are known to reflect emotional states. Mood changes were induced with music because it is a strong mood inducer, is less susceptible to experimental bias (i.e., that participants can guess the purpose of the experiment) compared to other mood induction techniques (Nykliček et al., 1997; Stemmler, 1987), and is often used in everyday life. The aim was to influence mood to two opposite mood directions to be able to show the greatest differentiation between moods; i.e., relatively happy (positive high energy) and relatively sad (negative low energy) moods (Wilhelm & Schoebi, 2007). Based on this, the aim of the study was to determine whether musically-induced moods adjust the baseline levels of physiological measurements, and to describe the direction in which and the temporal resolution over which musically-induced moods physiologically differentiate and stabilise.

2.2 Method

2.2.1 Participants

Thirty-seven volunteers (19 women, mean age 27.5 years SD= 3.1; 18 men, mean age 28.2 years, SD= 3.7) took part in two sessions. The participants were not aware of the purpose of the experiment and signed a written informed consent form before taking part.

2.2.2 Design

Two mood inductions were performed (towards happy and sad moods) with their order counterbalanced over the two sessions (first and second) and the participants (male and female). The participants took part in the second session exactly one week after the first (i.e., same time of day, same day of the week).

2.2.3 Apparatus and material

Music for the experiment was selected to induce the greatest difference between the two moods, i.e., relatively happy and sad. Because music is highly personal, the happy music was accordingly selected by the participants themselves as this is known to increase the chances of inducing a happier mood (Iwanaga & Moroki, 1999; Janssen, Van den Broek, & Westerink, 2009). The participants were asked to select three songs which made them feel good every time they listened to that music. The word 'mood' was not used to prevent suspicion concerning the aim of the experiment which might affect the mood induction. The sad music was selected by the experimenter as it turned out in a pilot for this experiment that participants found it very difficult to select music that makes them feel down. The selected sad music had been successfully used before to induce low valence (Gendolla & Krüsken, 2001), i.e., 'The Coup' by Hans Zimmer taken from the soundtrack of the film 'The House of Spirits'. The duration of the music was adjusted to eight minutes in total per session, with each of the three happy songs having the same duration (i.e. 2 minutes and 40 seconds). The music was played via a circum aural headphone (Sennheiser HD500 fusion).

Subjective mood measurements were assessed using the UWIST mood adjective checklist (UMACL) (Matthews et al., 1990), to assess the three mood dimensions valence (ranging from unpleasant to pleasant), energetic arousal (ranging from tired/without energy to awake/full of energy), and calm arousal (ranging from restless/under tension to calm/relaxed). The UMACL contains eight unipolar items for each mood dimension, starting with 'right now I am feeling..', with answers ranging from 0: 'not at all' to 4: 'very much'. The questionnaire was shown to the participants before the start of the experiment, so that unclear items could be clarified.

The physiological measurements included autonomic nervous system responses (i.e., facial muscle, cardiac activity, respiration, electrodermal activity, and skin temperature) that were measured with the NeXus-10 data recorder and its accompanying sensors (Mind Media BV, Roermond, the Netherlands). Physiological measurements were taken continuously throughout the experiment. The MATLAB programming environment (2007a, The Matworks, Natick, MA) was used for the preprocessing of the physiological signals.

Facial muscle tone

Electrodes were placed in accordance with the guidelines of Fridlund and Cacioppo (1986). The EMG electrodes were put on the left side of the face, sample frequency 1024 Hz. On each facial muscle, musculus zygomaticus major (EMGz) and musculus corrugator supercilii (EMGc), two Ag-AgCl disposable electrodes were placed parallel to the muscles. The signals were preprocessed by filtering the raw signal (high-pass filter: 20 Hz and band stop notch: 48-52 Hz) to remove low frequency artifacts and 50 Hz interference. The signal was then rectified, time integrated, and divided by the duration of the segment to obtain the mean rectified voltage (MRV) (Fridlund & Cacioppo, 1986).

Respiration

Respiration was measured using a gauge band around the chest (sample frequency 128 Hz). To obtain the respiration measurements, noise was excluded from the raw signal and movement artifacts were reduced by a .005 - 1.0 Hz band pass IIR filter. The number of respiration cycles per minute provided the respiration rate (RR) (Grossman & Taylor, 2007; Wientjes, 1992). The inhalation time (Ri), was taken as the time difference between the minimum amplitude just before the signal starts to increase at the beginning of the inhalation, and the moment at which the maximum amplitude of the inhalation was reached. Exhalation time (Re) was calculated as the time difference between the maximum of the inhalation and the starting point of the next inhalation. Lastly, amplitude differences between the signal values at the start of an inhalation and the accompanying maximum value were taken as the respiration amplitude (Ra).

Cardiac activity.

The electrical activity of the heart was measured with the standard lead II placement, sample frequency 1024 Hz (Stern, Ray, & Quigley, 2000). For this standard measurement, the negative and ground electrodes were placed right and left respectively, under the collarbones. The positive electrode was placed lateral anterior on the left chest, between the lowest two ribs. ECG measurements were taken using Ag-AgCl disposable sensors, containing a solid gel.

After amplification and filtering (Butterworth band pass: 0.5 - 40 Hz) of the recorded ECG signal, R-peaks were automatically detected. The distances between successive R-peaks, the interbeat intervals (IBI), were then calculated. An absolute threshold for IBI detection was set between 400 and 1400 ms. A moving threshold also detected IBIs that were 50 % greater or smaller than the average of the last 40 IBIs. IBI artifacts were removed from the data series. Less than 1 % of the whole data set contained an IBI outlier. Auto-regression was used to calculate the power spectral density of the IBIs (Berntson et al., 1997). Subsequently, the power in the high frequency range (0.15 - 40 Hz) was determined from the absolute values of this power spectral density. The high frequency range was corrected for respiration by regressing the respiration rate (RR) ($\beta = -.181$, $p < .001$) and respiration amplitude (Ra) ($\beta = .071$, $p = .025$) on the high frequency range. This regression was conducted for each participant individually, on all one-minute segments of the data, and the resulting standardised residuals were taken as a measure of RSA (Grossman & Taylor, 2007; Ritz, 2009).

Electrodermal activity

Skin conductance measurements were recorded using dry Ag-AgCl finger electrodes, attached to Velcro strips (sample frequency 32 Hz). The electrodes were strapped around the upper phalanxes of the index and middle fingers of the non-dominant hand. Small movement artifacts were removed (low-pass IIR filter: .5 Hz). The mean skin conductance value was taken as the skin conductance level (SCL). To obtain the skin conductance responses (SCR) the filtered signal was down-sampled to 2 Hz, and interpolated with cubic spline interpolation. The SCRGauge algorithm (Kohlisch, 1992) was used to extract the SCRs. An SCR was detected when the derivative of the signal was .5 μSiemens/sec, there was a descent for a maximum of five seconds, and the maximum amplitude was larger than .008 μSiemens (Dawson et al., 2000).

Skin temperature

A thermistor skin temperature (ST) sensor was attached to the upper phalanx of the little finger of the non-dominant hand using adhesive tape (sample frequency 128 Hz). The temperature sensor was sensitive enough to record temperature changes as small as 0.001 °C in a range from 10 °C to 40 °C. The average skin temperature value in each segment analysis was taken as skin temperature.

2.2.4 Procedure

When the participants arrived they were seated at a desk, in a simulated office situation. Next, physiological equipment was installed, sensors were attached and signal quality was visually inspected. The temperature (21 °C) and humidity (34 %) were kept constant in the experimental room. The whole experiment was computerised, instructions for each part were presented on the monitor. In the instructions participants were told that the experiment consisted of two sessions during which their physiological reactions to music listening would be recorded. The intention was to make sure that the participants did not suspect that mood induction would be taking place. Then a general questionnaire of the participant's personal data (gender, age, music knowledge) and the UMACL mood checklist had to be completed (Matthews et al., 1990). The UMACL was presented to the participants as a normal control procedure, which would be presented a couple of times during the experiment.

The experiment started with a habituation period where the participants watched an aquatic movie 'Coral Sea Dreaming, Small World Music, Inc.' (Piferi, Kline, Younger, & Lawler, 2000). After eight minutes of watching, the UMACL was presented on the monitor and had to be completed. Then music (happy or sad) was played for eight minutes. To ensure that the participants remained attentive to the music, they were asked to listen to the music carefully and told that there would be questions about the music at the end of the second session. Directly after the music presentation the UMACL had to be completed again. At the end of the session participants were detached from the equipment and thanked for their participation.

The second session of the experiment differed only in the mood induction (happy / sad), and took place exactly a week later (same day of the week, same time of day). The total duration of one experimental session was maximum of 20 minutes in total. If the instructions, attachment and detachment from the physiological equipment are included, one session took utmost 40 minutes in total.

2.2.5 Data analysis

Mood scores for each mood dimension were calculated by averaging the normal and the reverse coded items of the UMACL questions for each dimension. Difference scores were calculated each time by subtracting the mood values obtained after the baselines from the values obtained after the mood induction.

For the physiological measurements the third to the seventh minute of the baseline period were used to provide the baseline scores. The physiological measurements taken in these five minutes were calculated per minute and then averaged (Llabre, Spitzer, Saab, Ironson, & Schneiderman, 1991). Physiological measures taken during the mood induction were calculated for each minute of the eight minute period. These measurements were adjusted for the baseline scores in the following way: for the facial muscle tone measurements the percentage-change from the baseline to the average of each minute of music listening was taken as the reaction score of the mean rectified voltage (Fridlund & Cacioppo, 1986). For the cardiac and respiratory measurements, reaction scores were obtained by subtracting the average values for the five minutes of the baseline from the average of each minute of music listening (Llabre et al., 1991). The electrodermal and skin temperature reaction scores were obtained by applying z- transformations: for each participant the mean and standard deviation of the five minutes of the baseline session were taken as the mean and standard deviation for these z- transformations (Boucsein, 1992).

Outliers, scores that diverged more than three standard deviations from the group mean, and missing values were omitted from the analysis (Tabachnick & Fidell, 2006). All the physiological readings for two participants from one of the sessions were lost due to equipment failure. The data contained less than 5 % outliers or missing data in total. The missing values were not replaced, (i.e., derived from

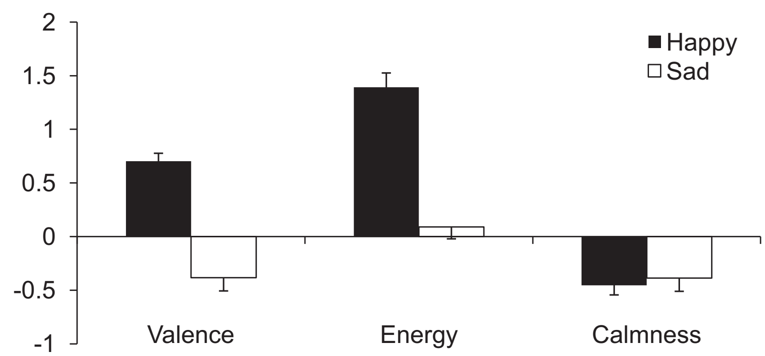


Figure 2.1 – The means and standard errors of the subjective mood reaction scores after happy and sad mood induction. Error bars depict +/- 1 standard error.

means or interpolation of data from the participant) as there were not many missing values and, more importantly, the plausibility of such replacement values would be unclear (Tabachnick & Fidell, 2006). The data were analysed with SPSS 17 for Windows (SPSS Inc., Chicago, IL) with the level of significance set at $p < .05$ (2-tailed). Pairwise comparisons were Bonferroni corrected. Effect sizes are expressed as η^2 values.

2.3 Results

2.3.1 Subjective characteristics

The reliability of the mood dimensions was determined, using the normal and the reverse coded items of the UMACL questions. This gave a Chronbach's alpha for valence and calmness of .86, and for energy of .85. A MANOVA test with Session (first / second) as the within-subject factor showed no significant difference between the mood scores obtained after the baselines of the two sessions ($p > .05$). The mean baselines of the two conditions were as follows: valence $M = 2.79$ ($SE = .08$), energy $M = 1.55$ ($SE = .01$), and calmness $M = 3.29$ ($SE = .08$).

A repeated-measures MANOVA test with Mood (happy / sad) as the within-subject factor showed a multivariate effect on the mood scores, indicating that the moods were different in the happy and sad states ($F(3, 34) = 33.33$, $p < .001$, $\eta^2 = .75$). As Figure 2.1 shows, subsequent univariate tests yielded higher levels of valence and energy after happy mood induction compared to the sad mood induction (Valence $F = 21.80$, $p < .001$, $\eta^2 = .60$, Energy $F = 31.35$, $p < .001$, $\eta^2 = .75$). No difference in calmness was found between the two inductions. These results show that the happy and sad mood manipulation was successful.

Table 2.1 – Results of the univariate tests for the Mood Induction, Time, and Mood Induction with Time interaction on the physiological measures ($n.s.$ = not significant.

	Mood Induction	**Time**
EMGc	$F = 9.43$, $p = .006$, $\eta^2 = .30$	$F = 12.18$, $p < .001$, $\eta^2 = .36$
EMGz	$F = 6.48$, $p = .019$, $\eta^2 = .24$	$n.s.$
IBI	$F = 8.27$, $p < .009$, $\eta^2 = .28$	$F = 11.23$, $p < .001$, $\eta^2 = .35$
RSA	$F = 3.30$, $p = .084$, $\eta^2 = .14$	$n.s.$
Ri	$F = 11.07$, $p = .002$, $\eta^2 = .27$	$n.s.$
Re	$n.s.$	$n.s.$
Ra	$n.s.$	$F = 2.73$, $p = .032$, $\eta^2 = .47$
RR	$n.s.$	$n.s.$
SCL	$F = 12.81$, $p < .001$, $\eta^2 = .28$	$F = 13.15$, $p < .001$, $\eta^2 = .77$
SCR	$F = 3.70$, $p = .017$, $\eta^2 = .24$	$F = 4.84$, $p = .005$, $\eta^2 = .69$
ST	$n.s.$	$F = 27.13$, $p < .001$, $\eta^2 = .18$
	Mood Induction with Time	
EMGc	$n.s.$	
EMGz	$n.s.$	
IBI	$n.s.$	
RSA	$F = 4.14$, $p < .001$, $\eta^2 = .17$	
Ri	$F = 3.96$, $p = .005$, $\eta^2 = .54$	
Re	$n.s.$	
Ra	$n.s.$	
RR	$n.s.$	
SCL	$F = 4.23$, $p = .003$, $\eta^2 = .52$	
SCR	$n.s.$	
ST	$F = 13.47$, $p < .001$, $\eta^2 = .30$	

2.3.2 Physiological reactivity

A repeated-measures MANOVA with Session (first / second) as the within-subject factor carried out on the physiological measurements separately, the baselines of the first and second sessions showed no difference for any of the physiological measures (all $p > .05$). To describe the physiological reactivity of mood induction over time a repeated-measures MANOVA with Mood Induction (happy / sad) and Time (minute 1 to minute 8) as within-subject factors was applied to the physiological reaction scores. An overview of the univariate effects of these analyses is shown in Table 2.1. Figures 2.2, 2.3, 2.4, and 2.5 show that most of the measures stabilised towards the end of the mood induction period (Mood Induction with Time interaction) at distinctly different levels for the two induced moods (main effect of Mood Induction).

Table 2.2 – The duration in minutes until happy and sad mood inductions are significantly differentiated in each physiological measure. These durations are derived from pairwise comparisons for each minute of the mood-induction period. n.s.: no significant difference, sig.: main effect of mood induction in ANOVA is not found again in the pairwise comparisons.

	EMGc	EMGz	IBI	RSA	Ri	Re	Ra	RR	SCL	SCR	ST
Minutes	1	2	sig.	4	2	$n.s.$	$n.s.$	$n.s.$	2	2	7

These observations were checked for each measure by means of pairwise comparisons for each minute of the mood-induction period. Table2.2 provides an overview of the duration to differentiate between happy and sad moods, as based on these pairwise comparisons.

Where a significant Mood Induction with Time interaction was found (i.e. the signal changes differently over time during happy and sad mood induction), polynomial trends were determined for the happy and sad mood inductions separately. Trend analysis (i.e., polynomial contrasts to investigate the response patterns to mood induction over time) was carried out to find the significant trends in the signals over time at the $p < 0.05$ level. When a significant trend was found for minutes 1-8, the trend analysis was repeated for minutes 2 till 8, etcetera, until no further significance was found. Table 2.3 provides an overview of the results of the trend analyses. Details for each of the separate physiological measurements are given below.

Facial muscle tension

The multivariate analysis for EMGz and EMGc showed significant effects for Mood Induction ($F(2, 20) = 4.97$, $p = .018$, $\eta^2 = .33$), and for Time ($F(2, 20) = 5.05$, $p < .001$, $\eta^2 = .19$). The univariate tests showed significant Mood Induction effects (Table 2.1). It can be seen in Figure 2.2 that the musculus corrugator was less contracted and musculus zygomaticus was more contracted during the happy mood compared to the sad mood induction. This difference had already occurred after one and two minutes, respectively (Table 2.2). The musculus corrugator shows a Time effect, which is explained by the first minute of music listening, where it shows more contraction than in the other minutes irrespective of mood induction (all $p < .05$ from the first compared to the other minutes). The trend analyses showed a similar pattern for happy and sad mood inductions, and stabilise at three minutes. Despite an increase in the contraction of the musculus zygomaticus for happy mood induction (Figure 2.2), the overall pattern was found to be stable over the whole fragment (Table 2.3). Overall, it may be concluded that the facial muscle tension differentiates between moods and was stable from the third minute onwards.

Table 2.3 – Effect sizes of trend analyses of linear (L) and quadratic (Q) contrasts; e.g., L1 shows a significant linear trend over the first to the eighth minute, L2 shows a significant linear trend over the second to the eighth minute, etc. If no trend is mentioned, no significant trend over time was found: the signal did not change over time. Separate trends for happy and sad mood inductions have been indicated when the mood induction with time interaction was significant in the univariate ANOVA (Table 2.1). The column 'stabilised at' shows the moment from which the signal in the period of mood induction remains stable in minutes, when no further linear or quadratic trends were found; e.g. '2' means that the physiological measure had already stabilised at the second minute of mood induction. The direction of the trends can be seen in Figures 2.2 till 2.5.

	Stabilised at	**Trend**
EMGc	3	L1 $\eta^2 = .41$; Q1 $\eta^2 = .60$, Q2= $\eta^2 = .15$
EMGz	1	$n.s.$
IBI	5	L1 $\eta^2 = .27$, L2 $\eta^2 = .40$, L3 $\eta^2 = .45$, L4 $\eta^2 = .28$
		Q1 $\eta^2 = .64$
RSA happy	2	L1 $\eta^2 = .13$
RSA sad	4	L1 $\eta^2 = .25$, L2 $\eta^2 = .16$, L3 $\eta^2 = .13$
Ri happy	1	$n.s.$
Ri sad	3	L1 $\eta^2 = .41$, L2 $\eta^2 = .27$; Q1 $\eta^2 = .26$, Q2 $\eta^2 = .32$
Re	5	L1 $\eta^2 = .22$, L2 $\eta^2 = .35$, L3 $\eta^2 = .38$, L4 $\eta^2 = .27$
Ra	5	L1 $\eta^2 = .27$, L2 $\eta^2 = .20$, L3 $\eta^2 = .24$, L4 $\eta^2 = .18$
		Q3 $\eta^2 = .31$; Q4 $\eta^2 = .34$
RR	5	L2 $\eta^2 = .19$, L3 $\eta^2 = .30$, L4 $\eta^2 = .24$
SCL happy	2	L1 $\eta^2 = .44$, L2 $\eta^2 = .11$; Q1 $\eta^2 = .39$,
SCL sad	5	L1 $\eta^2 = .16$, L2 $\eta^2 = .41$, L3 $\eta^2 = .16$,
		Q1 $\eta^2 = .16$, Q3 $\eta^2 = .16$, Q4 $\eta^2 = .16$,
SCR	3	L1 $\eta^2 = .26$, L2 $\eta^2 = .40$; Q2$\eta^2 = .37$
ST happy	?	L1 $\eta^2 = .36$, L2 $\eta^2 = .36$, L3 $\eta^2 = .33$, L4 $\eta^2 = .32$,
		L5 $\eta^2 = .35$, L6 $\eta^2 = .23$, L7 $\eta^2 = .33$
ST sad	1	$n.s.$

Cardiac activity

A repeated-measures MANOVA on the two cardiac measures mean IBI duration and RSA showed multivariate effects of Mood Induction ($F(2, 20) = 4.30$, $p = .028$, $\eta^2 = .30$), Time ($F(14, 294) = 4.91$, $p < .001$, $\eta^2 = .19$), and Mood Induction with Time interaction ($F(14, 294) = 2.11$, $p = .011$, $\eta^2 = .10$).

Over the eight minutes the mean IBI was shorter during the happy than the sad mood induction (see Figure 2.3 and Table 2.1). Pairwise comparisons showed that the mean IBI was shorter during the first minute than the other minutes of mood

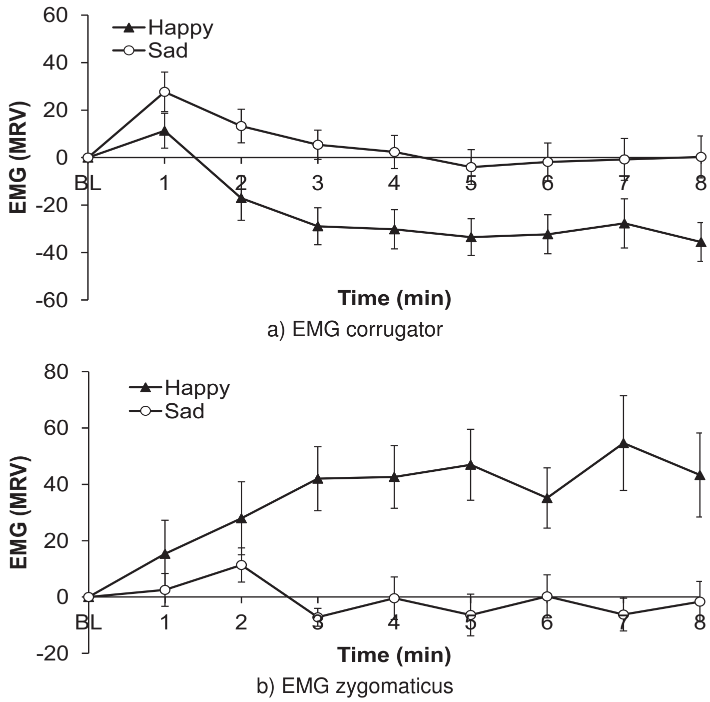


Figure 2.2 – The mean reaction scores and standard errors of the percentage-change scores of the mean rectified voltage (MRV) musculus Corrugator and Zygomaticus values during happy and sad mood inductions, BL= baseline.

induction (the first minute compared to the other minutes, $p < .01$). As Table 2.3 shows, trend analysis resulted in both a linear and a quadratic increase in IBI during the full eight minutes of music presentation. The quadratic trend vanished and linear trend continued until the fourth minute, after which the mean IBI did not change anymore over time; it stabilised at five minutes.

The univariate effect of Mood Induction, indicating that the RSA is lower during happy mood than sad moods, was almost significant (Figure 2.3, Table 2.1). Pairwise comparisons showed that the RSA was significantly lower during a happy mood than a sad mood from the fourth minute onward (Table 2.2). Trend analyses showed only a linear decrease in RSA during happy mood induction from the first until the eighth minute (see Table 2.3. This trend continued for longer during sad mood induction where a linear increase in RSA from the first three minutes to the eighth minute was found. Thus overall, the IBI and RSA differentiate between happy and sad moods and stabilised further to mood induction from the fourth and fifth minutes onward.

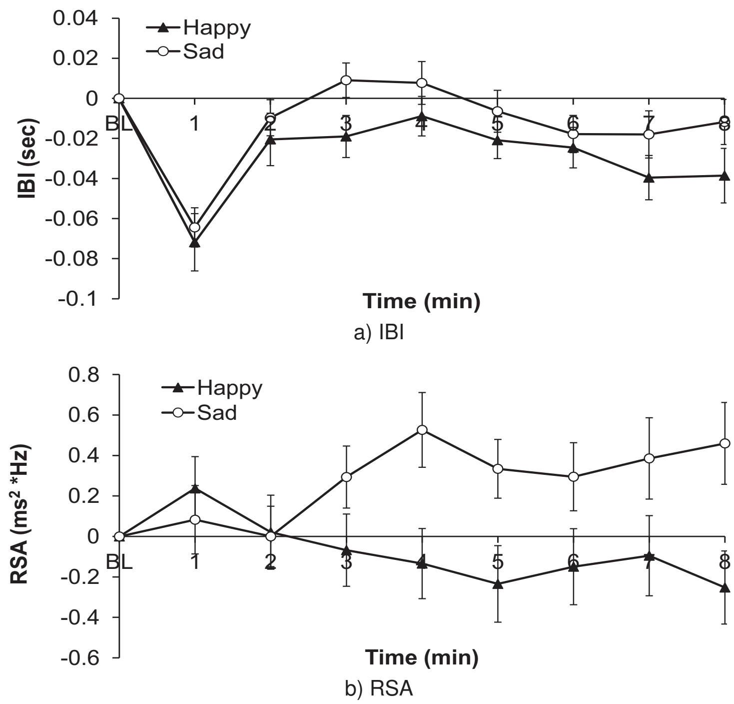


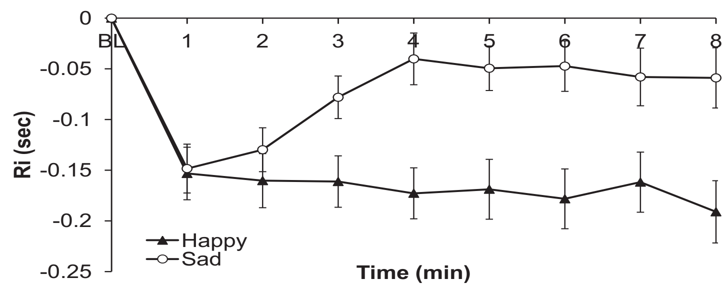
Figure 2.3 – The mean reaction scores and standard errors of the IBI and RSA responses during happy and sad mood inductions, BL= baseline.

Respiration.

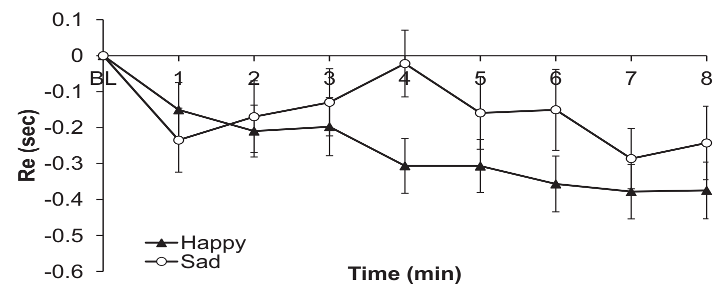
The repeated-measures MANOVA showed that the respiration measures changed over time (Time $F(28, 504)$=3.01, $p < .001$, $\eta^2 = .14$) and this change differed between exposure to happy and sad music (Mood Induction with Time $F(28, 504) = 1.58$, $p = .032$, $\eta^2 = .08$).

For the respiration inhalation time, longer inspiration times were found after two minutes of sad mood induction compared to happy mood induction (Table 2.2, Figure 2.4), also contributing to the main effect of overall mood induction (Table 2.1). Trend analysis explained the Mood Induction with Time interaction: during listening to happy music the inspiration duration does not change over time, whereas a linear and quadratic increase in inhalation times was shown from the first two minutes to the eighth minute of sad mood induction (Table 2.3).

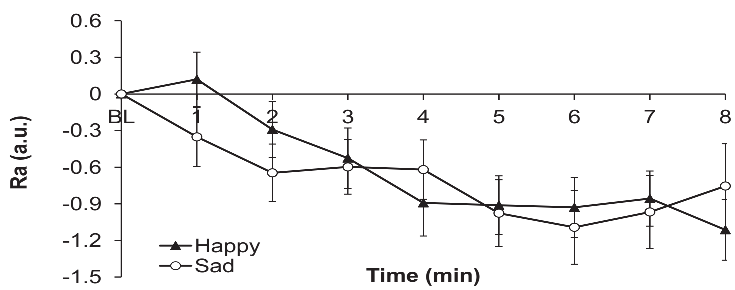
The respiration exhalation period, the respiration rate, and the respiration amplitude showed no significant differences between the two mood induction periods. However, while the respiration rate increased over time from the second till the fourth minute, the respiration exhalation time and the respiration amplitude de-



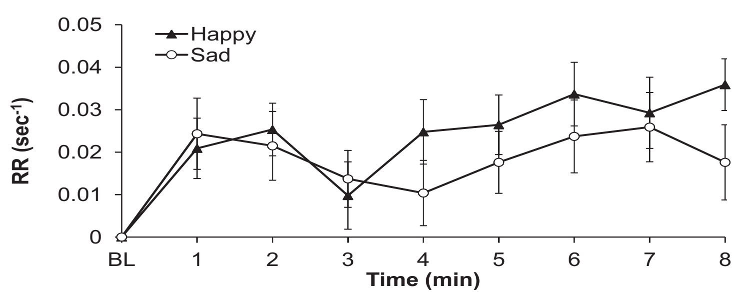
a) Ri



b) Re



c) Ra



d) RR

Figure 2.4 – The mean reaction scores and standard errors of the respiration inhalation time (Ri), the exhalation time (Re) in seconds, the respiration amplitude (Ra) in arbitrary units (a.u.), and the respiration rate (RR) in seconds^{-1} during happy and sad mood inductions, BL= baseline.

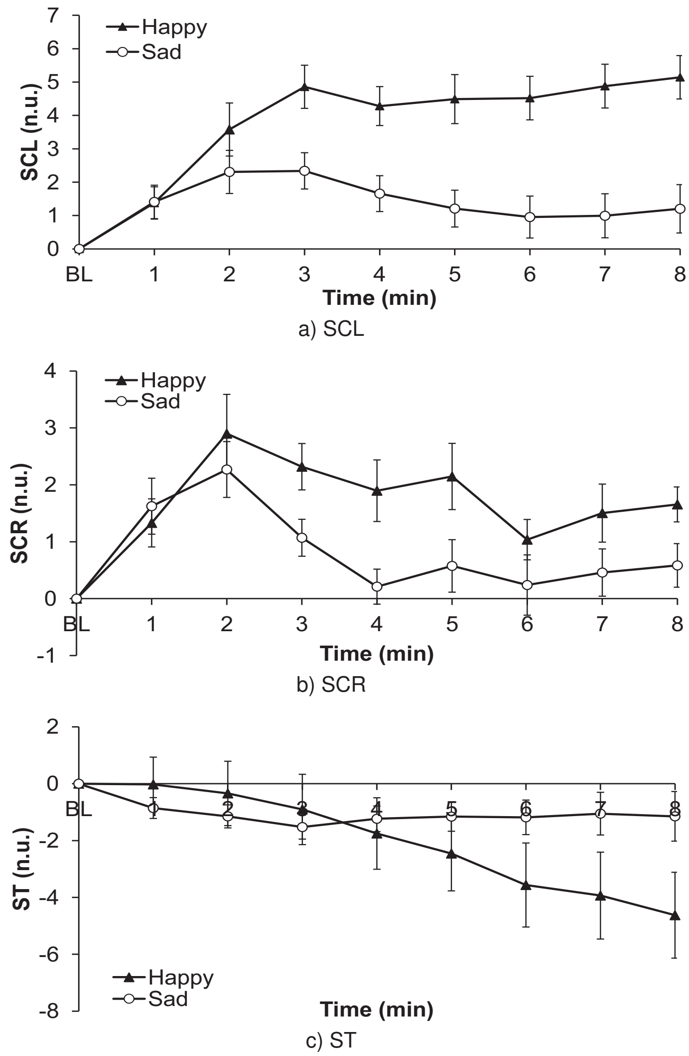


Figure 2.5 – The means and the standard errors of the normalised skin conductance level (SCL), the amount of skin conductance responses (SCR) and the skin temperature (ST) during happy and sad mood inductions. n.u. = normalised units, BL= baseline.

creased over time from the first four minutes in linear and quadratic manners, after which the signals stabilised (see also Table 2.2 and Figure 2.4). Generally, the respiration inhalation differentiates between moods and all the respiration measures stabilised at five minutes of mood induction.

Electrodermal activity.

The repeated-measures MANOVA of the electrodermal measures showed differentiation between the happy and sad mood induction and the effect changes over time (multivariate effects Mood Induction $F(2, 19) = 4.79$, $p = .021$, $\eta^2 = .34$, Time $F(14, 280) = 6.25$, $p < .001$, $\eta^2 = .24$), and Mood Induction with Time ($F(14, 280) = 3.98$, $p < .001$, $\eta^2 = .17$). Pairwise comparisons showed the skin conductance level to be higher and the amount of skin conductance responses to be greater during the happy compared to the sad mood after being exposed to two minutes of mood induction (Figures 2.5, Table 2.2), with an exception for the amount of skin conductance responses in the sixth minute ($p > .05$). The skin conductance level showed different patterns during exposure to happy and sad mood inductions (Mood Induction with Time interaction, Table 2.1). Trend analyses showed a linearly increasing trend from the first and second minutes to the eighth minute during happy mood induction, and that the signal stabilised after the second minute. During exposure to sad music the skin conductance level changed both linearly and quadratically over time. These trends both vanished in the fifth minute of sad mood induction (Table 2.3). Generally, skin conductance differentiates between the two induced moods, and was stable from the fifth minute onwards.

Skin temperature.

When exposed to happy mood-inducing music, the skin temperature linearly decreased over time, while the skin temperature remained stable when listening to sad mood-inducing music (Mood Induction with Time effect in Table 2.1, Figure 2.5). Pairwise comparisons showed that this decreasing pattern of skin temperature in the happy induction differentiated relatively happy from relatively sad moods from the seventh minute onwards (Table 2.2).

2.4 Discussion

Mood influences various cognitive functions and thus is important in regulating an appropriate state. Music is a popular method of regulating mood, however, it is not yet well understood how the characteristics of music and mood influence the bodily state. This study investigated whether physiological measurements change from their baseline level to a different level during musical mood induction. The temporal patterns of physiological responses to musically-induced mood were also investigated. Mood manipulation through music was confirmed by higher subjectively-reported valence and energy levels during happy compared to sad mood induction. For calmness we did not find any difference in subjective ratings between the two moods, so it is not possible to attribute any differences in physiological parameters to changes in calmness. Most of the physiological parameters included indeed showed a differentiation between the two musically induced moods, and they stabilised at new levels depending on the mood induced (Table 2.1). The divergence in the autonomic responses to mood induction and the temporal patterns during music mood induction will also both be discussed (Tables 2.2 and 2.3).

2.4.1 The influence of mood on physiology

These results show that the physiological responses to mood are not short, rapid and phasic responses, as with emotions. Instead we have shown that moods are able to alter physiological baseline levels which stabilise gradually over a longer time period of at least eight minutes. This confirms the results from subjective sources that moods are baseline body states (Ekman & Davidson, 1994; Thayer, 1996) and in line with this, show that moods adjust physiological baseline values as well. Physiological measures are therefore a useful way of showing differentiation between moods.

Both the skin conductance level and the number of responses, increased by the end of the happy mood induction period. During relatively sad moods the activity shown by the measurements remained close to the level obtained during the baseline. These results are in line with previous research that showed that aroused states are related to increased electrodermal activity compared to neutral or low arousal states (Boucsein, 1992; Khalfa et al., 2008). The higher skin conductance level and responses for more happy moods are most likely a reflection of the higher energy levels indicated by this state. Similar observations can be made for the skin temperature measurements, as skin temperature is also related to the sympathetic nervous system (Kistler et al., 1998). Indeed, the more happy moods indicated higher sympathetic activity and decreased skin temperature.

Various respiration measurements clearly differentiated between moods: Inhalation time was shorter during happier moods while the exhalation time and respiration rate showed the same trend for the two moods. This result underlines that respiratory changes correspond to changes in hedonic tone and energy levels (Boiten et al., 1994). These results are further believed to be the first reports on inhalation time differences between mood states. The lack of previous reports may be due to the fact that respiration inhalation is not often taken into account as a parameter in the affective domain (Wientjes, 1992). Respiration is also not often studied over longer time periods, and from this study it appears that it takes some time before a difference in mood is reflected in respiration measures. Therefore, the fact that previous studies did not find significant changes in respiration rates to affective stimuli could be explained by the duration of the stimulus. Finally, the respiration amplitude decreased over time which reflects a tendency to become less energetic while the induction lasted, irrespective of the mood induced (Boiten et al., 1994). This pattern may well reflect the adaptation to the music listening situation compared to the very calm baseline period.

Mood differences were also visible in the heart rate measurements i.e., in the mean IBI. Happier moods showed shorter IBIs, indicating an increased heart rate, compared to more sad moods. Although in line with Nater et al. (2006), this result contrasts with Gendolla and Krüsken (2001) who did not find IBI effects during music mood induction. An explanation for these contradictory result may lie in the songs chosen for mood induction. In this study, the difference between two moods was augmented as far as possible by presenting a personal music choice in the happy condition. This resulted in a greater differentiation between the two mood states induced, which was reflected in these significant HR differences between the two mood states. These results are also in line with results found with musically-induced emotions. For examples, Nykliček et al. (1997) found the same differences between sadness and happiness in the phasic IBIs.

The differentiation in the RSA values between the two moods showed increased activity of the parasympathetic nervous system during sadder moods, indicating decreases in energy levels. This result is in line with results in the emotion domain, where higher levels of RSA are accompanied by more negative emotions (Butler et al., 2006).

The activity in the facial muscles showed that the musculus corrugator is less contracted and the musculus zygomaticus is more contracted in the happier mood states than in the sadder moods. This is in line with research on inducing emotions (Fridlund & Cacioppo, 1986; Watson, 2000) which showed that the contraction of the musculus zygomaticus is greater and contraction of the musculus corrugator is smaller during positive than negative emotions. This therefore suggests that the differences in facial muscle tension between the happier and sadder moods are related to valence differences between the two moods.

When the respective physiological responses are combined a salient pattern emerges in which the happier compared to sadder mood evokes more sympathetic nervous system activity (e.g., as reflected by higher levels of skin conductance, see e.g., Boucsein (1992)). Conversely, the sadder mood shows more parasympathetic nervous system activity (i.e., less parasympathetic nervous system inhibition visible in higher RSA, for example, showing that mood affects the tonic vagal influence on the heart see Grossman and Taylor (2007). Both findings fit with the results of the subjective measurements with the happier moods being high energetic moods and the sadder moods low energetic moods. The fact that subjective ratings also indicate that both mood states differ in valence was reflected in the EMG responses of the musculus corrugator and musculus zygomaticus, as discussed above.

2.4.2 Temporal patterns

Most of the physiological measurements recorded showed a clear pattern over time during the mood induction. They rose and fell and then tended to stabilise (i.e., the measures did not change anymore over time) within the time frame of eight minutes. The one exception was the skin temperature which varied only slowly and was still linearly decreasing after eight minutes of mood induction. The general pattern, however, showed that the physiological responses do not occur instantly in reaction to the music presented. Instead, they developed relatively gradually over the time frame of a few minutes before they stabilise at a certain level. The time to stabilisation was roughly the same for these responses, i.e., 3-5 minutes, certainly for those measurements that indeed showed a substantial value change (EMG musculus zygomaticus, EMG musculus corrugator, IBI, RSA, respiration inhalation, skin conductance level, and skin conductance response). These slow stabilisation times support the notion that music induces tonic mood states, which are fully completed after about four minutes.

The stabilisation times of the physiological responses to happy and sad mood induction were not equal in all measurements (i.e., RSA, respiration inhalation, skin conductance level, and skin temperature), as illustrated in Table 2.3. In most cases stabilisation took less time during happy mood induction. The general pattern, however, showed that the physiological levels that change most during the mood induction took longer to stabilise. This can be viewed as an inherent property of physiological responses. Thus, this does not necessarily support claims that, for example, different moods have different underlying processes (Forgas, 2000). Future research could further investigate this aspect.

For the physiological measures that were sensitive to mood induction, with the exception of skin temperature, from the fourth minute of mood induction onwards moods can be differentiated (Table 2.2). It is not surprising that these differences are not found from the start because, in the first minute the presence of music is new and people have to adjust to the situation. This notion is supported by the fact that in the first minute the direction of most of the physiological changes is the same for both moods, irrespective of the direction of change in which the mood later stabilises. To illustrate this, during the first minute the musculus corrugator response is high with both moods inductions. However, as expected, in the happier state the musculus corrugator drops to below baseline in the subsequent minutes. Studies using only one or two minutes of stimulus presentation are therefore more likely to report different final results than those found here. Furthermore, as the physiological differentiation in the first two minutes of mood induction needs not be ascribed solely to the mood induction, it is suggested that these two minutes at least should be removed when comparing averaged results for different mood inductions. In addition, this study provides objective evidence (from physiological sources) that the eight minutes of mood induction which is currently used in many studies involving mood induction (Gendolla & Krüsken, 2001; Westermann et al., 1996) is indeed enough to induce moods.

2.4.3 Limitations and future research

The specific context of musically-induced mood has to be considered. For example, music as a mood induction technique is different from reminiscent techniques, such as autobiographical recall or the Velten mood induction procedure (Velten, 1968) for inducing a particular mood. From emotion and music research it is known that music and imagery produce similar physiological responses to emotions. However, to what extent the different mood induction techniques result in similar differentiation patterns of physiological responses is not described.

The present study shows that physiological baseline measurements adjust and stabilise according to the induced moods in eight minutes. This result has been taken to support the view that moods rather than emotions were induced, i.e., emotions would show a short change in the physiological response indicating arousal after which the response would return to the previous baseline values. Future research could further investigate how long moods can continue to be induced and remain visible in physiological measurements e.g., for time periods of 30 minutes to hours.

2.4.4 Conclusion

This study shows that music can be used to induce relatively happy and sad moods and that this results in specific physiological response patterns. The study further describes this physiological differentiation between moods as well as the accompanying temporal characteristics. Additional support was found for the notion that happier moods are accompanied by greater sympathetic nervous system activity and less parasympathetic nervous system activity compared to sadder moods. The physiological measurements changed from their baseline levels further to musical mood induction depending on mood. Hence, the current results based on physiological measurements support the notion that moods are tonic baseline states.

This study further showed that physiological differentiation takes four minutes on average. Hence, in order to show physiologically differentiation between moods, mood induction data from the fourth minute onward should be used for analysis.

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Chapter 3

Sustaining moods with background music: physiological patterns and subjective experience

Music is a powerful and popular means of regulating mood in daily life. However, most studies only use music to induce a mood without consideration of how such moods persist after the presentation of music has stopped or what happens when the effect of the mood on a dependent variable is tested. Yet this persistence is a key element of music listening in daily life. In this study, we investigated physiological responses to musically induced moods, specifically, their persistence during task conductance with continuing presentation of music. We induced various moods using individually selected music tailored to each quadrant of the valence-arousal model. Mood ratings show that the induced mood generally coincides with the direction of the affect expressed by the music but that the intensity of the mood reduced during task conductance. Physiological responses proved to be sensitive to the direction of each mood dimension. Skin conductance, skin temperature, and zygomaticus muscle activity continued to reflect differentiated moods during task conductance. These results show that the physiological responses, in particular, are influenced by background music.

3.1 Introduction

Music listening is a popular activity which is most often done in the background to other activities (DeNora, 2000; Saarikallio & Erkkilä, 2007; Thayer et al., 1994). The primary goal of music listening in this context is to maintain mood or to enhance mood via tension reduction or energy enhancement, for example (DeNora, 2000; Thayer et al., 1994). Mood induction with music is accomplished by providing a distraction from noise or other irrelevant stimuli in the environment, by increasing concentration, reducing feelings of solitude, or by providing entertainment (Juslin & Sloboda, 2010). Because mood is known to influence social behaviour and several cognitive processes (Isen, 2000), music is claimed to increase productivity and well-being (Dibben & Williamson, 2007; North & Hargreaves, 2008).

The property of inducing a more positive mood while listening to music in the background to concurrent activities is reported in several studies (Furnham & Bradley, 1997; Schellenberg, Nakata, Hunter, & Tamoto, 2007); Haake (2006), for example, showed that listening to self-selected music in the workplace inspired people and was relaxing to them. Lesiuk (2005) investigated the influence of music on the employees of four software companies and found that music induced a positive affect while working and the quality of the work was at its lowest when no music was played.

Mood changes to music occur concurrently with psycho-physiological shifts (cf., Hodges (2010) for an overview). In general, physiological responses to musically-induced moods have been found that are similar those induced in other ways than with music (Hodges, 2010). Most physiological responses are also primarily sensitive to either the valence or arousal dimension of musically-induced mood, e.g., skin conductance is innervated by the sympathetic nervous system and is positively related to mood energy levels (Boucsein, 1992; Khalfa et al., 2008; Krumhansl, 1997; Lundqvist, Carlsson, Hilmersson, & Juslin, 2009; Van der Zwaag & Westerink, 2012). Correspondingly, higher skin conductance levels and energy ratings were found during faster compared to slower tempo music (Van der Zwaag, Westerink, & Van den Broek, 2011). Lundqvist et al. (2009) further showed higher skin conductance responses to happier, high energy positive valence music, compared to sadder, low energy negative valence music. Heart rate has also been related to arousal levels. In several studies, heart rate increased during stimulating music compared to sedating music (Hodges, 2010). In general, however, inconsistent results have been found with heart rate changes due to mood changes (Hodges, 2010). Some studies show that any music increases heart rate (Krumhansl, 1997; Rickard, 2004) and at least 24 studies describe no heart rate changes due to music listening (Hodges, 2010). These inconsistent findings may be explained by the fact that heart rate and moods are both affected by the sympathetic and parasympathetic branches of the autonomic nervous system in complex and sometimes contrasting ways (Cacioppo et al., 2007).

The activity of the facial muscles (EMG) has repeatedly been shown to reflect valence levels (Witvliet & Vrana, 2007). For example, increases in EMG corrugator supercilii tension, the frown muscle, are found during sad music while increases in EMG zygomaticus major tone, the smile muscle, are found during happy music (Khalfa et al., 2008; Lundqvist et al., 2009; Van der Zwaag & Westerink, 2012). Skin temperature is related to the blood flow in the skin and reflects the vasoconstriction of the blood vessels and is related to valence (Hodges, 2010). Skin temperature increases during happy music compared to sad music (Lundqvist et al., 2009; Van der Zwaag & Westerink, 2012). In line with these findings, higher skin temperature levels have been reported with positive valence compared to negative valence music (McFarland, 1985; McFarland & Kadish, 1991).

The above overview shows that music is an established method of inducing mood. However, most of the above research involved listening to music as a primary task or did not investigate the related psychophysiological patterns. The precise extent to which induced moods and physiological states can be maintained when music is being played in the background to a concurrent activity is therefore unknown. This can be explained by the fact that during mood induction procedures the music is generally only used as a tool to induce mood, after which the influence of mood is assessed by its impact on the dependent variable, e.g., physiological constructs or performance of a specific task. Thus, the music stimulus is typically withdrawn after the mood has been induced (Gendolla & Krüsken, 2001; Gerrards-Hesse et al., 1994). Unfortunately, the mood is often not assessed after the task under investigation is completed, which makes it impossible to determine whether the induced mood persisted (Isen & Gorgoglione, 1983). Evidence for this is also provided by Gomez et al. (2009). They investigated whether mood influences were found after conductance of a task that began after moods were induced with film clips. They showed that induced arousal ratings do not persist at all during the task. The valence ratings of the negative valence states also improved significantly during the task (they became more positive), although their valence levels remained subtly lower compared to the positive moods induced. Garrett and Maddock (2001) showed that after withdrawal of negative affect inducing pictures, the induced affect declined by 60 % after eight seconds and by 80 % after 16 seconds. Altogether, these findings imply that the moods induced with mood induction procedures in the lab are not guaranteed to last during subsequent task conductance when the mood induction has been discontinued. They should be used with caution therefore when investigating the influence of mood on psychological constructs (Isen & Gorgoglione, 1983).

Research into the physiological patterns related to the persistence of musically-induced moods after withdrawal of the music is even more rare. Some support for a certain amount of persistence can be found in other mood induction procedures. Using the Velten mood induction procedure (Velten, 1968), Sirota, Schwartz, and Kristeller (1987) showed that depressed states carry over to one-minute rest intervals which was visible in continued increased corrugator electromyographic (EMG) activity. Bradley, Cuthbert, and Lang (1996) further investigated corrugator EMG activity and skin conductance level (SCL) while participants were watching blocks of pleasant, neutral, or unpleasant pictures. The results showed that the induced EMG and SCL activity persisted during six second picture intervals. Smith, Bradley, and Lang (2005) followed up on this study and investigated the sustained effect of affect on facial EMG activity and skin conductance responses after watching blocks of pleasant, neutral, or unpleasant pictures. They showed that the induced EMG corrugator activity and the number of skin conductance responses continued for 30 seconds, but no longer than 60 seconds, after viewing of the affective picture stopped. All in all, it can be concluded that little is known about the persistence of musically-induced moods in terms of minutes or longer during task conductance or the related physiological patterns.

In the current study we investigated whether music mood induction and the accompanying physiological patterns persisted when the mood-inducing music continued during task conductance (in our case, office work activities). As music is listened to during many activities (North & Hargreaves, 2008), the continuation of music during work may be expected to sustain the induced moods and the corresponding physiological patterns. We induced moods with music for each quadrant of the valence-arousal model (Russell, 1980). Our aim was to show the extent to which music can induce and maintain mood changes towards the direction of each quadrant of the valence arousal model and properly identify the influence of these mood changes on physiological responses.

In line with the literature described above, we expect that the relatively positive valence moods would be reflected in increased skin temperature, zygomaticus major muscle tension and in decreased corrugator supercilii muscle tension irrespective of whether a task was being performed or not. We further expected to see higher skin conductance levels during the higher energy moods. We did not have any specific expectations for heart rate responses to music listening owing to the inconsistent heart rate responses to mood reported in literature. Additionally, because the fulfilment of a task takes some effort, we expected the activation levels and the physiological indices of activation (i.e., skin conductance level and possibly heart rate) to increase irrespective of the mood change.

3.2 Method

3.2.1 Participants and design

Twenty participants (10 women, mean age = 24 years, SD = 1.6; 10 men, mean age 25 years, SD = 2.6) received € 40 for taking part in one introductory session and four experimental sessions. All the participants signed an informed consent form before taking part in the study. Mood was manipulated as a within-subject variable with four levels: low energetic positive valence (LE/PV - relaxed), high energetic positive valence (HE/PV - happy), low energetic negative valence (LE/NV - sad), and high energetic negative valence (HE/NV - agitated). The order of the mood inductions was counterbalanced over the sessions. It was checked beforehand that the participants were familiar with solving Sudoku puzzles and did not dislike doing them.

3.2.2 Music selection

As music preferences and hence the influence of songs on mood are highly personal, the music was selected by each individual (Juslin & Sloboda, 2010). To do this, in an introductory session participants rated the perceived valence and energy levels of 80 songs on 7-point Likert scales i.e., 20 songs per mood quadrant. Participants were encouraged to listen to each song for a few seconds at different places within the song to get a good impression of the song. The music rating was computerised and the order of the songs randomised. The initial 80 songs were selected from a database containing a wide variety of songs (i.e., 1800 songs in 12 genres). These songs were categorised into the four quadrants of the valence-energy model based on automatic classification of music using music characteristics (Skowronek et al., 2006, 2007). Music for the subsequent experimental sessions comprised the six most distinctive songs in each valence-energy quadrant for each individual participant (e.g., highest valence and energy ratings for the HE/PV target mood), provided that the automatic classification of that song was positioned in the same quadrant of the target mood.

To show that the selected songs did indeed vary in valence and energy ratings, a repeated-measures MANOVA with Music (LE/PV, HE/PV, LE/NV, HE/NV) as the within-subject factor was applied to the energy and valence ratings obtained during the music rating. The univariate results showed significant main effects for both energy and valence ratings (valence ratings $F(2, 58) = 206.81$, $p < .001$, $\eta^2 = .92$; energy ratings $F(2, 58) = 200.86$, $p < .001$, $\eta^2 = .91$). Pairwise comparisons showed that both the valence and the energy ratings differed between mood (all $p < .001$), except for the valence ratings of the LE/NV and HE/NV songs, which did not significantly differ in terms of valence ratings. Despite these differences, the mean valence and energy ratings of the selected songs emerged in the direction towards the four quadrants as expected (see Figure 3.1). After the songs had been selected for the subsequent experimental session, the duration of the selected songs was shortened using the Audacity software (version 1.2.4) to ensure that they all had an equal duration of two minutes and 45 seconds.

3.2.3 Experimental task

Four sets of two easy Sudoku puzzles were used as the experimental task in each session. In this way we could guarantee that the participants could continue solving puzzles in the given time period. The presentation of the four sets was counter-balanced over the experimental sessions. Lastly, the number of correctly entered numbers in the Sudokus puzzles were taken as the performance measure of the task.

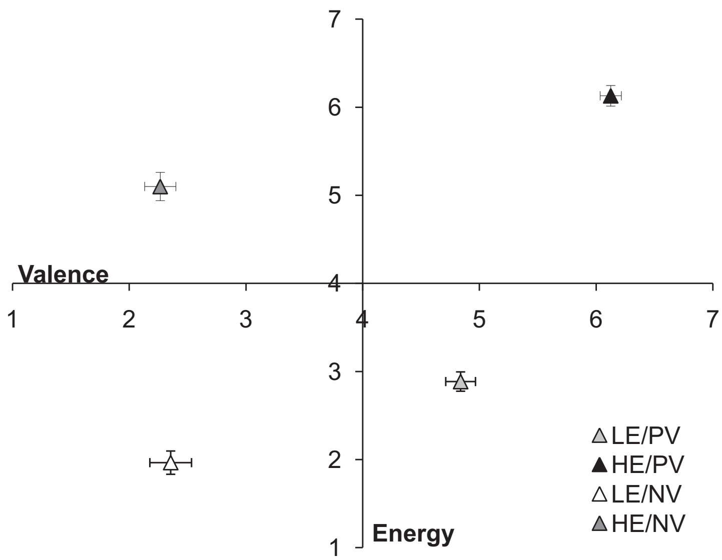


Figure 3.1 – The means and standard errors of the perceived energy and valence ratings of the selected songs for the experiment. Ratings were obtained during the music rating session. Error bars depict +/- 1 SE, LE/PV= low energy positive valence, LE/NV= low energy negative valence, HE/PV= high energy positive valence, HE/NV = high energy negative valence.

3.2.4 Subjective questionnaires

Subjective mood was assessed using the UMACL (Matthews et al., 1990). The UMACL was used to assess eight unipolar items for valence (ranging from unpleasant to pleasant) and energy (ranging from tired/without energy to awake/ full of energy), starting with 'right now I am feeling..', with answers from 1: 'not at all' to 7: 'very much'.

The rating scale for mental effort (RSME) was used to assess self-reported mental effort (Zijlstra, 1993). The RSME is a visual-analogue scale where ratings of invested effort can be indicated on a 15 cm long vertically positioned slider. Values between 0 and 150 can be indicated with the slider, were 0 meaning 'almost no effort' to 150 means 'extreme effort'.

3.2.5 Physiological responses

Physiological responses included facial muscle tension, skin conductance, skin temperature, and heart rate that were derived from signals measured with a NeXus-10 data recorder and its accompanying sensors (Mind Media BV, Roermond, the Netherlands). Physiological measurements were taken continuously during the experiment. The MATLAB programming environment (2009a, The Mathworks, Natick, MA) was used to preprocess the physiological signals.

The EMG M. zygomaticus major (EMGz) and EMG M. corrugator supercilii (EMGc) electrodes (Ag-AgCl disposable electrodes) were placed on the muscle in parallel in accordance with Fridlund and Cacioppo (1986). The signals (sample frequency 1024 Hz) were preprocessed by filtering the raw signal (high-pass filter: 20 Hz and band stop Notch: 48-52 Hz) to remove low frequency artifacts and 50 Hz interference. The signal was then rectified, time integrated over one minute intervals, and divided by the duration of the segment to obtain the mean rectified voltage (MRV) (Fridlund & Cacioppo, 1986).

Skin conductance was measured using dry Ag-AgCl electrodes attached to Velcro strips. The electrodes were strapped around the upper phalanxes of the index and middle fingers of the non dominant hand. Small movement artifacts in the signal (sample frequency 128 Hz) were removed with a low-pass IRR filter at 0.5 Hz. The mean skin conductance value over one minute intervals was taken as the skin conductance level (SCL).

A thermistor skin temperature sensor was attached to the upper phalanx of the little finger of the non-dominant hand using adhesive tape (sample frequency 128 Hz). The temperature sensor was sensitive enough to record temperature changes as small as 0.001 °C in a range from 10 °C to 40 °C. The average value over one minute intervals was used as the skin temperature (ST) measure. The ST measurements of one participant failed and were therefore omitted from the analysis.

The ECG was recorded via the standard lead II placement with a sample frequency of 1024 Hz (Stern et al., 2000). For this standard measurement, the negative and ground electrodes were placed right and left respectively under the collarbones. The positive electrode was placed in a lateral anterior position on the left chest, between the lowest two ribs. ECG measurements were taken using Ag-AgCl disposable sensors, type H124SG, containing a solid gel. R-peaks were automatically detected after amplification and filtering (Butterworth band pass: 0.5 - 40 Hz) of the ECG signal. The distances between successive R-peaks, the interbeat intervals (IBI), were then calculated. An absolute threshold for IBI detection was set at between 400 and 1400 ms. A moving threshold detected IBIs that were 50 % larger or smaller than the average of the last 40 IBIs. IBI artifacts were removed from the data series.

3.2.6 Procedure

In the introductory session the participants began by completing a general questionnaire with their personal data (gender, age) and the UMACL mood check list (Matthews et al., 1990). The UMACL was presented as a normal control procedure for participants that would be presented a couple of times during the experiment. The participants were told that during the four experimental sessions their physiological reactions to music listening would be recorded. This was to prevent the participants from suspecting that mood induction would take place. Lastly, participants rated the songs. The music rating procedure was computerised.

During the experimental sessions, participants were seated at a desk in a room which mimicked a living room. The physiological equipment was then attached. The whole experiment was computerised with the questionnaires and instructions for each part presented on a monitor. The experiment started with a habituation period in which the participants watched a coral-sea diving video (Piferi et al., 2000). After eight minutes the video stopped and the UMACL was presented on the monitor and had to be completed. Now one of the Music types (LE/PV, HE/PV, LE/NV, HE/PV) was presented for eight minutes (Van der Zwaag & Westerink, 2012). To ensure that the participants remained attentive to the music, they were asked to listen to the music carefully because there would be questions about the music at the end of the fourth session. Directly after the music presentation the UMACL had to be filled out again. The instructions for the task were presented on the screen. The participants were then asked to work on the Sudoku puzzles for five minutes. Music of the same type continued to be played during conductance of the task. Directly after the task the RSME and the UMACL had to be filled out.

At the end of each session the participants were detached from the equipment and thanked for their participation. All four sessions of the experiment differed in mood induction energy (LE / HE) or valence (PV / NV), and took place at the same time on successive days in the same week. The total duration of each experimental session was 30 minutes. Including the instructions and the attachment and detachment of the physiological equipment, a session took 45 minutes at most.

3.2.7 Statistical analyses

The data were analysed using SPSS 17 for Windows (SPSS Inc., Chicago, IL) with the level of significance set at $p < .05$ (2-tailed). Pairwise comparisons were Bonferroni corrected. Partial effect sizes were expressed as η^2 values. Outliers, scores that diverged more than three standard deviations of the group mean, and missing values were deleted from the analysis (Tabachnick & Fidell, 2006). In total, the data contained less than 1 % of outliers or missing data points.

3.3 Results

3.3.1 Subjective responses

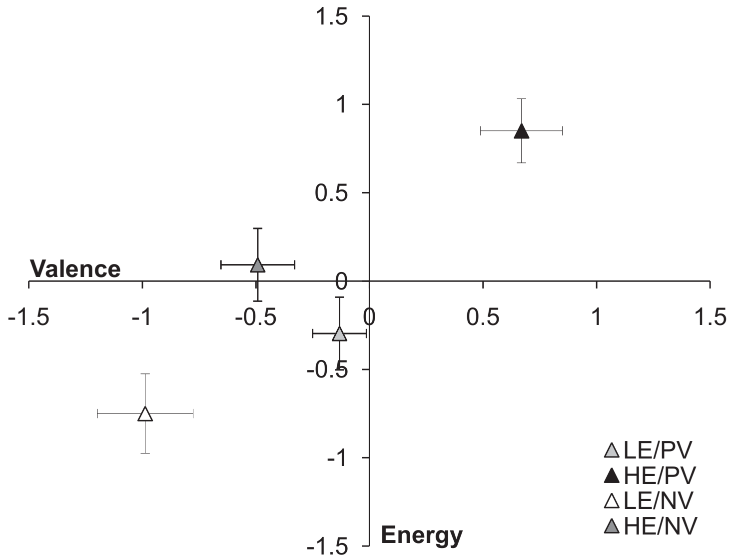
Mood scores for each mood dimension were calculated by averaging the normal and the reverse coded items of the UMACL questions for each dimension (Chronbach's alpha for energy = .82 and valence = .88). Next, a repeated-measures MANOVA with Music Energy (Low / High) and Music Valence (Negative / Positive) as within-subject factors was applied to the valence and energy ratings obtained after the baselines. As expected, no significant differences were found (Music Valence $F(2,18) = .07$, $p = .934$, $\eta^2 = .01$, Music Energy $F(2,18) = 1.42$, $p = .267$, $\eta^2 = .13$). The mean ratings after the baseline were as follows mean (standard error), valence ratings: positive valence music $5.00(.13)$, negative valence music $5.04(.13)$, energy ratings: low energy music $3.60(.16)$, high energy music $3.63(.17)$.

Both for the induction and for the task part per participant per session, mood reaction scores were calculated by subtracting the mood values obtained after the baselines from the values obtained after the induction or task. To test whether the mood induction manipulation towards the valence and energy dimensions was successful, we applied a repeated-measures MANOVA with Music Energy (Low / High), Music Valence (Negative / Positive), and Activity (Induction / Task) as the within-subject factors to the valence and energy reaction scores. The results of the univariate tests are presented in Table 3.1, and the mean reaction scores obtained after the induction and task are shown in Figure 3.2.

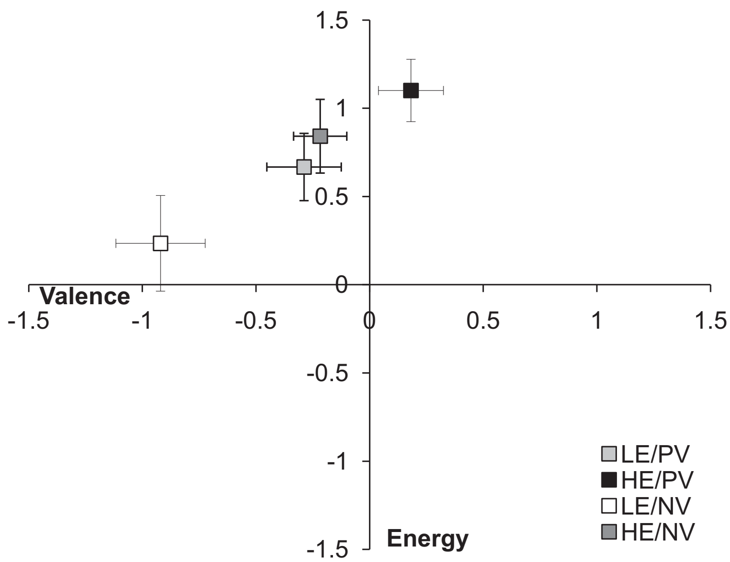
As expected, the main effects of Music Valence and Music Energy on both the valence and energy reaction scores showed higher valence reaction scores after listening to positive compared to negative valence music and higher energy reaction scores after listening to high compared to low energy music (all $p < 0.1$). Higher valence reaction scores were seen after high energetic compared to low energetic music of the same music valence, and higher energy reaction scores were shown after positive valence compared to negative valence music of the same music energy. The interaction of Music Valence with Activity on the valence reaction scores revealed that for positive valence music higher valence reaction scores were given during mood induction compared to task conductance ($p = .03$), while the valence reaction scores after the negative valence music persisted from mood induction to task conductance ($p = .08$).

The significant Music Energy with Activity interaction on the energy reaction scores shows that the energy reaction scores of both the high energy music ($p < .001$) and the low energy music ($p = .001$) significantly increased from inductance to task conductance. The interaction also indicated that the energy reaction scores increased more during low energy music than high energy music.

Finally, we investigated the influence of music type on the amount of invested effort during task conductance. A repeated-measures ANOVA with Music Energy (Low / High) and Music Valence (Positive / Negative) was therefore applied to the RSME levels. The results did not show any significant effects among the given RSME ratings; Music Energy $F(1,19) = .02$, $p = .879$, $\eta^2 = .01$; Music Valence $F(1,19) = .83$, $p = .374$, $\eta^2 = .04$. The mean RSME values per music type were Mean (SE): LE/PV $66.10(5.72)$; HE/PV $69.10(5.53)$; LE/NV $71.75(5.31)$; HE/NV $70.00, (6.20)$.



a) after induction



b) after task

Figure 3.2 – The subjective mood reaction scores during mood induction (Panel a) and task conductance (Panel b), to positive valence and negative valence high and low energetic mood inductions. Error bars depict +/- 1 SE, LE/PV= low energy positive valence, LE/NV= low energy negative valence, HE/PV= high energy positive valence, HE/NV = high energy negative valence.

Table 3.1 – Univariate effects of music energy (low / high), music valence (negative / positive), activity (induction / task) as well as their interactions on the subjective reaction scores and physiological reaction scores responses. n.s. = non significant.

	Music Energy	**Music Valence**	**Activity**
Valence	$F = 13.29$, $p = .002$, $\eta^2 = .41$	$F = 27.05$, $p < .001$, $\eta^2 = .59$	$F = 1.34$, $n.s.$
Energy	$F = 22.99$, $p < .001$, $\eta^2 = .55$	$F = 4.47$, $p = .048$, $\eta^2 = .19$	$F = 41.80$, $p < .001$, $\eta^2 = .69$
EMGc	$F = .64$, $n.s.$	$F = 1.00$, $n.s.$	$F = 1.83$, $n.s.$
EMGz	$F = 1.25$, $n.s.$	$F = 10.59$, $p = .004$, $\eta^2 = .36$	$F = .30$, $n.s.$
SCL	$F = 4.49$, $p = .047$, $\eta^2 = .19$	$F = .13$, $n.s.$	$F = 70.72$, $p < .001$, $\eta^2 = .79$
ST	$F = 1.50$, $n.s.$	$F = 10.52$, $p = .006$, $\eta^2 = .43$	$F = 14.97$, $p = .002$, $\eta^2 = .52$
IBI	$F = 2.25$, $n.s.$	$F = .36$, $n.s.$	$F = 3.14$, $p = .092$, $\eta^2 = .14$
	Music Energy * Activity	**Music Valence * Activity**	**Music Valence * Music Energy**
Valence	$F = .10$, $n.s.$	$F = 6.49$, $p = .020$, $\eta^2 = .26$	$F = .035$, $n.s.$
Energy	$F = 6.65$, $p = .018$, $\eta^2 = .26$	$F = 2.22$, $n.s.$	$F = .041$, $n.s.$
EMGc	$F = .04$, $n.s.$	$F = 4.01$, $p = .060$, $\eta^2 = .17$	$F = .13$, $n.s.$
EMGz	$F = 1.18$, $n.s.$	$F = 1.20$, $n.s.$	$F = 3.58$, $n.s.$
SCL	$F = .10$, $n.s.$	$F = .10$, $n.s.$	$F = .34$, $n.s.$
ST	$F = .01$, $n.s.$	$F = .02$, $n.s.$	$F = .26$, $n.s.$
IBI	$F = 3.34$, $p = .081$, $\eta^2 = .15$	$F = .01$, n.s.	$F = .17$, $n.s.$

3.3.2 Results on physiology

Physiological measurements for the last four minutes of the baseline, of the induction period and of the Sudoku task were calculated per participant and then averaged for the analysis (Llabre et al., 1991; Van der Zwaag & Westerink, 2012). To show that the physiological baseline values did not differ from each other a repeated-measures MANOVA with Music Energy (Low / High) and Music Valence (Positive / Negative) as the within-subject factors was applied to the physiological baseline measurements. The results showed no significance, all main and interaction effects for all physiological variables were insignificant($p > .10$).

Next, the physiological signals were adjusted for the baseline in the following ways: the facial muscle expression measures were adjusted using the percentage-change from the baseline to the average of the music listening period or task conductance. This resulted in the reaction score of the EMGc and EMGz (Fridlund & Cacioppo, 1986). For IBI, reaction scores were obtained by subtracting the average values obtained during the baseline from the average of mood induction or task conductance (Llabre et al., 1991). The electrodermal and skin temperature reaction scores were obtained by applying z- transformations to compensate for differences between individual in the data for the mood induction and task conductance periods. The mean and standard deviation of the last four minutes of the baseline measurement were taken as the mean and standard deviation for these z- transformations (Boucsein, 1992).

To test the effect of music valence and energy on the physiological measures, a repeated-measures ANOVA with Music Energy (Low / High), Music Valence (Positive / Negative) and Activity (Induction / Task) was applied separately for each physiological reaction scores. The outcomes of these analyses can be found in Table 3.1. The baseline-adjusted physiological responses were used for all these analyses. Only the significant results of these analyses of the separate physiological reaction scores are described below.

EMG

The main effect of Music Valence on the EMGz showed higher EMGz tone while listening to positive valence music, irrespective of activity (the means are presented in Figure 3.3). The EMGc showed a trend of a Music Valence with Activity interaction (see also Figure 3.3). Post-hoc analysis of this trend indicated more EMGc activity when negative valence rather than positive valence music was played during the induction (Induction $p = .10$, Task $p = .70$). Post-hoc analysis of this interaction further showed less EMGc activity during the task compared to the induction while listening to negative valence music (Positive Valence Music $p = .59$, Negative Valence Music $p = .07$).

Electrodermal activity

A significant main effect of Music Energy on SCL revealed higher SCLs during the high energy music compared to low energy music, irrespective of activity (see also Figure 3.3). A significant main effect of Activity also showed that the SCL was higher during task conductance than during induction.

Skin temperature

A significant main effect of Music Valence on ST revealed higher ST while listening to positive valence music compared to negative valence music during both activities (see also Figure 3.3). The significant main effect of Activity also showed a higher skin temperatures during the music mood induction compared to conductance of the task.

Interbeat Interval

A marginally significant main effect of Activity on IBI was found. Pairwise comparisons of this trend showed shorter IBI durations during the task compared to the induction period (see also Figure 3.3). Another marginally significant effect for the Music Valence with Activity interaction on IBI was found. Pairwise comparisons of this trend showed that the IBI duration was significantly shorter during the task conductance compared to the induction period but only while listening to positive valence music (Positive Valence Music $p = .03$; Negative Valence Music $p = .80$).

3.3.3 Task performance

To test the effect of music valence and energy on the performance of the task, a repeated-measures ANOVA with Music Energy (Low, High) and Music Valence (Positive / Negative) was applied to the Sudoku performance as expressed by the number of correctly entered numbers. The analysis revealed no significant effects; Music Valence $F(1, 19) = .67$, $p = .422$, $\eta^2 = .034$; Music Energy $F(1, 19) = 1.13$, $p = .302$, $\eta^2 = .056$; Music Valence with Music Energy $F(1, 19) = .12$, $p = .734$, $\eta^2 = .01$. The mean Sudoku values were Mean (SE), LE/PV $13.15(3.66)$, HE/PV $12.20(2.26)$, LE/NV $12.20(2.71)$, HE/PV $10.15(2.11)$.

3.3.4 Correlations

Pearson's correlations (r) over N=80 (four experimental parts for 20 participants) were calculated to investigate the relationship between the valence and energy reaction scores and the physiological reaction scores. Valence was shown to be positively correlated with energy during mood induction ($r = .477$, $p < .001$) as well as during task conductance ($r = .366$, $p < .001$).

After the induction, the physiological measurements of SCL and EMGz were positively correlated with valence whereas the EMGc was correlated negatively with valence (SCL $r = .260$, $p = .020$, EMGz $r = .316$, $p = .004$, EMGc $r = -.303$,

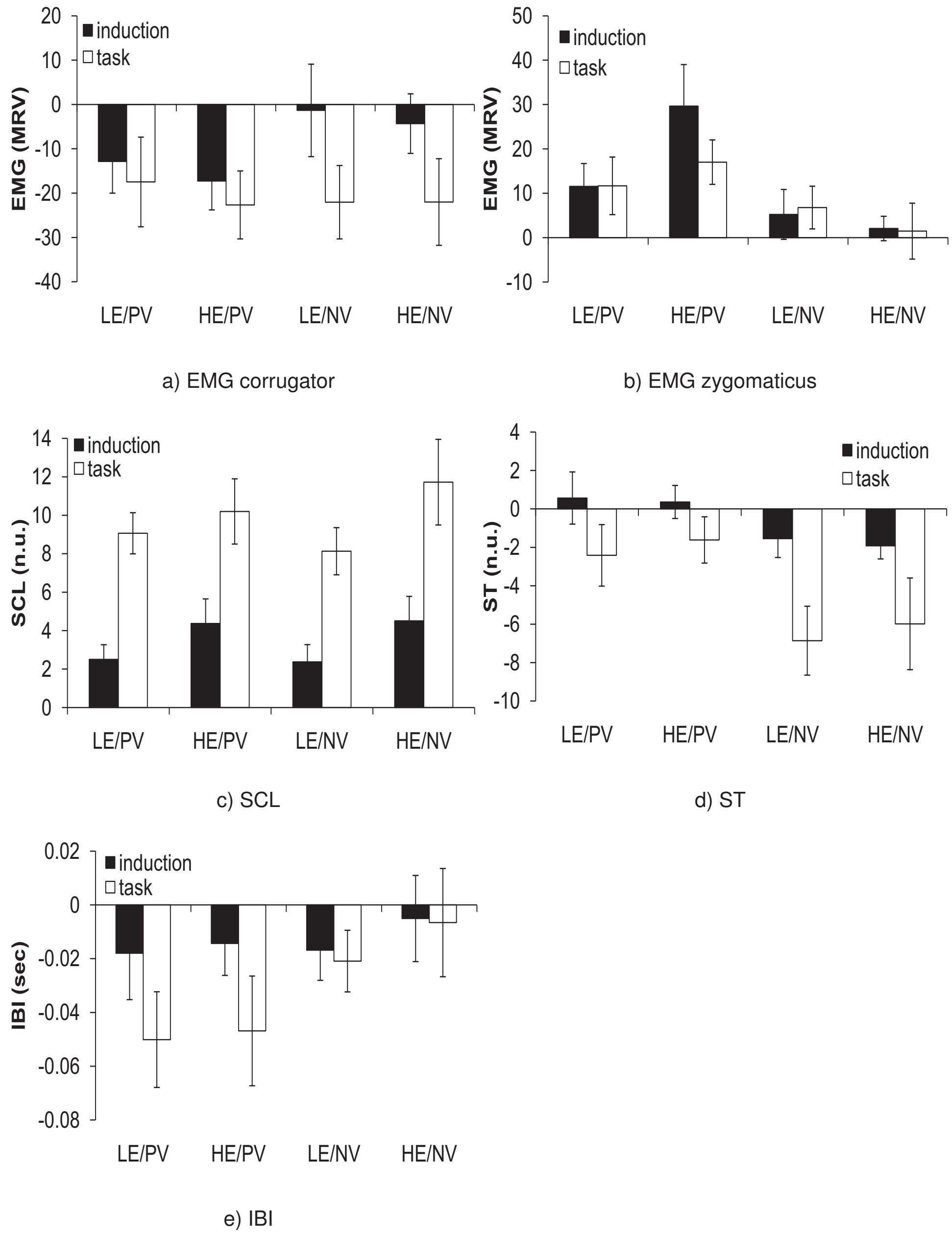


Figure 3.3 – The means and standard errors of the EMG, SCL, ST, and IBI reaction scores during mood induction and task conductance. Error bars depict +/- 1 SE, LE/PV= low energy positive valence, LE/NV= low energy negative valence, HE/PV= high energy positive valence, HE/NV = high energy negative valence.

$p = .006$). Only EMGz continued to be significantly positively correlated with valence after task conductance ($r = .269$, $p = .016$). With regard to the energy scores, SCL and EMGz had a positive correlation with energy after the induction part (SCL $r = .293$, $p = .008$, EMGz $r = .260$, $p = .020$). SCL remained significantly correlated with the energy reaction scores after task conductance ($r = .209$, $p = .063$). Both the ST and the IBI reaction scores did not show any significant correlation with the mood reaction scores after either induction or task conductance.

3.4 Discussion

The aim of this study was to investigate whether there is a sustained effect of musical mood induction on physiological responses during task conductance when music presentation continues. The results showed that individually selected music can direct moods towards most of the quadrants of the valence-energy model, as subjectively estimated. Although the range of the scores declined, the induced moods persisted in valence and increased in energy during task conductance. The physiological measurements of skin temperature, EMG corrugator, and EMG zygomaticus, proved to be most sensitive to the music mood valence. By contrast, the SCL responded most strongly to music mood energy, while heart rate (IBI) was not sensitive to music mood induction at all. Altogether, the physiological measurements varied with the valence and energy dimensions of the four induced moods. This influence was present not only during musical mood induction but generally persisted when music continued during task conductance.

3.4.1 Subjective experience

The mood ratings to musical mood induction revealed some apparent connections between music and mood as well as between the mood dimensions. Firstly, where the ratings of the selected music show a clear distribution in the four quadrants of the valence-energy model, this distribution declines during mood induction with the same music. During task conductance, the ranges of both valence and energy ratings for the induced moods further declined. This differs slightly from the results of Gomez et al. (2009) who showed that the induced energy disappears completely, and is similar in that the induced valence reduced after mood induction. However, contrary to Gomez et al. (2009) in this study the music presentation continued during task conductance which may account for the difference.

Secondly, in our study the mood ratings provided during the introductory rating session did equate to the four quadrants of the valence-energy model whereas the experienced moods did not fully equate these quadrants. The results therefore indicate that music ratings do not fully predict the moods that can actually be induced with the music. This finding also suggests that during music rating the mood expressed by the music is rated, rather than the perceived mood actually induced (Juslin & Sloboda, 2010; Kivy, 1990).

Thirdly, there was a positive linear relationship between the valence and energy ratings. This relationship indicates that the valence and energy dimensions are not fully independent of each other. This is in line with Wilhelm and Schoebi (2007), for example, who showed that positive valence high energetic (happy) and negative valence low energetic (sad) moods are the most opposite moods.

Lastly, while listening to music during task conductance, energy levels increased compared to music listening as a primary activity, irrespective of the mood induced by the music. The mood induced by high energy positive valence (happy) music, however, showed a ceiling effect: the ratings for energy in this happy mood were already high during induction and did not further increase when the task started. These increased energy ratings after task conductance may reflect the fact that effort is mobilised for the proper conductance of the task (Cacioppo et al., 2007). Further support for this finding was found in the increased physiological responses of SCL to task conductance, which will be discussed below.

3.4.2 Physiological patterns and task performance

The present study induced mood for each quadrant of the valence-energy model to be able to check whether the physiological responses could be clearly mapped to a single mood dimension. Except for IBI duration, each physiological measurement taken was shown to be sensitive to primarily one mood dimension. This thus illustrates the importance of separating the valence and energy mood dimensions to be able to demonstrate an autonomic response to moods. This finding was in line with Healey and Picard (2005) who suggested that multiple physiological measurements should be taken to be able to distinguish between moods that are directed towards every quadrant of the valence-energy model. As expected - and in line with literature - the skin conductance level was correlated to and increased most with the high energy moods (Boucsein, 1992; Rickard, 2004). Consistent with the subjective energy reaction scores, the skin conductance level also increased during task conductance, irrespective of the mood induced. The skin conductance also increased during mood induction irrespective of the moods induced. This can be explained by a time-on-task effect, which leads to changes in physiological measurements over time irrespective of the condition (Fairclough & Venables, 2006).

In accordance with the literature, skin temperature showed a positive relationship with valence (McFarland, 1985; McFarland & Kadish, 1991). Skin temperature also dropped during task conductance, irrespective of the mood induced. This may be explained by vasoconstriction of the vessels in the hand as energy is redistributed during task conductance.

The EMG zygomaticus activity showed a positive relationship and the EMG corrugator activity showed a negative relationship with the valence mood dimension during induction. This finding was as expected and is in line with previous research which showed that these facial muscles are primarily activated by valence (Witvliet & Vrana, 2007). During task conductance EMG zygomaticus activity persists becoming higher during positive moods, while the influence of mood on the EMG corrugator disappeared. EMG corrugator contraction seems to be insensitive to musically-induced moods during task conductance as the contraction drops irrespective of mood. This is in line with Hess, Philippot, and Blairy (1998) who describe that EMG corrugator tone may be influenced by factors other than mood, such as cognitive factors.

Lastly, heart rate does not appear to be sensitive to either the valence or energy dimensions of mood. This was not surprising as many inconsistent results have been reported regarding the relationship between mood and heart rate (Hodges, 2010), including our own positive results in Chapter 2. During task conductance, however, IBI only decreased (i.e. heart rate increased) for the positive valence moods. This result seems to be in line with the literature on the mood behavioural model, which states that a mood does not have to induce autonomic adjustments as such but may interact with performance on a task, depending on the difficulty of the task (Gendolla, 2000). Following this model, if a difficult task is anticipated, stronger IBI reactivity may be expected with a positive mood as thoughts will be more optimistic about successful task fulfilment. Indeed, Gendolla and Krüsken (2001) found increased heart rate to a difficult letter cancellation task only for positive moods. The decreased IBI duration during positive mood induction in the current study can be caused by more optimistic feelings and task enjoyments, resulting in increased motivation to invest effort in the task. All in all, the influence of mood on heart rate seems to be mediated more by the effort invested in task performance rather than being primarily influenced by mood.

In line with the subjective ratings, the physiological differentiation then between moods reduced during task conductance even when the music continued to be played. Only the EMG zygomaticus and the skin temperature continued to differentiate according to music valence, and the skin conductance level continued to differentiate between music energy while music was played in the background. The correlation analysis corroborated these observations for the correlation between EMG zygomaticus and valence, and for that between SCL and energy. These thus remained significant after task conductance. Our study therefore expands on the current literature and shows that moods can persist during task conductance when the mood inducing stimulus is continued (Gomez et al., 2009).

The present study showed that personally selected music can successfully direct mood towards most of the quadrants of the valence-energy model during induction and energy levels increased during task conductance. One effect should be mentioned, however. Despite this successful persistent induction of various moods, performance on the task appeared not to be affected by the type of music. It could be assumed that some types of music might have more impact during more difficult tasks than those used in this study, which could therefore influence the moods induced with music or the performance on the task (North & Hargreaves, 1999). Further research could investigate to what extent task difficulty influences the impact of music on mood, physiology, and performance on a task. The relationship between moods perceived by the music and the mood that are actually induced by the music can also be further investigated. In the present experiment, we have used a different set of questionnaires to indicate the moods that participants perceived by the songs (for the song selection), and to indicate the moods actually induced with the same music (during mood induction). As a result we cannot compare them with each other.

3.4.3 Conclusion

Music is frequently used to regulate mood in everyday life in the background of many activities. It enhances and maintains moods which could help to improve performance on work or reduce physiological strain. The present study showed that musically-induced moods and the accompanying physiological patterns persist when music is played in the background to a task. More specifically, music induces moods into the various directions of the valence-arousal model and this induced direction is sustained during subsequent task conductance, although to a lesser extent. Physiological measurements showed the same patterns and appeared to be responsive to a single mood dimension; skin conductance level was responsive to energy levels, and skin temperature, EMG zygomaticus, and EMG corrugator appeared to be sensitive to mood valence. Therefore, this study showed the impact of individually selected music from each quadrant of the valence-energy model on mood and the corresponding physiological responses as well as the persistence of the induced mood directions during task conductance. These findings indicate the usefulness of continuing of musical mood induction during task conductance to ensure that moods persist. This additionally supports the use of music during everyday activities, including mental work, as it may have a positive effect on subjective mood as well as reduce physiological strain.

Submitted as: Van der Zwaag, M. D., Westerink, J. H. D. M.. Inducing moods with background music.

Chapter 4

Inducing moods with background music

Music is listened to in many places at many different times. An important aspect of music when played as primary activity is its ability to direct mood. This is beneficial as moods influence several cognitive functions. In this study we investigated whether and to what extent background music mood induction results in similar patterns to music mood induction as a primary activity. Thirty participants took part in two experimental sessions in which they listened to individually selected music (happy, sad, or no music) and performed an activity (Sudoku or nothing) in a within-subject design. The results showed that mood ratings of valence and energy, skin conductance level, and zygomaticus major facial muscle tension responded best and in similar ways to both types of music mood induction. All in all, the present study showed that moods can be induced when played in the background to an activity. This study therefore shows the potential for systems which select background music that is tuned to direct mood towards a desired state and which can benefit cognitive functioning.

4.1 Introduction

Mood induction techniques are an important factor in many psychological studies. With traditional mood induction techniques moods are first induced, after which the influence of a mood on a dependent variable is tested (Isen & Gorgoglione, 1983; Van der Zwaag, Westerink, Mulder, Waard, & Brookhuis, 2012). It is not certain, however, whether these induced moods are sustained after the mood inducer is removed (Van der Zwaag, Westerink, et al., 2012). It is also uncertain whether they can be successfully used in combination with a concurrent task. Mood is important as it influences several cognitive functions (Isen, 2000). Therefore, it would be very helpful if mood induction techniques could be used in various everyday life situations. Playing music is a popular and powerful mood induction technique which offers this possibility when used in many everyday situations (Juslin & Sloboda, 2010). It is unknown, however, whether and to what extent music is able to induce moods and change physiological responses when listened to in the background to performing a task. When background music mood induction reliably influences mood and physiology, it will enable the development of systems that select music to change the mood of a user towards a desired state while performing everyday activities such as office work or driving a car.

Mood is a baseline body state that varies over minutes to days (Thayer, 1989). Even though the exact function of mood is unknown, it influences several cognitive and behavioural functions. For example, problem-solving capacity and memory consolidation are greater during positive rather than negative moods (Isen, 2000). Feelings of optimism predominate during positive moods (Gendolla, 2000). While a person is in a positive mood this creates the perception of being able to handle a wide range of challenges, hence he will not give up easily (Gendolla & Krüsken, 2001). A positive mood also increases well-being in several ways. For example, more pain and discomfort is noted during sad moods and people do not feel optimistic about their ability to carry out effective pain-alleviating actions (Salovey & Birnbaum, 1989).

Although it is not exactly clear how the influence of mood on our behaviour and functioning can be explained, it is known that mood has a direct effect on the physiological and immune processes (M. Lewis et al., 2008). Here a distinction has to be made between the two dimensions that constitute mood: energy and valence. The energy dimension is related to how energetic or tired a person is. Physiological responses such as skin conductance levels have been found to be positively correlated to mood energy levels (Boucsein, 1992). By contrast, valence is related to how positive or negative a person feels. Zygomaticus facial muscle tension is positively correlated to valence and the corrugator facial muscle has been negatively related to valence levels (Witvliet & Vrana, 2007).

There are various mood induction techniques that are intended to induce moods (Gross, 2007). The Velten mood induction procedure (Velten, 1968), looking at affective pictures or watching film clips (Kreibig, Wilhelm, Roth, & Gross, 2007; Lang et al., 1993), autobiographical recall (Strack, Schwarz, & Gschneidinger, 1985), or music listening (Juslin & Sloboda, 2010) are all examples of mood induction techniques. These procedures are used in laboratory situations, mostly to test the influence of mood on a dependent variable. Unfortunately, it is uncertain how long these mood induction techniques last after the mood induction stops (Gomez et al., 2009; Isen & Gorgoglione, 1983; Van der Zwaag, Westerink, et al., 2012). Music is the one mood induction technique which can be easily applied and potentially for a long period of time in the background to various everyday life situations.

Music is often listened to in the background to other activities which may be at home, in shops, pubs, restaurants, or while working (Juslin & Sloboda, 2010).

Among the reasons why people listen to music are that it provides entertainment, distracts them from a boring task, and reduces feelings of solitude. Primarily, however, music is used to regulate mood (Gross, 2007; North & Hargreaves, 2008; Parkinson, Torrerdell, Brinder, & Reynolds, 1996). DeNora (2000) showed that music is used to reduce stress levels or increase relaxation. Cassidy and MacDonald (2009) further showed that self-selected music reduced tension and increased relaxation during a driving game. Music listening at work has the potential to influence work productivity and well-being in the workplace. Lesiuk (2005) investigated the influence of music listening on employees working in software companies. She found that positive affect and productivity were lowest when the employees did not listen to music. Haake (2006) showed that personally selected music relaxes people during office work. All in all, there is evidence from everyday life situations that music influences our mood when played in the background. However, it is unknown to what extent the moods are really induced, and whether or not physiological changes related to mood occur when listening to music in everyday life situations.

The aim of this study was to investigate to what extent moods can be induced with music at the background to an activity. We compared the traditional music mood induction technique when music is listened to as a primary activity, with music mood induction in the background to an activity. To provide a control situation a task conducted without music being played was also added. To obtain the greatest effects possible we used mood induction of the two most divergent moods; happy and sad (Witvliet & Vrana, 2007). We expected that mood would be induced during both types of music mood induction, and that energy levels would be higher in the task situation. In line with previous research we would expect the skin conductance level and the tension of the zygomaticus facial muscle to be highest during the happy mood (i.e., high energetic positive valence). The tension of the facial corrugator muscle would be expected to be greatest during the sad mood.

4.2 Method

4.2.1 Participants and design

Thirty participants (15 male, mean age 27.2 years, SD 3.3; 15 female mean age 27.5 years, SD 3.8) received a € 40 voucher for taking part. All the participants signed an informed consent form before completing an introductory session and two experimental sessions.

There were two experimental sessions in which one type of music was presented: happy (high energetic positive valence) or sad (low energetic negative valence) music. Each experimental session consisted of three activities: regular mood induction with music (MusicOnly), mood induction with music in the background to a task (Task&Music), and a control situation where a task was conducted without music

(TaskOnly). The control was thus presented once in each session. Hence data of this condition was obtained twice. The presentation order of the music type was counterbalanced over the sessions as was the type of activities in each experimental session.

4.2.2 Music stimuli selection

Music was selected per participant based on an individual music selection procedure. This procedure was completed during the introduction part of the experiment. Each participant rated 60 songs in terms of the perceived valence (pleasant to unpleasant) and energy (low energy to high energy) levels on 7-point Likert scales. The initial set of songs was chosen based on automatic classification of music features (Skowronek et al., 2006, 2007) in accordance with each quadrant of the valence-arousal model (Russell, 1980). The whole music rating aspect was computerised.

After the rating, eight songs with the highest valence and energy ratings were selected for the experimental sessions with the happy music type (four songs for each of the two activities with music). Correspondingly, eight songs with the lowest valence and energy ratings were selected for the sad music experimental session. Next, the songs were adjusted in length with the Audacity software (Version 1.2.4) to about three minutes each, so that they were all equal in duration. This was done by cutting the song at about three minutes and then fading it out at the new end of the song. This gave the playlist per activity a duration of twelve minutes in total.

To show whether the happy and sad song stimuli differed from one another in valence and energy ratings a MANOVA with Music Type (happy, sad) was applied to the valence and energy ratings of the selected songs. The results showed significant main effects of Music Type on the valence and energy ratings (valence $F(1, 469) = 2922.31$, $p < .001$, $\eta^2 = .86$; energy $F(1, 467) = 3514.81$, $p < .001$, $\eta^2 = .88$). Pairwise comparisons showed that the happy songs had significantly higher valence and energy ratings compared to the sad songs; Mean (Standard Error), Happy, valence $5.22(.05)$, energy $5.33(.05)$; Sad, valence $1.46(.05)$, energy $1.03(.05)$.

4.2.3 Experimental task

Four sets of two easy Sudoku puzzles were used as the experimental task for each session. The presentation of the four sets of puzzles was counterbalanced over the experimental sessions. Finally, the number of correctly entered figures in the Sudoku puzzles was taken as a performance measure of the task.

4.2.4 Measurements

Subjective mood scores of valence (ranging from unpleasant to pleasant) and energy (ranging from tired/without energy to awake/full of energy) were assessed using the

UWIST Mood Adjective CheckList (UMACL) (Matthews et al., 1990). This UMACL contains eight unipolar items for each dimension, which start with: 'right now I am feeling', and range from 1: 'not at all' to 7: 'very much'.

The Rating Scale Mental Effort (RSME) was used to assess mental effort (Zijlstra, 1993). The RSME is a one dimensional scale ranging from 0 to 150, and is used to rate mental effort. In addition to digits, several effort indications (calibrated anchor points) are visible along the scale to further guide the rating. Indicators start with 'absolutely no effort' (RSME score of 2) and end with 'extreme effort' (RSME score of 112).

The physiological measurements included facial muscle tension, skin conductance, and heart rate derived from signals measured with a NeXus-10 data recorder and accompanying sensors (Mind Media BV, Roermond, the Netherlands). Physiological responses were continuously assessed during the experiment. The MATLAB programming environment (2009a, The Mathworks, Natick, MA) was used to preprocess the physiological signals.

The EMG M. zygomaticus major (EMGz) and EMG M. corrugator supercilii (EMGc) electrodes (Ag-AgCl disposable electrodes) were placed in parallel on the muscle following Fridlund and Cacioppo (1986). The signals (sample frequency 1024 Hz) were preprocessed by filtering the raw signal (high-pass filter: 20 Hz and band stop Notch: 48-52 Hz) to remove low frequency artifacts and 50 Hz interference. The signal was then rectified, time integrated over one minute intervals, and divided by the duration of the segment to obtain the mean rectified voltage (MRV) (Fridlund & Cacioppo, 1986).

Skin conductance was measured using dry Ag-AgCl electrodes, which were attached to Velcro strips. The electrodes were strapped around the upper phalanxes of the index and middle fingers of the non-dominant hand. Small movement artifacts in the signal (sample frequency 128 Hz) were removed with a low-pass IRR filter at .5 Hz. The mean skin conductance value over one minute intervals was taken as the skin conductance level (SCL).

The ECG was recorded via the standard Lead II placement with a sample frequency of 1024 Hz (Stern et al., 2000). For this standard measurement, the negative and ground electrodes were placed right and left respectively under the collarbones. The positive electrode was placed on the lateral anterior left chest, between the lowest two ribs. ECG measurements were done using Ag-AgCl disposable sensors, type H124SG, containing a solid gel. R-peaks were automatically detected after amplification and filtering (Butterworth band pass: 0.5 - 40 Hz) of the ECG signal. The distances between successive R-peaks, the interbeat intervals (IBI), were then calculated. An absolute threshold for IBI detection was set at between 400 and 1400 ms. A moving threshold detected IBIs that were 50 % larger or smaller than the average of the last 40 IBIs. IBI artifacts were removed from the data series.

4.2.5 Procedure

The participants were seated in an office like environment. The physiological sensors were then attached to the participants. The participants were told that the aim of the experiment was to study the influence of music on physiology, thus they were unaware that mood induction would take place. As such, they were told that each session of the experiment consisted of three blocks during which music would be presented during parts of the experiment. The experiment was fully computerised. First of all, an eight minute baseline period began in which the participants watched an aquatic video while the physiological baseline measurements were acquired (Piferi et al., 2000). After the baseline period the participants were asked to fill out the UMACL. Secondly, instructions were given depending on the activity (a Sudoku puzzle (TaskOnly and Task&Music) or nothing (MusicOnly)). Those with the task activities were asked to complete the Sudoku puzzle at the same pace they would normally do. The total time which could be spent on a Sudoku puzzle was twelve minutes. If a Sudoku puzzle was completed within that time, a new Sudoku puzzle was presented. Music was also presented during task conductance in the Task&Music state. In the MusicOnly situation the participants were just asked to listen to the music for twelve minutes. After spending twelve minutes on either just the Sudoku, or the Sudoku while listening to music, the participants were asked to complete the UMACL and RSME. The whole block, including baseline, the task, and the questionnaires, was then repeated twice so that all three situations were presented in each session. In between the blocks, the participants could take a break if they so wished. The second session of the experiment differed in music type only, and took place a week later at the same time on the same day. Each experimental session took up to a maximum of 75 minutes including the time necessary for the attachment and detachment of the physiological sensors.

4.3 Results

4.3.1 Subjective results

To test the reliability of the mood items that constituted the two mood dimensions Chronbach's alpha was calculated and showed reliable scores; valence .86, energy .87. To test whether the baselines of the various states did not differ from each other a repeated-measures MANOVA with Music Type (Happy, Sad) and Activity (MusicOnly, Task&Music, TaskOnly) was applied to the subjective ratings obtained after the baselines. The results showed that, as expected, there were no differences between the baseline mood scores for either the music types or the activities; multivariate effects Music Type $F(3,6) = .32$, $p = .810$, $\eta^2 = .04$; Activity $F(3,6) = .67$, $p = .677$, $\eta^2 = .03$. The mean (SE between parentheses) valence and energy baseline scores were the following: valence ($M = 4.79$, $SE = .14$) and energy ($M = 3.15$,

$SE = .34$).

The mood reaction scores were then calculated by subtracting the mood values obtained after the baseline from the mood values obtained after the activities. To test the influence of music type on mood a repeated-measures MANOVA with Music Type (Happy, Sad) and Activity (MusicOnly, Task&Music, TaskOnly) was applied to the subjective mood reaction scores. The mean values and standard errors of this analysis are presented in Figure 4.1. The results showed univariate main effects for Music Type on valence ($F(1, 29) = 28.31$, $p < .001$, $\eta^2 = .49$), and energy ($F(1, 29) = 22.28$, $p < .001$, $\eta^2 = .43$). Pairwise comparisons of these main effects showed higher valence and energy reaction scores during the happy compared to the sad mood inductions. A significant main effect on Activity was also found for the energy reaction scores ($F(2, 58) = 13.15$, $p < .001$, $\eta^2 = .31$). Pairwise comparisons of this main effect showed that the energy reaction scores were significantly higher after the two activities in which participants did a Sudoku puzzle compared to just listening to music (all $p < .001$).

Lastly, the interaction effect of Music Type and Activity showed significance with both the valence and energy reaction scores; valence $F(2, 58) = 12.18$, $p < .001$, $\eta^2 = .30$; energy $F(1, 29) = 14.05$, $p < .001$, $\eta^2 = .33$. Pairwise comparisons of the interaction revealed that only during the activities in which music was presented, and not in the control situations (TaskOnly), were the valence and energy reaction scores higher in the happy compared to the sad sessions (all $p < .001$). As expected the two control situations also did not significantly differ from one another in either valence or energy reaction scores (both $p > .200$). The pairwise comparisons of the interaction further showed that during the happy sessions higher valence reaction scores were found during the activities in which music was presented compared to the control situation in which no music was played (all $p < .001$). The sad music sessions resulted in lower valence ratings for the MusicOnly situation compared to the Task&Music ($p = .044$) and the TaskOnly state ($p = .001$). For the energy reaction scores, the music type with activity interaction showed that during the happy music sessions, no significant difference in energy reaction scores were found between the three activities (all $p > .05$). During the sad music sessions the energy reaction scores were all significantly different from each other (all $p < .013$), with the MusicOnly having the lowest energy scores and the TaskOnly highest scores.

RSME

To investigate whether the amount of effort invested in the tasks was different for the different music types a repeated-measures ANOVA was applied to Music Type (Happy, Sad) with Activity (Task&Music, TaskOnly) as within-subject factors on the RSME scores obtained after these activities. The results did not show any significant multivariate effect, indicating that the RSME scores did not differ after task conductance with different types of music in the background: Music Type $F(1, 29) = .39$,

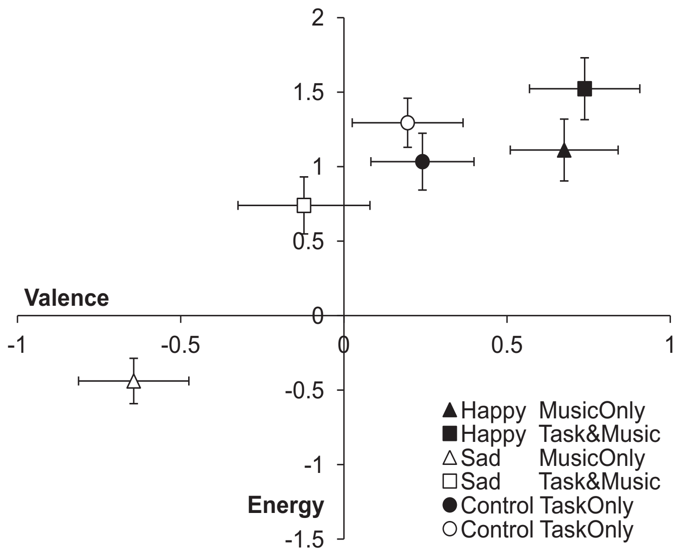


Figure 4.1 – The subjective valence and energy reaction scores obtained after the mood induction. Happy and sad moods were induced when music listening was the primary task or in the background to a task. In the control situation no music was presented during task conductance, this is indicated by the black and white round markers of the happy and sad music sessions, respectively. Error bars represent standard errors.

$n.s.$; Activity $F(1, 29) = .85$, $n.s.$; Music Type with Activity $F(1, 29) = .38$, $n.s.$. The mean values are the following MusicOnly $M = 57.73$ $SE = 4.45$, Task&Music $M = 59.10$ $SE = 4.28$, TaskOnly $M = 54.93$ $SE = 4.46$.

4.3.2 Physiological responses

The physiological measurements of two participants were not recorded due to equipment failure. The data for these participants were therefore not included in the analysis. To test whether the baselines of the various physiological measurements differed a repeated-measures MANOVA with Music Type (happy, sad) and Activity (MusicOnly, Task&Music, TaskOnly) was applied to the average SCL, IBI, EMGc, and EMGz values obtained during the last four minutes of the baseline period. The results showed that the mean physiological responses obtained during the baseline period did not differ from each other (all $p > .05$).

The physiological signals were then adjusted for the baseline level in the following ways: the facial muscle expression measurements were adjusted using the percentage-change from the baseline to the average of the activity period. This resulted in the reaction score of the EMGc and EMGz (Fridlund & Cacioppo, 1986). For IBI, reaction scores were obtained by subtracting the average values obtained during the baseline from the average of the activity period (Llabre et al., 1991). The electrodermal reaction scores were obtained by applying z- transformations to compensate for differences between individuals. The mean and standard deviation of the last four minutes of the baseline measurement were taken as the mean and standard deviation for these z-transformations (Boucsein, 1992).

To test the effect of the mood induction on the physiological measurements, a repeated-measures ANOVA with Music Type (Happy, Sad) and Activity (MusicOnly, Task&Music, TaskOnly) was applied separately to each baseline adjusted physiological measurement. The means and standard errors of the analysis are shown in Figure 4.2. The significant results of these analyses of the separate physiological measurements will be described below.

SCL

The results only showed a significant main effect of Activity $F(2, 54) = 4.51$, $p = .008$, $\eta^2 = .14$; Music Type $F(2, 54) = .11$, $n.s.$. Pairwise comparisons of this main effect showed that the SCL is significantly lower during the MusicOnly situation compared to the two situations in which a task was conducted (all $p > .05$), see also Figure 4.2. The Music Type with Activity interaction also showed significance $F(2, 54) = 3.04$, $p = .028$, $\eta^2 = .11$. Firstly, the pairwise comparisons of this interaction revealed higher SCL values during the happy music compared to the sad music during both the Task&Music and the MusicOnly activities ($p < .05$). The SCL did not significantly differ between the two control situations ($p = .353$). Pairwise comparisons of this interaction additionally showed that the SCL was higher during the Task&Music induction compared to the traditional MusicOnly situation for both music types (all $p < .01$). When sad music was played the SCL was also significantly lower during the MusicOnly compared to the control TaskOnly activity ($p = .005$).

IBI

The results revealed significant main effects of Music Type and Activity; Music Type, $F(1, 27) = 7.58$, $p = .005$, $\eta^2 = .22$; Activity $F(2, 54) = 10.43$, $p < .001$, $\eta^2 = .28$; Music Type with Activity $F(2, 54) = 2.11$, $n.s.$. Pairwise comparisons of the Music Type main effect showed slower heart rates during sad music compared to happy music. Pairwise comparisons of the interaction of Music Type with Activity further revealed that this main effect of Music Type was due to the Task&Music activity; faster heart rates were found during the happy compared to the sad mood inductions only during this activity (Task&Music $p = .023$, MusicOnly $p = .07$, TaskOnly (Control) $p = .211$). Pairwise comparisons of the Activity main effect showed that the heart rate was slowest when no task was performed, intermediate in the control situation and fastest during the Task&Music activity (all $p < .05$).

EMG

The EMGz showed a significant main effect of Music Type, $F(1, 27) = 5.89$, $p = .011$, $\eta^2 = .179$; Activity $F(2, 54) = .54$, $n.s.$; Music Type with Activity $F(2, 54) = 1.69$,

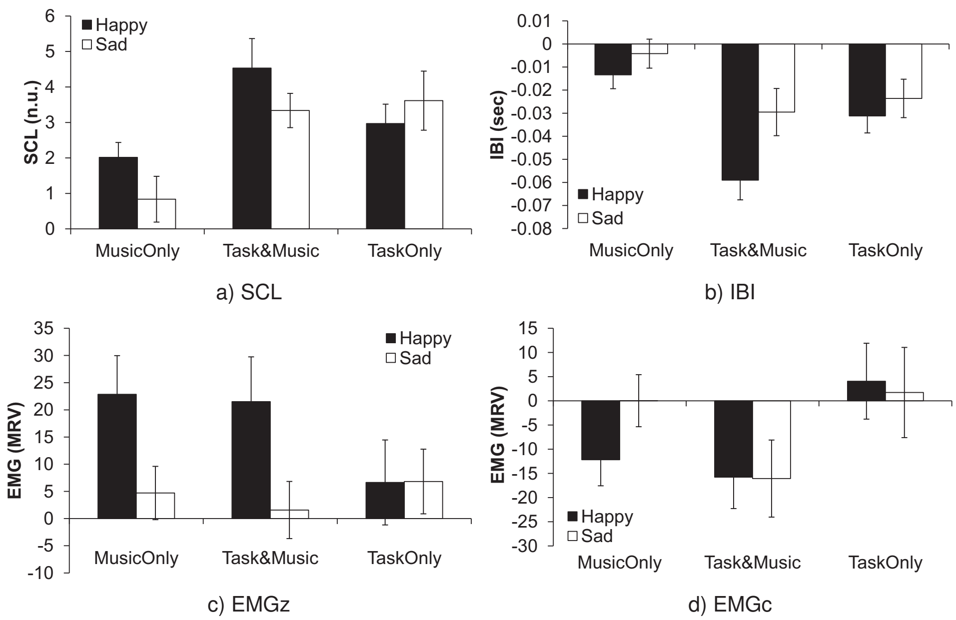


Figure 4.2 – The SCL, IBI, EMG zygomaticus, and EMG corrugator reaction scores during the two types of mood inductions and the control situation. The colours in the control condition (TaskOnly) indicate which session (happy or sad) the control situation was part of, even though no music was presented in this situation. Error bars represent +/-1 standard error.

$n.s.$. Pairwise comparisons of the main effect of Music Type showed significantly more EMGz activity during the Happy music session compared to the Sad music session. Pairwise comparisons of the interaction further revealed that EMGz tension was only significantly higher for happy rather than sad music during the two activities where music was played ($p < .05$). EMGz activity during the two control situations did not significantly differ from one another ($p = .985$).

The EMGc showed a significant main effect of Activity $F(2, 54) = 4.42$, $p = .009$, $\eta^2 = .14$; Music Type $F(1, 27) = .41$, $n.s.$ Music Type with Activity $F(2, 54) = 1.09$, $n.s.$. Pairwise comparisons of the main effect of Activity showed that there is less EMGc activity during the Task&Music activity compared to the TaskOnly situation ($p = .008$). No further significant effects were found.

4.4 Discussion

The study described in this paper aimed to show whether and to what extent music can induce moods while being played in the background to a concurrent activity. Results from subjective ratings and physiological responses showed that changes in moods can be successfully induced with background music. As music can be played almost anywhere, this study therefore provides support for the idea that music can be used to induce moods during common activities in daily life.

The subjective mood measurements indicated that the moods were induced towards the expected direction, both with the traditional mood induction technique and when music is presented in the background to a task. Some differences can be indicated as well. Firstly, the mood induction during task conductance revealed higher energy levels compared to the traditional mood induction without task conductance. This can be explained by the fact that performance of the task itself requires mental resources so the energy levels naturally increase in this situation (Cacioppo et al., 2007). Indeed the energy levels at the TaskOnly (control) situation were also high. Nevertheless, the difference in energy levels was most apparent in the sad music mood induction. This can be explained by a ceiling effect; The energy of the happy induction was already high when no task was performed, performing the task did not lead to a further increase in energy levels. Secondly, valence levels were higher after the sad mood induction with music played in the background compared to when no task was performed during mood induction. This might be because mood regulation towards a neutral or happy mood tends to start naturally when someone is in a sad mood (Isen, 2000). As task conductance distracts from the sad mood induction, it might help to regulate mood upwards.

The physiological measurements appeared to be sensitive to mood induction as well. In accordance with the literature, skin conductance was sensitive to energy levels (Boucsein, 1992; Van der Zwaag, Westerink, & Van den Broek, 2011), and was greater during happy mood induction compared to sad mood induction. The present study expands on previous findings in that skin conductance was shown to be not only sensitive to musical mood induction as a primary activity but also to musical mood induction in the background. In line with the subjective responses to energy, the skin conductance levels increased during task conductance irrespective of the mood being induced. This implies that resources are allocated during task conductance to ensure proper performance on the task. It has to be noted that the skin conductance level seemed higher compared to baseline irrespective of the moods or condition. This might be explained by a time-on-task effect, which leads to changes in physiological measurements over time irrespective of the condition (Fairclough & Venables, 2006).

The heart rate, indicated by the interbeat interval, only showed responsiveness to mood induction when this mood induction takes place in the background to a task. With background music mood induction the heart rate was faster during the happy music mood induction compared to the sad music mood induction. This finding can be explained by the extra amount of effort put into the task during the happy mood induction. Given that optimistic feelings predominate during more positive moods (Gendolla, 2000), a person will generally be more optimistic about their ability to handle a task and therefore put more effort into it. This explanation implies that heart rate does not necessarily indicate that energy levels are induced by moods but by the motivation and effort put into the task. This is plausible given that heart rate has been found to relate to effort (Cacioppo et al., 2007), and thus far no reliable correlation has been found between music mood induction and heart rate (Hodges, 2010; Van der Zwaag & Westerink, 2012).

In line with the literature, with the traditional mood induction technique the facial muscle tension of the corrugator muscle is highest during sad moods and the tension of the zygomaticus muscle is highest during happy moods (Van der Zwaag & Westerink, 2012; Witvliet & Vrana, 2007). For the zygomaticus muscle, this pattern is similar to when moods are induced in the background to a task. This pattern is not present in the corrugator muscle, however, when music is presented in the background. A comparable pattern has been shown before by Van der Zwaag, Westerink, et al. (2012), who showed that the EMG corrugator activity of musically induced mood disappears, while that of the EMG zygomaticus activity persists when music mood induction continues in the background to a task. This finding may be explained by the fact that EMG corrugator tension can be influenced by factors other than mood, such as cognitive factors (Hess et al., 1998), or the focus directed towards a task (Hess et al., 1998).

The present study investigated whether moods can be induced in the background to a concurrent activity. It was conducted in a lab, however. To improve ecological validity future research could investigate to what extent the current results can be generalised to various daily activities, also incorporating a wide variety of music. These results could be used in a music player that suggests music to influence mood in certain situations.

As already suggested by some studies (Haake, 2006; Lesiuk, 2005), this study actually showed that background music can induce moods. Background music further results in changes in physiological responses. This is beneficial as it enables applications that use measurements from an objective source (i.e., physiological measurements) to indicate mood and to react to it by selecting music. The music selected can have the aim to change mood or physiology in a predefined way, for example to calm or energise the user. Possible applications that can benefit from this are music players that regulate mood by playing music in the background of office work or while driving (Lesiuk, 2005; Van der Zwaag, Fairclough, Spiridon, & Westerink, 2011; Van der Zwaag, Dijksterhuis, et al., 2012).

To conclude, the present study showed that moods can be induced with music when played in the background to a concurrent activity. The subjective mood ratings as well as the skin conductance level and the EMG zygomaticus activity best reflected this type of music mood induction. The results imply that moods and physiological changes can be induced during everyday activities, which is useful given that mood influences several cognitive functions.

Based on: Van der Zwaag, M. D., Dijksterhuis, C., De Waard, D., Mulder, L. J. M., Westerink, J. H. D. M., & Brookhuis, K. A. (2012). The influence of music on mood and performance while driving. *Ergonomics, 55(1), 12-22.*

Chapter 5

The influence of music on mood and performance while driving

Mood can influence our everyday behaviour and people often seek to reinforce or alter their mood by turning on music, for example. Music listening while driving is a popular activity. However, little is known about the impact of music listening while driving on physiological state and driving performance. In the present experiment it was investigated whether individually selected music can induce and maintain moods during simulated driving conditions. In addition, the effects of positive, negative, or no music on driving behaviour and physiological responses were assessed for normal and high cognitive demand driving. Subjective mood ratings indicated that music successfully maintained mood while driving. Narrow lane width drives increased task demand as shown by the effort ratings and increased swerving. Respiration rate was also lower during music listening compared to trips without music, while no effects of music were found on heart rate. Overall, the present study demonstrated that in car music listening influences the mood experienced while driving, which in turn can impact driving behaviour.

5.1 Introduction

In western society, music listening has become a frequent activity in the background to almost any other activity (DeNora, 2000; North & Hargreaves, 2008). Music research has now started to focus on music listening in these specific everyday life situations to improve our understanding of how music can influence personal experience and behaviour (Juslin & Sloboda, 2010; DeNora, 2003). Driving is one of the most popular music-listening situational contexts. While driving, people listen to music for enjoyment or to feel engaged when driving in solitude (DeNora, 2000; Walsh, 2010). It has also been suggested that music listening distracts from driving and can therefore influence safety (Brodsky, 2001). Although the impact of music on driving performance has received some attention (Dibben & Williamson, 2007), its impact on mood and physiological responses has not. Neither has a distinction been made between the respective impacts of the specific types of music, like positive and negative valence music. This chapter looks at these relationships between music valence and driving demand on mood, physiological measurements, and driving performance.

5.1.1 Music listening

The potential of music to influence mood is described as one of its most important functions (Juslin & Sloboda, 2010; Van der Zwaag, Westerink, & Van den Broek, 2011). Although music is known to influence mood, it is still under discussion whether people perceive the expressed state within the music (cognitivist view) or whether music can actually induce moods in listeners (emotivist view) (Kivy, 1989, 1990). Evidence of the fact that music induces emotions was found by Kastner and Crowder (1990) for example, who showed that major mode music is perceived as happier compared to minor mode music. Fast tempo music has also consistently been shown to increase arousal levels compared to slow tempo music (Krumhansl, 1997; Van der Zwaag, Westerink, & Van den Broek, 2011).

Support for the emotivist view of the influence of music on emotion comes from the growing body of evidence that music can influence physiological responses and thus body state (for an overview see Hodges (2010)). Heart rate and respiration rate are the most frequently investigated psycho-physiological responses to music (Hodges, 2010). Most studies in the music literature have found that arousing music increases heart rate compared to tranquil (low arousing) music (De Jong, Van Mourik, & Schellekines, 1973; Knight & Rickard, 2001). Still, others have found that any music, arousing or tranquil, increases heart rate (Iwanaga & Moroki, 1999; Krumhansl, 1997; Rickard, 2004). Respiration rate has also been found to increase with highly arousing music compared to calming music (Gomez, Stahel, & Danuser, 2004; Gomez & Danuser, 2004; Iwanaga & Moroki, 1999; Krumhansl, 1997; Nykliček et al., 1997). In yet other studies no difference in respiration rate was found while listening to different types of music (Davis, 1992; Van der Zwaag & Westerink, 2012). Thus the results found for heart and respiration rate responses to music listening are inconsistent. It should be further noted that these latter studies presented music listening as the main task and not in the background to a concurrent activity, such as driving. Nevertheless, it is implied that mood can remain when music is played in the background of a concurrent activity, as Van der Zwaag, Westerink, et al. (2012) showed the persistence of musically induced moods in the background of a distracting task.

There are several possible explanations for the inconsistent results found for the influence of music on physiological measurements. One explanation may be that the physiological responses studied are affected by the regulatory effects of the autonomic nervous system (ANS) which is primarily responsible for maintaining homeostasis (Cacioppo et al., 2007). As a result, physiological responses are not solely influenced by emotional state via music listening, for example, but also by physical activity, cognitive demand, and other psychological constructs (Cacioppo et al., 2007; Van den Broek & Westerink, 2009). Hence, the situational context needs to be taken into account when interpreting physiological responses to music listening. A second possible explanation may by that most studies in music research differ widely in terms of important methodological aspects, such as song selection method and duration of the music presentation. Van der Zwaag and Westerink (2012), for example, showed that the physiological response patterns to positive and negative music mood induction start to differentiate after four minutes on average. Hence, the physiological responses to music listening in studies presenting relatively short music excerpts cannot be compared with studies inducing moods with music over longer periods. For the study of physiological responses to music, it is necessary to be aware of these methodological aspects, as well as the importance of always describing the impact of music on the emotions in relation to the personal and situational context (Blacking, 1973; North & Hargreaves, 2008; Saarikallio & Erkkilä, 2007; Sloboda & Juslin, 2010).

5.1.2 Music while driving

Music may be beneficial while driving as the mood-arousal hypothesis predicts that in the event of boredom and drowsiness, for example, music could lead to a better level of arousal which would benefit driving performance (North & Hargreaves, 2008; Shek & Schubert, 2009). However, following the distraction hypothesis, music could also divert the driver's attention from the driving task (Shek & Schubert, 2009). This distracting effect of music on driving may be disadvantageous if it reduces safety when highly arousing music is played during high demand driving situations (Dibben & Williamson, 2007). Contrary to this, Wiesenthal, Hennessy, and Totten (2000) showed that a person's favourite music alleviates stress during high congestion driving and found higher stress levels when no music was compared to favourite music during high congestion driving. It was also shown that driver aggression can be tempered with a person's favourite music compared to no music in high demand driving situations (Wiesenthal, Hennessy, & Totten, 2003).

Explanations for the effect of music listening while performing a concurrent task such as driving often focus on processing capacity in the service of the primary task (e.g., Dalton and Behm (2007); North and Hargreaves (1999); Pêcher, Lemercier, and Cellier (2009)) and assume that listening to music may be arousing and therefore requires mental resources. Following the information-distraction approach, music adds additional irrelevant stimuli to a task which leads to increased cognitive load and thus could impact task performance (Konečni, 1982; North & Hargreaves, 1999; Recarte & Nunes, 2000). Consequently, the more attention particular music requires, the more it competes for processing resources with the primary task of driving. To illustrate this, North and Hargreaves (1999) manipulated the cognitive load of participants by exposing them to low or high arousing music by varying tempo and volume in a driving game. They found that high arousing music resulted in worse racing performance defined as slower lap times, while the quickest lap times were recorded when listening to low arousing music. Interestingly, they also found a connection between task demand and music liking and concluded that competition for processing resources caused participants to dislike music. Pêcher et al. (2009) mentioned that post-experiment interviews revealed that drivers found happy music the most disturbing and, combined with behavioural data, took this as support for their conclusion that listening to happy music resulted in a deterioration in driving performance.

The impact of in-vehicle music listening on driving speed depends on the road situational context. Reducing speed is found to be used as a compensatory reaction when faced with high load situations, because it enables the driver to maintain safety margins by increasing the necessary reaction times (Summala, 2005). As mentioned above, it may also be that drivers allocate more attention and thus mental resources to positive music which could have a detrimental effect on vehicle control or result in a compensatory reaction, such as slowing down.

Because task performance and music listening may compete for the same mental resources, the impact of musically-evoked cognitive demand on performance may be dependent on the cognitive demand of a concurrent task (Konečni, 1982; North & Hargreaves, 1999). In low demand driving situations, there is less competition for attention. Hence, it is likely that mental resources can more easily be divided between listening to music and driving as the limits of mental resources have not been reached. Therefore, listening to music will not impact driving performance in these low-demand situations. As lane width is known to influence drivers' load, this variable can be used to manipulate primary task demands when studying the relationship between listening to positively and negatively rated music. Results reported in the literature show that when driving in narrow lanes, there is less manoeuvring space available to the driver, and more attention is required to prevent driving errors such as drifting out of the lane, and to maintain personal safety margins (De Waard, Jessurun, Steyvers, Raggatt, & Brookhuis, 1995; Dijksterhuis, De Waard, & Brookhuis, 2011). This results in smaller deviations from the driver's preferred lateral position on the road (De Waard et al., 1995; Dijksterhuis et al., 2011) and a compensatory speed reduction (e.g., Godley, Triggs, and Fildres (2004)). In terms of physiological responses, higher demand situations should lead to increased heart rate and respiration rate.

5.1.3 Expectations

The aim of the present study was twofold. Firstly, we wanted to investigate whether musically-induced relatively positive and negative moods persist during low and high demand driving. We further investigated whether the presence of positive compared to negative music influences the resources mobilised as reflected by the amount of effort invested in driving. We expected that relatively positive and negative valence could be successfully induced by music mood induction (Van der Zwaag & Westerink, 2012). Based on Van der Zwaag, Westerink, et al. (2012) we further expected that positive and negative musically induced moods would persist while driving. The presence of relatively positive or negative moods was also expected to persist during high demand driving.

Secondly, the influence of musically-induced mood on driving performance in high (narrow lane width) and low (wide lane width) demand driving was investigated. Thus, lane width was used to further investigate the relationship between listening to positively and negatively rated music and primary task demands. First of all, while driving, we expected to see increased respiration and heart rates during high compared to low demand driving. In accordance with Dijksterhuis et al. (2011), less swerving (i.e., reduced variation in lateral position) was expected in narrow lanes. We further expected that lane width reduction would reduce speed in order to compensate for the higher levels of resources allocated to the more demanding driving situation (De Waard et al., 1995; Godley et al., 2004). We expected that music would solely influence driving performance in highly demanding driving situation, as in these situations music competes with the limited amount of mental resources available.

5.2 Method

5.2.1 Participants

The study was approved by the local ethics committee and informed consent was obtained from all the participants. Nineteen participants, 13 men and 6 women, were paid € 45 each for taking part. The participants' ages ranged from 22 to 44 years ($mean = 27.5$, $SD = 5.2$) and they had held their driving licence for 4 to 22 years ($mean = 8.8$, $SD = 4.9$). Self-reported total mileage driven ranged from 6,000 to 700,000 km (median = 45,000 km; inter-quartile range (IQR) = 77,500 km) and current yearly mileage ranged from 1,500 to 60,000 km/year (median = 7,000 km/year, IQR = 5,000 km/year).

5.2.2 Design

Three music states were used; positive music, negative music, and no music (which was included as an extra control situation). Two levels of lane width (wide $3.00m$

or narrow $2.50m$) were also created in the driving simulator, corresponding to low and high demand driving, respectively (Dijksterhuis et al., 2011). The participants completed four sessions on separate days: one introductory session and three experimental sessions. In each experimental session one music level was presented and both lane widths were used. This resulted in a within-subject design including two repeated-measure factors; Music (3) and Lane width (2). The orders of both the music and lane width factors were counterbalanced over the participants.

5.2.3 Music stimuli selection

Because music preference is highly personal (Hargreaves & North, 2010), songs used as stimuli were selected individually. To do so, participants completed an introductory session prior to the experimental sessions. In this session participants rated 60 songs for perceived valence and energy levels on 7-point Likert scales. The participants did not have to listen to the entire song but were encouraged to sample each song for a few moments and at a few locations within the song to get a good impression of the song. The 60 songs included were selected to provide a wide range of valence and energy values and were taken from a database containing 1800 songs in total. The songs were selected based on energy and valence labels which were acquired by automatic classification of music characteristics by mood labels (Skowronek et al., 2006, 2007). The order of the song presentation was randomised over the participants.

After the participants had finished the ratings, nine songs were selected per participant per music state (positive / negative) in such a way that valence ratings differed as much as possible between the positive and negative songs while keeping energy ratings as average as possible. Subsequently, three of the selected songs were used for the music mood induction, three songs for the high demand drive, and three songs for the low demand drive. The duration of the three songs was adjusted to eight minutes using Audacity (Version 1.2.4), keeping the average duration of each song about equal. This was done by cutting the song to about 2.45 minutes and fading out the new ending of the song.

To check the selected song stimuli for their valence and energy ratings, a repeated-measures ANOVA with Music (Positive / Negative) as within-subject factor was applied to the valence and energy ratings of the selected songs. The results showed a main effects of Music on both energy and valence ratings; valence $F(1, 17) = 231.20$, $p < .001$, $\eta^2 = .93$; energy $F(1, 17) = 16.04$, $p < .001$, $\eta^2 = .49$. This confirmed that the selected song stimuli for the two Music states were significantly different from each other in valence and energy. The positive songs showed higher valence and energy ratings compared to the negative songs; Positive songs Mean (SE) Valence $M = 5.8(.17)$, Energy $M = 4.7(.20)$, Negative songs Valence $M = 2.3(1.4)$, Energy $M = 3.3(.26)$, on a scale from 1 to 7.

5.2.4 Simulator and driving conditions

The study was conducted using a ST Software©driving simulator. This simulator consists of a fixed-base vehicle mock-up with a functional steering wheel, indicators, and pedals. The simulator was surrounded by three 32” diagonal plasma screens. Each screen provided a 70 ° view, giving a total 210 ° view. A detailed description of the functionality of the driving simulator used can be found in Van Winsum and Van Wolffelaar (1993).

Participants drove the simulated car (width: 1.65 m) over two sections of uninterrupted two-lane roads (2.50 m or 3.00 m wide lanes), winding through rural scenery and separated by a small town. Roads in each section consisted mainly of easy curves (about 80 %) with a constant radius of 380 m and ranging in length from 120 to 800 m. The edge of the road surface was marked on both sides by a continuous line (20 cm wide), in the centre by a broken line (15 cm), with a soft shoulder on the verges. The posted speed limit during the drive was 80 km/h. In addition, a stream of oncoming traffic was introduced with a random interval gap of between 2 and 6 seconds, resulting in 15 passing cars (width: 1.75 m) per minute on average. No vehicles appeared in the participant’s own driving lane.

5.2.5 Measurements

Subjective ratings

Subjective mood scores of valence (ranging from unpleasant to pleasant) and energy (ranging from tired/without energy to awake/full of energy) and calmness ratings (ranging from tense to calm) were assessed using the UWIST Mood Adjective Check-List (UMACL) (Matthews et al., 1990). This UMACL contains eight unipolar items for each dimension, which start with: ‘right now I am feeling’, and range from 1: ‘not at all’ to 7: ‘very much’.

The Rating Scale of Mental Effort (RSME) was used to assess mental effort (Zijlstra, 1993). The RSME is a one-dimensional scale, ranging from 0 to 150, used to rate mental effort. In addition to digits, several effort indicators (calibrated anchor points) are visible alongside the scale to further guide rating. The indicators start with ‘absolutely no effort’ (RSME score of 2) and end with ‘extreme effort’ (RSME score of 112).

Physiology

Physiological measurements included autonomic nervous system reactions in the cardiovascular and respiratory domain. The Portilab data recorder and its accompanying sensors were used to record these responses with a sample frequency of 250 Hz (version 1.10, Twente Medical Systems International, Oldenzaal, the Netherlands). Physiological measurements were assessed continuously during the experiment. The MATLAB programming environment (2009a, The Mathworks, Natick, MA) was used for the preprocessing of the respiration signals.

Cardiovascular measurements were recorded with an electrocardiogram (ECG) using three Ag-AgCl electrodes, which were placed following the standard lead II placement (Stern et al., 2000). R-peaks in the ECG signal were detected automatically, after amplification and filtering of the signal (Butterworth band pass: 0.5 - 40 Hz). The distances between successive R peaks, the interbeat intervals (IBI), were then calculated.

Respiration was recorded by means of a respiration belt (RespitraceTM, Twente Medical Systems). To obtain the respiration measurements, noise was excluded from the raw signal and movement artifacts were reduced by a .005 - 1.0 Hz band pass IIR filter. The number of respiration cycles per minute provided the respiration rate (RR) (Grossman & Taylor, 2007); (Wientjes, 1992).

Driving parameters

Speed and Lateral Position (LP) were sampled at 10 Hz. LP is defined as the difference in metres between the centre of the participant's car and the middle of the (right hand) driving lane. Positive LP values correspond to deviations towards the left hand shoulder and negative values correspond to deviations towards the right hand shoulder. The sampled LP values were used to calculate mean LP and the standard deviation of LP, i.e., swerving.

5.2.6 Procedure

Participants were invited four times to the driving simulator facility of the University of Groningen. During the first introductory session the participants were informed about the experiment, signed an informed consent form, drove a six minute practice drive, and completed the music rating.

During the three subsequent experimental sessions, physiological sensors were attached and participants were seated in the simulator chair. Physiological baseline values were then acquired in a habituation period during which participants watched a coral sea diving video for eight minutes (Piferi et al., 2000). The participants then completed the UMACL. An eight minute musical mood induction period then started in which the participants were asked to listen to the music. To ensure that the participants remained attentive to the music, they were asked to listen to the music carefully to be able to answer questions about the music after the entire experiment. During the control session in which no music was presented, participants were asked to sit and relax for eight minutes. The participants were not informed that mood induction would take place during these eight minutes, as this could bias the results. After eight minutes the participants filled out the UMACL again.

Next, the first simulated drive began. The participants were instructed to drive as they would normally drive. After approximately eight minutes participants were instructed to park the car and the music was stopped. During this break participants were asked to complete the UMACL questionnaire and the RSME scale. Following this, the second eight minute drive started which differed from the first drive only in lane width. After completing the drive, participants filled out the UMACL and RSME again. The total duration of each experimental session (including instructions and attaching and de-attaching the physiological equipment) was approximately 70 minutes.

5.3 Data analysis

Data were analysed using SPSS 17 for Windows (SPSS Inc., Chicago, IL) with the level of significance set at $p < .05$ (2-tailed). The data acquired during the music mood induction period were analysed using a repeated-measures ANOVA with Music (Positive / Negative / No Music) as within-subject variable to confirm that successful mood induction took place. The data obtained during the drives were further analysed using a repeated-measures ANOVA with Music (Positive / Negative / No Music) and Driving Demand (Wide / Narrow) as within-subject variables to show the effect of music on driving. Pairwise comparisons were Bonferroni corrected.

5.4 Results

5.4.1 Subjective ratings

The reliability of the mood dimensions was determined, using the normal and reverse coded items of the UMACL questions. This rendered Chronbach's alphas for energy of .84, valence of .89, and calmness of .90. Next, to show whether the baseline values did not differ from each other between the three music sessions a repeated-measures MANOVA with Music (Positive / Negative / No Music) as the within-subject factor was applied to the Valence, Energy, and Calmness ratings obtained directly after the baseline period, i.e., before the music mood induction. The results did not show a significant multivariate effect of Music ($F(6, 70) = 1.54$, $p = .18$, $\eta^2 = .12$). The baselines ratings were as follows: Valence ($M = 5.5$, $SE = .18$), Energy ($M = 3.8$, $SE = .13$), and Calmness ($M = 6.0$, $SE = .12$). Mood reaction scores were then found by subtracting the values obtained during baseline measurements from the values obtained during the different situations; either mood induction or the two drives.

A repeated-measures MANOVA with the within-subject factor of Music (Positive / Negative / No Music) was applied to the subjective Valence, Energy, and Calmness reaction scores obtained after the music mood induction. A significant multivariate effect of Music was found ($F(6, 70) = 2.51$, $p = .029$, $\eta^2 = .177$). Univariate tests showed significant main effects on valence and energy reaction scores during the mood induction (Valence: $F(2, 36) = 4.21$, $p = .023$, $\eta^2 = .19$, Energy: $F(2, 36) = 6.0$, $p = .006$, $\eta^2 = .25$, Calmness: $F(2, 36) = 2.22$, $p = .12$, $\eta^2 = .11$).

Pairwise comparisons showed that Positive music results in higher Valence and Energy reaction scores compared to both the Negative Music (Valence $p = .042$, Energy $p = .042$) and the No Music situation (Valence $p = .024$, Energy $p = .004$). Figure 5.1 shows the mean Energy and Valence ratings obtained after the drives. Average and Standard Errors (in parentheses) of the calmness ratings were -.25 (.15) for positive music, -.71 (.17) for negative music, and -.58 (.15) for no music.

A repeated-measures MANOVA with Music (Positive / Negative / No Music) and Driving Demand (Wide / Narrow) as the within-subject factors was then applied to the Valence, Energy, and Calmness reaction scores obtained after the two drives. The results showed a marginally significant multivariate effect of Music ($F(6, 70) = 2.22$, $p = .053$, $\eta^2 = .160$). No significant multivariate effects were found for Driving Demand ($F(3, 16) = .82$, $p = .50$, $\eta^2 = .13$) or the Music with Drive Demand interaction ($F(6, 70) = .42$, $p = .86$, $\eta^2 = .04$). The univariate results for Music showed significant main effects on Valence and Energy reaction scores (Valence $F(2, 36) = 4.33$, p = .021, $\eta^2 = .19$; Energy $F(6, 70) = 3.49$, $p = .041$, $\eta^2 = .16$; Calmness ($F(2, 36) = 2.21$, $p = .124$, $\eta^2 = .11$). Pairwise comparisons of Music showed marginally higher Valence reaction scores ($p = 0.051$) and marginally higher Energy reaction scores ($p = 0.095$) during the Positive condition compared to the No Music situation irrespective of Driving Demand. Figure 5.1 shows the mean Energy and Valence reaction scores obtained after the drives. Average Calmness reaction scores were as follows: Mean (Standard Error) Positive wide $M = -.27(.14)$, narrow $M = -.55(.18)$, Negative wide $M = -.74(.20)$, narrow $M = -.82(.23)$, No Music wide $M = -.76(.19)$, narrow $M = -.87(.19)$.

To evaluate the perceived degree of mental effort (RSME scores) during the drives, a repeated-measures ANOVA of Music (Positive / Negative / No Music) with Driving Demand (Wide / Narrow) as within-subject factors was applied to the RSME ratings. A significant effect of Driving Demand was found ($F(1, 18) = 9.12$, $p = .007$, $\eta^2 = .34$). Pairwise comparisons of Driving Demand revealed higher RSME ratings during the Narrow drive ($M = 39.37$, $SE = 5.42$) compared to the Wide drive ($M = 33.10$, $SE = 4.68$). No significant effects of Music or the Music with Driving Demand interaction were found; Music $F(2, 36) = 1.96$, $p = .156$, $\eta^2 = .10$; Music with Driving Demand $F(2, 36) = .10$, $p = .907$, $\eta^2 = .005$.

5.4.2 Physiological responses

A repeated-measures MANOVA with Music (Positive / Negative / No Music) as within-subject factor was applied to both the respiration rate and the mean IBI duration obtained during the last three minutes of the baseline period. The results did not show a significant main effect of Music on respiration rate or on mean IBI, indicating that the baseline respiration rates and IBI duration did not differ in the different sessions; respiration rate $F(2, 36) < 1$, $p = .54$, $\eta^2 = .04$, Mean (SE) in breath/min:

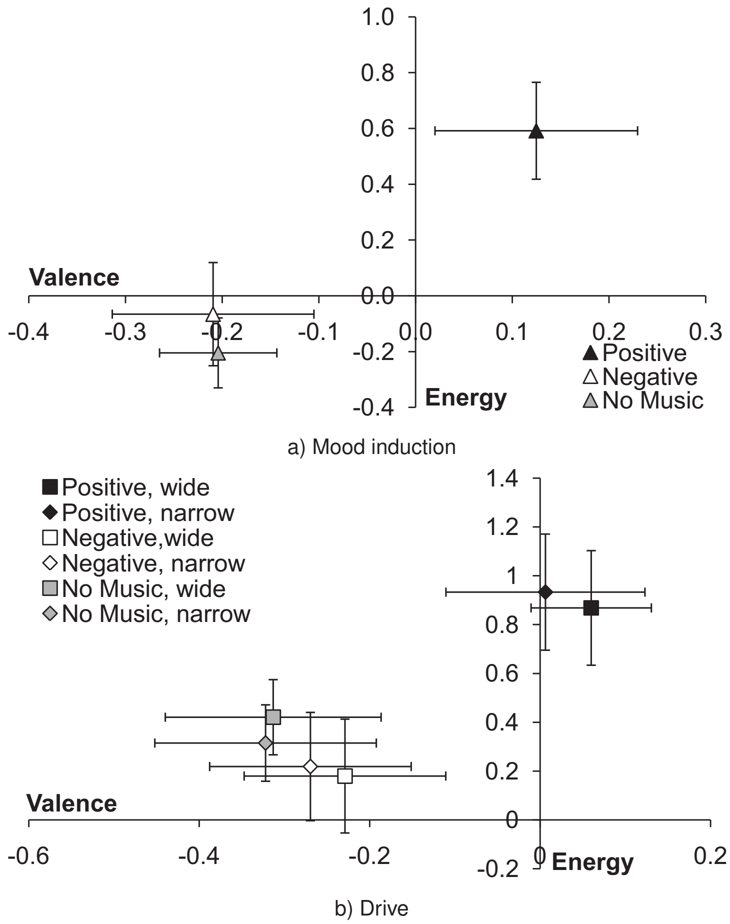


Figure 5.1 – Subjective valence and energy reaction scores provided after the music mood induction (Panel a), and after the wide and the narrow drives (Panel b). The error bars represent standard errors.

Positive $14.61(.95)$, Negative $14.04(.73)$, No Music $15.20(.76)$; IBI $F(2,36) = 1.18$, $p = .36$, $\eta^2 = .62$, Mean (SE) IBI duration in seconds: Positive = $.874(.03)$, Negative = $.846(.03)$, No Music = $.876(.03)$. Physiological reaction scores were then calculated by subtracting the average values obtained during the last four minutes of the baseline period from the values obtained during the induction and the drives.

Respiration rate

A repeated-measures ANOVA with Music (Positive / Negative / No Music) as the within-subject variable was applied to the reaction scores of the respiration rate obtained during the induction. No significant main effects were found showing

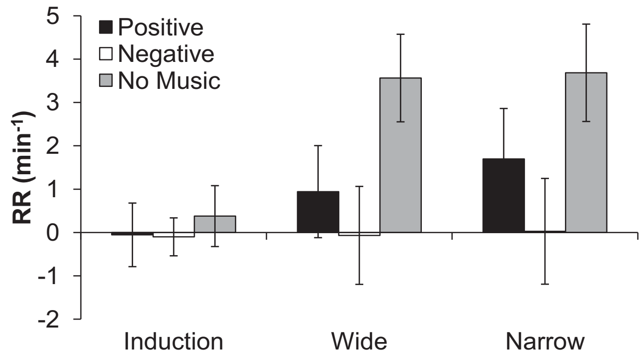


Figure 5.2 – The respiration rate reaction scores for the induction and the two drives. Error bars represent +-1 standard errors.

that the respiration rates did not differ during the induction period ($F(2, 36) < 1$, $p = .78$, $\eta^2 = .013$) (see Figure 5.2). A repeated-measures ANOVA with Music (Positive / Negative / No Music) with Driving Demand (Wide / Narrow) as the within-subject factors was then applied to the respiration rate. The results showed a main effect of music; $F(2, 36) = 3.25$, $p = .050$, $\eta^2 = .153$. Pairwise comparisons show a significantly lower respiration rate during the Negative compared to the No Music condition ($p = .046$) irrespective of Driving Demand, see also Figure 5.2. No significant effects of the Driving Demand or interaction effect of Music with Driving Demand were found.

Cardiovascular measures

A repeated-measures ANOVA with Music (Positive / Negative / No Music) as the within-subject variable was applied to the IBI reaction scores of the induction. No significant main effect of Music was found showing that IBI duration did not differ during the induction; $F(2, 36) < 1$, $p = .40$, $\eta^2 = .049$, Mean (SE) Positive $-.01(.006)$, Negative $-.008(.006)$, No Music $-.001(.006)$. A repeated-measures ANOVA with Music (Positive / Negative / No Music) and Driving Demand (Wide / Narrow) as the within-subject factors was then applied to the average IBI durations obtained during the drives. The results showed no significant effect for Music or Driving Demand (all $p > 0.05$) Positive Mean (SE) = $-.017(.009)$, Negative = $-.019(.008)$, No Music = $-.022(.007)$, Wide Drive = $-.018(0.07)$, Narrow Drive = $-.019(0.07)$.

5.4.3 Driving performance

Separate repeated-measures analysis of Music (Positive / Negative / No Music) with Driving Demand (Wide / Narrow) as the within-subject factors were applied to the mean of the lateral position, the standard deviation of the lateral position (SDLP,

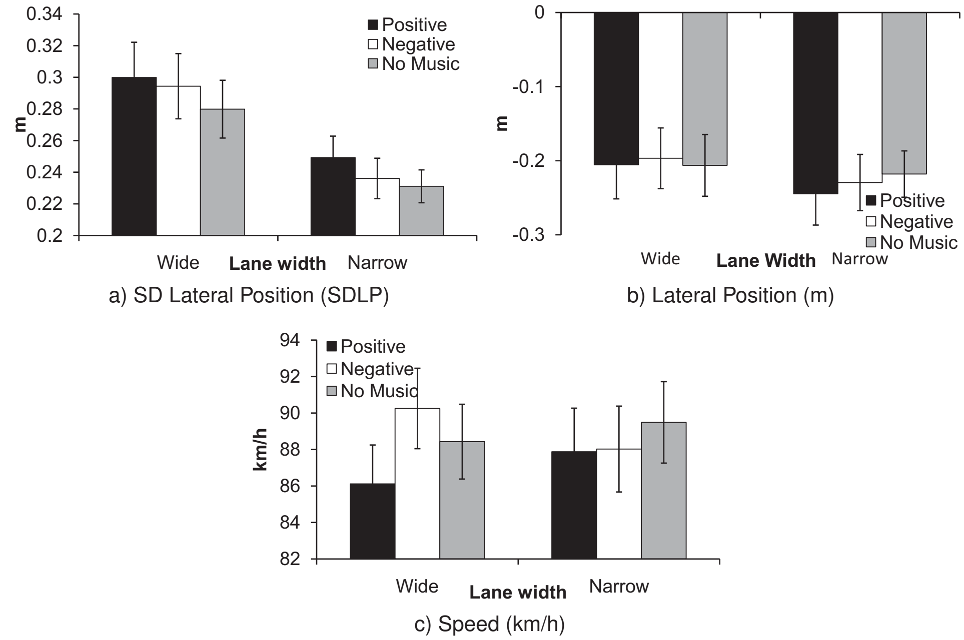


Figure 5.3 – The SDLP (standard deviation of the lateral position, swerving), average lateral position from the centerline of the road, and speed obtained during the wide (3.00 m) and narrow (2.50 m) drives. Error bars represent +- 1 standard errors.

i.e., swerving), and the speed. A trend was found for mean lateral position, and a significant main effect of Driving Demand was found for SDLP; lateral position (m) $F(1, 17) = 3.51$, $p = 0.082$, $\eta^2 = .201$; lateral position (sd) $F(1, 17) = 23.80$, $p < 0.001$, $\eta^2 = .583$. During the Narrow lane drive more distance from the centre line was found and the SDLP was smaller compared to the Wide lane drive (see also Figure 5.3). The results for speed showed a marginally significant main effect of Music ($F(2, 13) = 3.18$, $p = 0.075$, $\eta^2 = .329$). Pairwise comparisons showed greater speed during the No Music state compared to the Positive music situation ($p = .023$) irrespective of Driving Demand, the average speed values are given in Figure 5.3.

5.5 Discussion

Music listening is a very popular secondary activity while driving. However, the influence of listening to music on body state and driving performance is not yet fully understood. This study investigated whether personally selected positive and negative music influences mood, body state, and driving performance. The results showed that mood induction with music was successful: the induced moods were consistently directed towards the expected moods based on the song stimuli which were selected per participant. Listening to music as a primary activity furthermore did not alter cardiovascular or respiratory responses. By contrast, lower respiration rates were found in the situations where music was presented during driving compared to situations where no music was presented at all. Finally, as hypothesised, less swerving was observed in the higher demand drives, irrespective of music presence. The current findings therefore support the view that music and driving demand influence mood, physiological state, and driving performance to a certain extent.

5.5.1 Mood induction through music

In line with the literature, in the two music conditions relatively positive or negative moods were induced with music over eight minute periods in which listening to music was the primary task (Gendolla, 2000). The situation without music induced an equal mood state comparable to the mood induction with negative music. This may be explained by the fact that music is known to influence time perception causing the music listening situations to be perceived as shorter in duration (Cassidy & MacDonald, 2010). MacDonald et al. (2003), for instance, have shown that waiting in a hospital context with music makes participants less anxious than if they have to wait without music. Hence, a situation in which no music is presented might be perceived as long and boring, thereby inducing a negative mood (Juslin & Sloboda, 2010).

In line with previous research, respiration rate and heart rate did not vary between the positive and negative mood inductions (Gendolla & Brinkmann, 2005; Silvestrini & Gendolla, 2007; Van der Zwaag & Westerink, 2012). This finding can be explained by the fact that mood does not immediately result in action tendencies and therefore altered physiological responses (Gendolla, 2000). In contrast, it has been shown that differentiation between moods during music mood induction can be observed for other physiological measurements than heart rate and respiration rate, such as skin conductance and facial muscle tension (Cacioppo et al., 2007; Van der Zwaag & Westerink, 2012).

5.5.2 Effects of music during high and low demand driving

As expected, the (subjective) effort invested in driving was greater while driving in the narrow lanes (Dijksterhuis et al., 2011). As expected while driving, the induced mood also persisted in terms of valence and energy ratings irrespective of driving demand and music type. The energy ratings increased during the drive regardless of whether the music was positive or negative, which can be attributed to the execution of a concurrent task while driving. The result confirms previous research findings (Van der Zwaag, Westerink, et al., 2012) and also extends the literature as it indicates that moods induced with music can persist concurrently with a task irrespective of the task demands.

Listening to negative music compared to no music at all while driving resulted in lower respiration rates, irrespective of driving demand. This finding holds even though subjective mood ratings were equal when listening to negative music compared to not listening to music. This implies that music may be used unconsciously to decrease the body stress of the driver as respiration rate has been linked to arousal (Boiten et al., 1994; Homma & Masaoka, 2008; Nykliček et al., 1997; Ritz, 2009). Nykliček et al. (1997), for example, have shown that stimulating music leads to faster respiration rates. This result emphasises the importance of incorporating physiological measurements as they can uncover aspects that would remain unnoticed by subjective ratings (Van den Broek & Westerink, 2009).

Driving performance was influenced by both driving demand and the music played during the drive. During high demand road sections, participants drove more towards the shoulder and swerved less compared to low demand driving. As expected, driving in a narrow lane was associated with a reduction in swerving. This confirms that more effort was put into the lane keeping task to deal with the reduced lateral margins. This is in accordance with Summala's Multiple Monitor Theory (Summala, 2005, 2007) which states that mental load increases when less time is available to maintain safety margins. In a more general sense, these results can be seen as an indication that more effort was invested in the driving task to prevent performance degradation (Hockey, 1997, 2003) or that the level of effort was matched to the current task demands (Hancock & Warm, 1989; Matthews & Desmond, 2002). In contrast to Pêcher et al. (2009), in the current study swerving did not decrease in the no music situation, hence music listening did not affect lateral safety. This difference in results can be explained by the fact that Pêcher et al. (2009) alternated music periods with silent periods of one minute each. This alternation could distract the driver and therefore decrease swerving while listening to music. The current results thus might reflect a more ecologically valid situation.

Driving in a narrow lane did not decrease driving speed. This could imply that the high demand situation was not demanding enough to lead to changes in driving performance. The data did show lower speed during the positive music drives compared to the drives without music. This could be caused by increased engagement in the drive while listening to personally selected positive music which resulted in context-appropriate speed choices, rather than having a distracting effect (Cassidy & MacDonald, 2009). This finding is in line with the increased respiration rates during the no music situation; faster speed coincides with greater physical effort.

Lastly, the present study did not show an interaction between driving demand and music. There may be several reasons for this. Firstly, the music used in this study might not have demanded much in terms of attention resources because it was moderately rather than highly arousing (Cassidy & MacDonald, 2009). Listening to music, therefore, did not demand more than the resources still available besides those required for driving, so there was no real competition for resources. This is in line with Beh and Hirst (1999) who showed that high intensity music, which demands for more resources, did reduce performance during high demand situations in a driving-related task. Secondly, the drivers who took part in the study were all experienced drivers. The additional load created by music listening while driving therefore could have been minimal, as the driving task itself may be expected to be fairly automatic. Music listening by novice drivers, however, might result in a different outcomes. Altogether, these results indicate that music intensity may be an important factor in predicting the influence of music on reducing driving performance during high demand driving situations.

5.5.3 Limitations and future research

The song stimuli varied in valence and to a lesser extent in energy levels as well. It should be noted that the songs selected were not the most contrasting songs, i.e., favourite songs would have had the highest valence and energy levels, and sad songs would have had the lowest energy and valence levels. From the individual song selection it appeared to be impossible to select songs that varied only in mood valence with equal energy levels. This means that the valence and energy ratings were not fully independent of each other in inducing mood with music. This result is in line with the psychobiological theory of aesthetics (Berlyne, 1971) which proposes that there is a U-shaped relationship between arousal and liking; i.e., an average arousal level has the optimum liking level, increasing and decreasing arousal levels would decrease liking levels (Berlyne, 1971; North & Hargreaves, 2008).

To cope with the large individual differences in music preference, individually selected song stimuli were chosen in the present study (Juslin & Sloboda, 2010). This method ensured that the song stimuli selected did indeed induce the intended moods. However, this method also resulted in stimuli that were not controlled for other music characteristics such as familiarity, or characteristics, inherent to the music, such as tempo or mode, which could also affect mood (Juslin & Sloboda, 2010; Van der Zwaag, Westerink, & Van den Broek, 2011). Future research could look at how the lessons learned from this study can be generalised to show the impact of listening to different types of music in a wide variety of driving scenarios.

5.5.4 Conclusion

This study investigated the influence of listening to music on mood and body state changes, and driving performance during high and low demand driving tasks. Moods were successfully induced with music, and driving without music was perceived with equally negative feelings as driving with negative valence music. Listening to negative music compared to no music while driving led to decreased respiration rates while listening to positive music compared to no music leads to slower driving speed. Increased driving demand, however, led to a greater degree of swerving. In the present study music did not impair driving performance as has often been found in the literature. By contrast, listening to music can even lead to an improved mood and a more relaxed bodily state which in the long run could be beneficial to health.

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De Waard, D.. Using music to regulate mood while driving.

Chapter 6

Using music to regulate mood while driving

This study investigated whether calming music should be selected abruptly (following the mood regulation theory) or gradually (following the mood congruency theory) to most efficiently calm drivers during high demand driving situations. Twenty-eight participants were subjected to two types of music change (gradual, abrupt) in a within subject-design. Firstly, a relatively happy mood was induced with personally selected music during an eight minute simulated high-demand drive. The drive then continued and the mood was changed either gradually or abruptly. Subjective results showed successful music mood induction irrespective of how it was arrived at. The results further showed lower skin conductance (less arousal) during the abrupt music change and more facial corrugator muscle tension (more sadness) during the gradual music change. Fewer accidents occurred during the abrupt music mood change. To conclude, the results support the mood regulation theory. During high-demand driving abrupt changes in music led to more rapid physiological calmness and improved driving performance, and was thus safer and more efficient.

6.1 Introduction

Music listening while driving is a popular activity. Music can be used to provide a sense of company, as a distraction on a long and boring drive, to regulate mood, or just as entertainment while driving (DeNora, 2000; Dibben & Williamson, 2007). The influence of music on driving can have both positive and negative aspects. The many car accidents which occur during busy road situations while the driver's favourite music is playing is an example of a negative aspect (Brodsky, 2001). In line with this, North and Hargreaves (2004) showed that negative effects of music (i.e., annoyance and reduction in driving performance) were most common during high demand activities.

Music can also have positive effects on mood and driving performance. In high demand driving situations, calm music has been shown to relax, calm, and relieve stress or other negative emotions in drivers (Wiesenthal et al., 2000). Calm music can also improve driving performance (Dibben & Williamson, 2007; Saarikallio & Erkkilä, 2007). For example, slow compared to fast tempo music reduces the number of illegal lane crossings and collisions (Brodsky, 2001). Vigilance performance (i.e., reaction times to sudden events) also increases when low-intensity music is played while driving (Beh & Hirst, 1999). In addition, Beljovic, Slepcevic, and Jakoljevici (2001) showed that calmer compared to noisier conditions (e.g., when a persons's favourite music is played) during demanding task situations led to less attention problems and fatigue. Taken together, this suggests that calm music can lead to more relaxation and safer driving conditions.

The way in which music changes mood is not yet fully understood (Juslin & Sloboda, 2010; North & Hargreaves, 2008). There are two theories on mood change that provide possible hypotheses for this: the mood regulation theory and the mood congruency theory. The mood regulation theory describes the deliberate attempts to influence affect (Gross, 2007). According to this theory, whether mood, or certain aspects of mood, are enhanced, changed, or maintained depends on the regulation goal. The regulation of moods starts when there is a discrepancy between the current mood and the target mood (Larsen, 2000; Gendolla, 2000; Parkinson et al., 1996). This happens, for instance, when the current mood is neither helpful nor harmful (Parrot, 1993). There may be a desire to regulate affect in social interactions, for example, to enhance cognitive functioning like memory, or to calm a person when driving in high demand situations (Gross, 2007). Music has been applied successfully in several deliberate mood regulation strategies (Gross, 2007; Parkinson & Totterdell, 1999; Thayer et al., 1994), and is also one of the most popular methods used for mood regulation (DeNora, 1999; Saarikallio & Erkkilä, 2007).

Mood congruency theory claims that there is congruence between a person's mood and their behavioural responses related to that mood (Elliot, Rubinsztein, Sahakian, & Dolan, 2002; P. A. Lewis, Critchley, Smith, & Dolan, 2005; Mayer, Gaschke, Braverman, & Evans, 1992); see Blaney (1986) for a review. Studies on memory, for example, show mood congruent memory facilitation; the recall of positive information is better during positive moods while negative moods improve the recall of negative information (Elliot et al., 2002). Forgas and Bower (1987) further showed that people are judged more positively when participants were in a happy state. Additionally, it has been found that music closer to the current state (e.g., music that enhances or maintains the current state rather than changing it completely), increases the success level of the induction procedure, as measured with mood ratings (Albersnagel, 1988; Gerrards-Hesse et al., 1994).

The mood regulation theory and the mood congruency theory lead to different predictions of musical mood changes from an uplifting to a calm mood during high demand driving situations. According to the mood regulation theory it would be expected that music which changes mood abruptly would be most efficient in calming the driver, because uplifting happy music would be inconsistent with the mood goal during high demand driving as it may be expected to be too demanding. Therefore, the mood goal would be to achieve a calm mood with music selection being the method to accomplish this goal. Conversely, according to the mood congruency theory it would be expected that mood would be most efficiently changed gradually, because music more compatible with the current state would be preferred most and therefore have a stronger influence on mood. Hence, more gradual changes in mood would steer a person towards a calm state more efficiently. The present study compares abrupt and gradual strategies to investigate how music can be selected to most efficiently direct a driver towards a more calm state in high demand driving situations.

To test this, a situation consistent with an everyday listening situation was created in which participants' favourite happy music was played while driving in high demand situations. After a while, the music was changed either gradually or abruptly to induce a calmer mood. As negative valence low energy mood (i.e., sad) is the calmest mood, this mood was chosen as the calm state in the current experiment (Wilhelm & Schoebi, 2007). The effect of the music was assessed with self-reported measurements, physiological responses, and driving performance. Physiological measurements were incorporated to capture the continuous changes in mood induction that would remain unnoticed in self-reporting. The most efficient strategy for achieving a calm mood would be reflected in quicker physiological relaxation. This would be shown by lower skin conductance levels (Boucsein, 1992; Sloboda & Juslin, 2010; Van der Zwaag & Westerink, 2012), and less facial zygomaticus and more corrugator muscle tension in a low valence calm state (Lundqvist et al., 2009; Khalfa et al., 2008; Witvliet & Vrana, 2007). The most efficient strategy would also be reflected in safer driving which would be shown by fewer accidents while driving in high demand situations.

6.2 Method

6.2.1 Participants and design

Twenty-eight Stanford University students (14 men, age M= 21.7 years, SD= 1.3 years, 14 women, age M= 21.3 years, SD= 0.4 years) received course credits for taking part in the study. Music change (abrupt / gradual) was administered as a within-subject factor. The order of the two music change levels was counterbalanced over the participants.

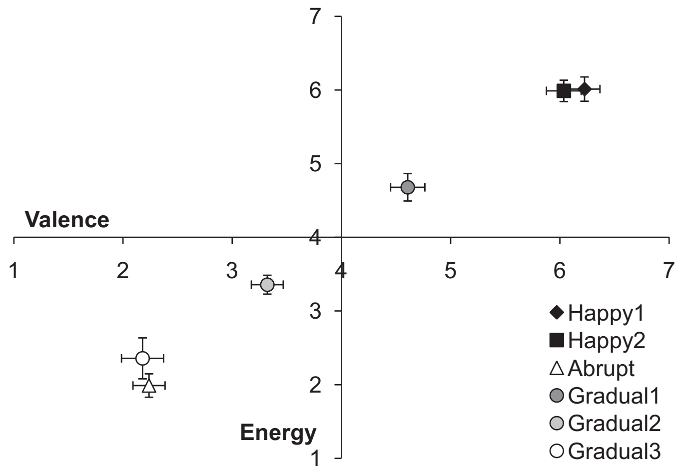


Figure 6.1 – The average ratings of the selected songs for the happy music drives (happy1, happy2) and for the negative valence calm directing (abrupt, gradual) music driving conditions. Error bars represent +- 1 standard error.

6.2.2 Music selection

Prior to the experiment, each participant completed an online music rating session. Because affective reactions to music are highly personal (Juslin & Sloboda, 2010) the music ratings from each participant were used to select sets of song stimuli for that participant. An initial selection of 62 songs for this music rating was based on automatic classification of music features to have examples along all dimensions of the valence-arousal model (Skowronek et al., 2006, 2007). Participants used 7-point Likert scales to rate each song's valence (ranging from unpleasant to pleasant) and energy (ranging from without energy to energetic). For each participant, the six songs with the highest valence and energy ratings were selected for the happy music drives. The three songs with the lowest valence and energy ratings were selected for the abrupt change. Three songs with decreasing valence and energy ratings were selected for the gradual change. More specifically, similar to the music in the abrupt change, the last song was the one with the lowest valence and energy ratings. The first and second songs in the abrupt situations, were selected so that they were 1/3rd and 2/3rds in both valence and energy ratings between the highest and lowest song, respectively. To clarify this, the valence and energy ratings for each condition are presented in Figure 6.1. Each song was adjusted to 2.45 minutes in length so that all songs had the same duration.

To confirm that the songs for the different music states differed in valence and energy ratings, a repeated-measures ANOVA with the six types of selected music was applied to the energy and valence ratings. The results showed significant main effects for both valence ($F(5, 135) = 261.08$, $p < .001$, $\eta^2 = .91$) and energy ratings ($F(5, 5) = 121.33$, $p < .001$, $\eta^2 = .82$). Post-hoc analysis (Bonferroni corrected) showed that all music groups were significantly different in both valence and energy ratings (all $p < .01$) with the following intended exceptions. First of all, the two sets of happy music did not differ significantly (valence $p = .25$, energy $p = .80$). Secondly, the music in the abrupt condition and the third song in the gradual condition did not significantly differ from each other (valence $p = .66$, energy $p = .22$) (see also Figure 6.1).

6.2.3 Simulator and driving conditions

The study was conducted using a STISIM driving simulator (STISim, Hawthorne, CA, USA). This simulator consisted of a fixed-base vehicle mock-up with a functional steering wheel, indicators, pedals, with a 182.9 cm (6 feet) rear projection screen. The simulator was set up in a room with all the windows blacked out to be able to see the screen projection properly.

To induce a high demand drive, the following driving situations were implemented. Firstly, a relatively broad vehicle (2.1 m) with a relatively small road width of 2.9 m, similar to a road under construction) was employed (Dijksterhuis, Kroiß, & De Waard, 2010). Secondly, 40 approaching cars per minute were implemented, with a random interval gap of between 6.1 m and 42.7 m (Dijksterhuis et al., 2010). Thirdly, on average there was one curve per 304.8, with an equal number of left and right curves, with curve lengths of between 121.9 m and 304.8 m. Each curve had a constant radius of between 240 m (easy turn) and 980 m (sharp turn). The simulated road wound through rural scenery and had two uninterrupted lanes.

6.2.4 Measurements

Subjective measurements

Subjective data were collected regarding the participant's mood using the UWIST mood adjective checklist (UMACL; (Matthews et al., 1990). The UMACL was used to assess valence (ranging from unpleasant to pleasant) and energy (ranging from tired to full of energy) on 7-point Likert scales. Mental effort was verified after each drive with the rating scale for mental effort (RSME; (Zijlstra, 1993). Values between 0 and 150 could be indicated with 0 signifying 'almost no effort' and 150 signifying 'extreme effort' invested.

Physiological measurements

Physiological measurements were done continuously during the experiment using Nexus-10 equipment (Mind media BV, Roermond, the Netherlands). Skin conductance was measured with a sample frequency of 128 Hz using dry finger electrodes, which were attached to Velcro strips. The electrodes were strapped around the index and middle fingers of the non-dominant hand (Cacioppo et al., 2007). Skin conductance was preprocessed with a low-pass IRR filter: 0.5 Hz. The mean skin conductance value was taken as the skin conductance level (SCL).

Facial muscle tension of two sets of muscles, the Corrugator Supercilii (frown muscle) and the Zygomaticus major (smile muscle), were measured following the guidelines of Fridlund and Cacioppo (1986). The EMG signal was sampled with 1024 Hz and preprocessed with a high-pass (20 Hz) and band stop notch filter (48-52 Hz) to remove low frequency artifacts and 50 Hz interference. The signal was then rectified, time integrated, and divided by the duration of the segment to obtain the mean rectified voltage (MRV) (Fridlund & Cacioppo, 1986)).

Driving parameters

Several driving parameters were extracted during the drive. The number of accidents indicates all accidents when the driver's vehicle collided with another vehicle plus the number of times a crash occurred after the driver's vehicle left the road. The number of line crossings indicated the number of times the vehicle crossed the centre line or road edge. Lastly, the speed was recorded in miles per hour.

6.2.5 Procedure

During the session in the lab the participants were seated in the driving simulator and connected to the physiological sensors. From there on, instructions and questionnaires were presented on a standalone laptop. The participants then watched a coral sea diving video for six minutes to acquire the physiological baselines measurements, after which they filled out the UMACL (Piferi et al., 2000). The participants then started driving in the high demand situation for eight minutes while listening to the happy music. The participants were explicitly asked to drive as they would normally drive. After filling out the UMACL and the RSME, a second high demand eight minute drive started during which the music changed in one of two ways according to which situation the participant was in at that moment: either three very calm songs were played for the abrupt condition, or three songs increasing in calmness were played for the gradual condition. The UMACL and the RSME were again administered. Finally, the participants repeated the baseline period, two drives, and all questionnaires in a second cycle with the music change condition that they had not received before. A diagram of the procedure is presented in Figure 6.2.

6.3 Results

6.3.1 Subjective measurements

Mood

Reaction scores were calculated for the happy music drive by subtracting the ratings obtained after the baseline from the ratings obtained after the happy music drive.

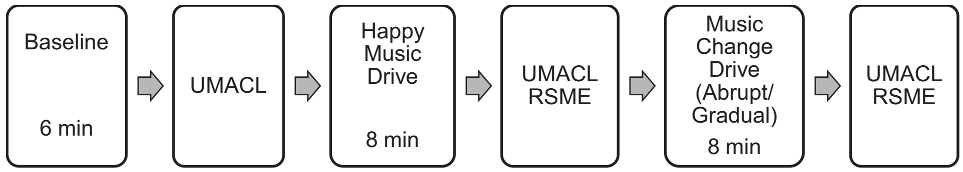


Figure 6.2 – This figure represents the procedure for one block of the experiment. This block was repeated once in the experiment with the music change (abrupt, gradual) as the only difference.

To test if the mood scores did not differ based on the trial order a repeated-measures MANOVA with Trial number (first, second) was applied to the valence and energy reaction ratings obtained after the happy music drives. The results showed a nearly significant main effect for valence but not for energy (Valence; $F(1, 27) = 5.39$, $p = .08$, $\eta^2 = .23$, Energy: $F(1, 27) = 0.01$, $p = .97$, $\eta^2 = .01$). Post-hoc analysis revealed lower valence ratings during the first happy drive compared to the second happy drive; valence first $M = -.25$, $SE = .18$, second $M = .37$, $SE = .14$; energy first $M = .13$, $SE = .16$, second $M = .13$, $SE = .18$.

Music change reaction scores were calculated by subtracting the ratings after the pleasant drives from the ratings after the music change drives (Llabre et al., 1991). To test whether the music change situations differed in the mood scores a repeated-measures MANOVA with Condition (Abrupt, Gradual) as within-subject factor and Order (Abrupt-Gradual, Gradual-Abrupt) as between-subject factor was applied to the valence and energy reaction ratings. The results did not show significant differences in mood between the music change conditions (Condition, Valence; $F(1, 26) = 1.76$, $p = .20$, $\eta^2 = .06$, Energy: $F(1, 26) = 1.25$, $p = .27$, $\eta^2 = .05$; for Order and Order with Condition $p > .50$). The average mood change scores were the following: Valence Gradual $M = -.54$, $SE = .19$, Abrupt $M = -.88$, $SE = .15$; Energy Gradual $M = -.94$, $SE = .15$, Abrupt $M = -1.17$, $SE = .18$.

RSME

To test if equal amounts of effort were invested in the two drives with happy music a repeated-measures ANOVA with Trial number (first, second) as the within-subject factor was applied to the RSME scores obtained after the happy music drives. The results showed a main effect of Trial number ($F(1, 27) = 5.9$, $p < .025$, $\eta^2 = .18$). Higher effort ratings were given during the first ($M = 66.04$, $SE = 5.9$) compared to the second happy music drive ($M = 56.71$, $SE = 4.9$).

To test if the effort invested in the music condition drives was different, a repeated-measures ANOVA with Condition (Abrupt, Gradual) as within-subject factor and Order (Abrupt-Gradual, Gradual-Abrupt) as between-subject factor was applied to the RSME ratings obtained after the music change drives. No significant effect was found on RSME for Condition but only for Order ($F(1, 26) = 169.06$, $p < .001$, $\eta^2 = .87$), all other $p > .037$. The average RSME values were as follows: Abrupt $M = 59.95$, $SE = 4.69$, Gradual $M = 64.51$, $SE = 6.04$.

6.3.2 Physiological measures

Due to a malfunction of the physiological equipment, the data of five participants had to be omitted from the physiological analyses. This left a sample of N=23 for these analyses.

Skin conductance level

A repeated-measures ANOVA of Trial number (first, second) was applied to the SCL values in μSiemens obtained during the last three minutes of the drive, as it was assumed that the moods were fully induced by that time (Van der Zwaag & Westerink, 2012). As expected, the results did not show a significant difference in SCL between the two happy music drives $F(1, 22) = 42$, $p = .53$, $\eta^2 = .02$. Mean values were as follows: first $M = 3.23$ μSiemens, $SE = .28$ μSiemens, second $M = 3.16$ μSiemens, $SE = .24$ μSiemens. These happy music drives were then taken as a baseline period. The SCL values obtained during the situations where the music changed were therefore normalised with z-transformation using the mean and standard deviation of the last three minutes of the happy music drives (Boucsein, 1992).

To test the effect of music change on SCL a repeated-measures ANOVA with Condition (Abrupt, Gradual) and Time (minute 1 till 8) as within-subject factors and Order (Abrupt-Gradual, Gradual-Abrupt) as between-subject factor was applied to the SCL. Significant main effects were found for Condition ($F(1, 22) = 9.91$, $p = .005$, $\eta^2 = .31$) and Time ($F(7, 16) = 4.05$, $p = .010$, $\eta^2 = .64$) and not for any other effect (all $p > 0.1$). Post-hoc comparisons of Conditions showed higher SCLs in the gradual compared to the abrupt condition (see Figure 6.3 for means and SEs). The post-hoc analysis of Time showed that the SCL was higher in the first three minutes compared to all other minutes. This indicates that the SCL stabilised from the fourth minute onwards.

Facial EMG

To test whether the EMG activity differed between the happy music drives, a repeated-measures MANOVA with Trial number (first, second) as within-subject factor on the EMGz and EMGc was applied using the data obtained during the last three minutes of the happy music drive. The results did not show significant differences between the Music conditions; EMGz $F(1, 21) = .11$, $p = .74$, $\eta^2 = .01$, EMGc $F(1, 21) = 4.38$, $p = .83$, $\eta^2 = .01$. Mean MRV values were as follows: EMGz first $M = 7.36$, $SE = 3.4$, second $M = 6.56$, $SE = 1.90$, EMGc first $M = 14.39$ $SE = 4.07$, second $M = 15.04$, $SE = 4.78$. EMG reaction responses were calculated by taking the percentage change in MRV of the music change drive from the last three minutes of the

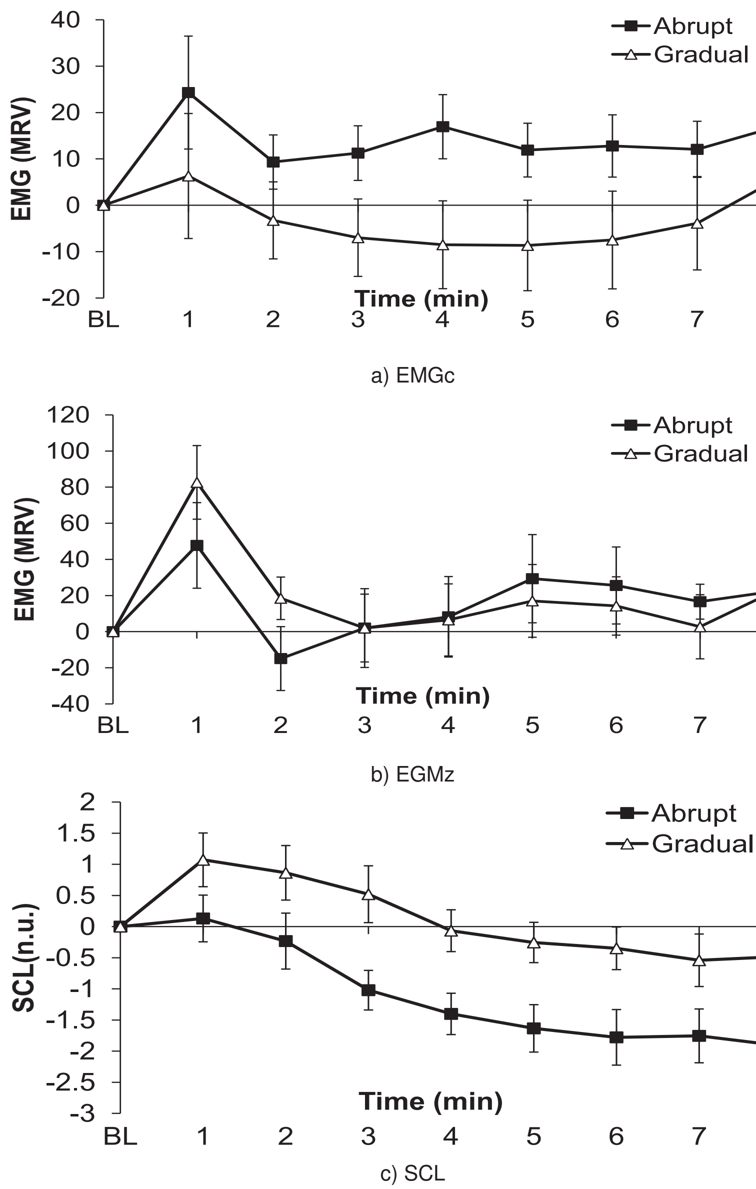


Figure 6.3 – The means and standard errors of the physiological measurements of the facial muscles corrugator (Panel a) and zygomaticus (Panel b) and skin conductance level (SCL; Panel c) during the abrupt and gradual mood change conditions. The horizontal axis shows the induction time in minutes, and the vertical axis shows either the normalised SCL scores, or the MRV values adjusted for the baseline physiological measurements. Error bars represent +- 1 standard error, BL= baseline.

happy music drive that immediately preceded the music change drive (Fridlund & Cacioppo, 1986).

To test whether the EMG activity differed during the two music change drives, a repeated-measures MANOVA with Condition (Abrupt, Gradual) and Time (average for each minute; minute 1 - 8) as the within-subject factors and Order (Abrupt-Gradual, Gradual-Abrupt) as the between-subject factor was applied to the zygomaticus and corrugator MRV reaction responses. The results showed a significant main effect of Condition for EMGc but not for EMGz (see Figure 6.3); EMGz $F(1,21) = .04$, $p = .85$, $\eta^2 = .01$, EMGc $F(1,21) = 6.37$, $p = .02$, $\eta^2 = .23$. Post-hoc comparisons showed that the EMGc muscle tension was higher during the abrupt condition compared to the gradual music change drive. A main effect of Time was also apparent for the EMGz ($F(7,147) = 3.32$, $p = .003$, $\eta^2 = .14$). Post-hoc analysis of this main effect showed that the effect can be explained by the first minute of the drive; as it is significantly higher than compared to all other minutes. No interaction effect of Condition with Time $F(7,147) = .44$, $p = .57$, $\eta^2 = .04$) was found for the EMGc. Post-hoc analysis of this interaction, however, showed that the EMGc is significantly more contracted in the abrupt compared to the gradual condition in the third to the fifth minutes ($p < .02$), and marginally significantly higher during the sixth minute ($p < .07$). No other significant main or interaction effects were found.

Driving data

A repeated-measures MANOVA was applied to the driving parameters obtained during the happy drives with Trial number (first, second) as the within-subject variable. The results showed significant main effects for all three parameters; Accidents $F(1,27) = 6.68$, $p = .016$, $\eta^2 = 0.20$; Line crossings $F(1,27) = 7.56$, $p = .011$, $\eta^2 = 0.22$; Speed $F(1,27) = 6.8$, $p = .015$, $\eta^2 = 0.21$. No other significant main or interaction effects were found. Mean values for the driving parameters were as follows: Accidents first $M = 4.69$, $SE = .57$ second $M = 3.30$, $SE = .59$; Line Crossings, first $M = 39.46$, $SE = 3.46$, second $M = 31.78$, $SE = 3.26$; Speed, first $M = 44.81$ mi/h, $SE = .83$, second, $M = 46.54$ mi/h, $SE = 1.01$.

Subsequently, driving reaction scores were calculated by subtracting the driving parameters obtained during the happy music drives from the driving parameters obtained during the music change drives (Llabre et al., 1991). A repeated-measure sMANOVA with Condition (Abrupt, Gradual) as the within-subject factor and Order (Abrupt-Gradual, Gradual-Abrupt) as the between-subject factor was applied to the driving parameter reaction scores. A significant main effect of Condition on the number of accidents and marginally significant effects of the number of line crossings and the speed were found: Accidents $F(1,26) = 4.97$, $p = .035$, $\eta^2 = 0.16$, Line Crossings $F(1,26) = 3.04$, $p = .093$, $\eta^2 = .11$; Speed $F(1,26) = 3.09$, $p = .091$, $\eta^2 = 0.11$. See Figure 6.4 for the means. Post-hoc analysis show fewer accidents, line crossings, and lower speed reaction scores during the abrupt compared to the gradual condi-

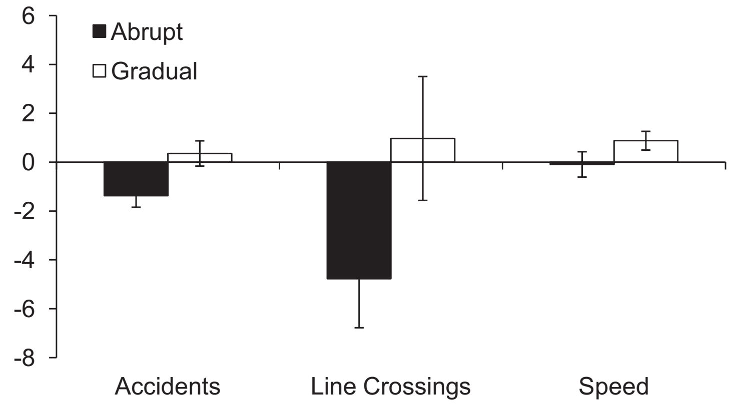


Figure 6.4 – The means and standard errors of the driving performance reaction scores in terms of number of accidents, line crossings and speed (mi/h). Error bars represent +- 1 standard error.

tion. No other significant main or interaction effects were found. Mean values of the driving reaction scores are as follows: Accidents, gradual $M = .35$, $SE = .52$, abrupt $M = -1.38$, $SE = .47$; Line crossings, gradual $M = .97$, $SE = 2.5$, abrupt $M = -4.78$, $SE = 2.01$; Speed, gradual $M = .88$ mi/h, $SE = .38$, abrupt, $M = -.09$ mi/h, $SE = .52$ (see also Figure 6.4).

6.4 Discussion

People are used to listen to their favourite music while driving (Brodsky, 2001). Playing happy music in combination with high demand driving situations may be difficult for a driver, leading to physiological stress and reduced driving safety (Dibben & Williamson, 2007). The present study examined how music can best be selected to calm a relatively happy mood state of a driver most effectively. Predictions were made based on the mood regulation theory and the mood congruency theory. Accordingly, during a high demand drive with the participants' favourite music, the music was changed in an abrupt (mood regulation theory) or gradual (mood congruency theory) manner to a negative valence calm state. The results showed that music directed mood in the expected direction. The effort ratings further indicated that the drives were completed with considerable effort investment. Physiological responses showed lower physiological energy levels, reflected by lower skin conductance levels, and higher negative valence, reflected by more facial corrugator muscle tension, when the music was abruptly compared to gradually changed towards a negative valence calm state. Fewer driving mistakes were also made when music was abruptly changed to calm the driver. Altogether, this study shows that abrupt music changes changed moods most efficiently, thereby supporting the mood regulation theory.

The mood ratings indicated that the music during driving successfully induced the targeted mood states. As expected, no noticeable differences were found in the subjectively indicated mood after the drive with the gradual or the abrupt music changes to a calm state. This can be explained by the fact that the last song in both manipulations (abrupt and gradual) had equal valence and energy ratings and the subjective ratings took place at the end of each driving session. Hence, the participants ultimately arrived at the same relatively negative calm mood state, regardless of how the music in between was selected.

To be able to indicate how moods changed during the drive, physiological responses were tracked to continuously monitor the participants' state. As expected, SCLs were higher when the music was changed gradually compared to abruptly. SCLs are related to the body's sympathetic nervous system and increase when a person is more energised (Boucsein, 1992). Hence, the results imply that the abrupt music changes calmed the participants faster and more effectively. These results agree with the music that was presented in the gradual condition, having higher energy ratings on average. It should also be noted that even though in the gradual condition the last song had equal valence and energy ratings to the song in the abrupt music condition, the SCL values remained higher during the last part of the drive. Mood congruent gradual music changes therefore lead to higher physiological arousal for a longer period, and abrupt music changes (mood regulation) lead to faster physiological calmness.

More expression of the corrugator facial muscle was shown when the music was changed abruptly compared to gradually. This implies that participants experienced higher negative valence throughout the drive where the music was changed abruptly to a calmer negative valence state (Witvliet & Vrana, 2007). During the last two minutes of the drive, the tension of the corrugator muscle did not significantly differentiate between the gradual and abrupt conditions anymore. This implies that the corrugator muscle responded to the changes in music, leading to equal corrugator muscle tension in the two conditions by the end of the drive. This is in line with the music presented and the subjective valence scores that were both equal at the end of the gradual and abrupt music change drives. All in all, the EMG corrugator activity indicates that a driver remains happier for a longer time period when music valence and energy is changed in a gradual (mood congruent) rather than in an abrupt manner to a calm state.

The zygomaticus muscle, which has been related to positive valence, did not significantly differentiate between the two music states. This could be because the participants were driving in a high demand situation during the music mood change induction. The attention needed for the demanding drive could have overshadowed the affective expression of this facial muscle (Tassinary, Cacioppo, & Vanman, 2007). This might also account for the fact that the activity during the change conditions was comparable during happy music condition, which served as a baseline.

Further insight into the effects of the music changes was gained by analysing the driving performance. Fewer accidents, line crossings, and lower speed were observed when music changed in the quickest, most abrupt compared to gradual way to calm the driver's mood. These results are in line with Brodsky (2001), who showed that slower tempo music decreased the number of driving errors.

The influence of music on driving performance may be explained by the fact that the musically-evoked energy levels can compete with the attention resources needed for the driving task (Dibben & Williamson, 2007; Konečni, 1982). The higher energy, or activation, the music induces, the more it competes for the attention resources available for driving. This is particularly dangerous in high demand driving situations where the limit of attention resources may be reached (North & Hargreaves, 1999).

In this study, the music presented to abruptly calm driver mood had lower overall energy levels compared to the gradual music change situation. Corresponding to this, the physiological activation of the driver was lower when the music was switched abruptly to calm the driver, as shown by lower SCLs from the first minute of the drive onwards. Hence, when music is changed abruptly (mood regulation) to alter the driver's mood to a calmer state, the driver becomes calmer more quickly and for a longer time. This could be the reason for the improved driving performance in this abrupt music change condition.

Only young people, students, took part in this study. This could have caused a bias in the results as they tend to take more risks and therefore might have made more errors. The current study could therefore be replicated with an older target group. A simulator was also used to mimic high demand driving situations. The external validity could be further enhanced by studying the influence of in-car music listening on mood, body responses, and driving performance in a real car on the motor-way.

The current results may be useful for professionals who need to spend much of their time on the road. An intelligent music player that detects driving demand and mood from physiological measurements, for example, could be envisaged for this purpose (Janssen et al., 2009; Van der Zwaag, Westerink, & Van den Broek, 2011). This music player could generate a playlist based on the current mood state of the driver to optimise driver mood and hence driving safety. Such a music player could also be beneficial in many other application scenarios e.g., during office work (Lesiuk, 2005), to calm surgeons (Ullmann et al., 2008), or to reduce patient anxiety (Van der Zwaag, Tijs, Westerink, & Molegraaf, 2011).

To conclude, the present study showed that music presentation and music changes while driving can steer drivers' experienced mood, physiological responses, and driving performance. While valence remains higher for a longer period during gradual changes, abrupt changes in music to calm drivers proved to be most effective, thus providing support for mood regulation theory rather than mood congruency theory. Abrupt changes also generate safer driving conditions. Hence, intelligent music selection systems could be envisaged to improve driving performance and decrease physiological stress while driving.

Based on: Van der Zwaag, M. D., Fairclough, S. H., Spiridon, E, & Westerink, J. H. D. M. (2011). The impact of music on affect during anger inducing drives. In S. DMello et al. (Eds.) *Proceedings of the 4th International Conference on Affective Computing and Intelligent Interaction (ACII), Part I, LNCS 6974,* pp. 407-416, Springer, Heidelberg.

Chapter 7

The impact of music on affect during anger inducing drives

Driver anger could be potentially harmful for road safety and long-term health. Because of its mood inducing properties, music is assumed to be a potential medium that could prevent anger induction during driving. In the present study the influence of music on anger, mood, skin conductance, and systolic blood pressure was investigated during anger inducing scenarios in a driving simulator. One hundred participants were split into five groups: four listened to different types of music (high/low energy in combination with both positive/negative valence) or a no music control. Results showed that anger induction was greatest during high energy negative music compared to positive music irrespective of energy level. Systolic blood pressure and skin conductance levels were higher during high energy negative music and no music compared to low energy music. Music was demonstrated to mediate the state of anger and therefore can have positive health benefits in the long run.

7.1 Introduction

The experience of anger is a relatively common emotion for many drivers (Mesken, Hagenzieker, Rothengatter, & De Waard, 2007; Underwood et al., 1999). The inconsiderate behaviour of other road users coupled with natural sources of frustration, such as being lost or encountering traffic jams may combine to induce negative emotional experiences while driving. Driver anger may stem principally from several sources: uncertainty due to the erratic behaviour of others (e.g., drivers who brake and slow down for no apparent reason), shock/surprise due to driver error (e.g., turning without signalling) or recklessness (e.g., high speeds, vehicles cutting across the path of one's own vehicle) and frustration due to obstacles (e.g., slow moving traffic, diversions or getting lost) (Van der Hulst, Meijman, & Rothengatter, 2001).

The function of anger is to regulate body processes related to self-defence and social behaviours (Lemerise & Dodge, 2010). In real terms, this means that anger may serve a function in removing obstacles to task goals. Feelings of anger may be classified as 'unhealthy' emotions as these episodes are associated with increased cardiovascular reactivity and a heightened response from the sympathetic nervous system. This is not to say that episodes of anger constitute a health risk as such, but rather that repeated exposure to increased anger and cardiovascular reactivity represents a form of wear and tear on the human body that may have a cumulative effect on health in the long-term (Mauss, Cook, & Gross, 2007).

Music is able to influence mood, directing it to a wide variety of states from elation and relaxation, to sadness (Juslin & Sloboda, 2010). The pleasurable effects of music may be shown through affect. Hence, changing affect has been mentioned as one of the most important functions of music. Music, for example, has been shown to reduce anxiety in hospital environments (MacDonald et al., 2003), and several negative emotions were reduced as a result of music therapy (Juslin & Sloboda, 2010). The changes in affect due to music have also been linked to physiological changes. Arousing music, for example, has been found to increase sympathetic nervous system activity as shown by skin conductance (Rickard, 2004). Music has further been found to reduce skin conductance levels during sad low energy music (Krumhansl, 1997; Salimpoor, Benovoy, Longo, Cooperstock, & Zatorre, 2009).

Listening to music while driving is a common activity (Dibben & Williamson, 2007) which may influence behaviour and mood states. Brodsky (2001) described how listening to high tempo house music increased driving speed. It has additionally been found that listening to self-selected music compared to no music decreased stress while driving (Wiesenthal et al., 2000). Music listening compared to a no music situation lowered aggression during driving with time urgency (Wiesenthal et al., 2003). People listen to music while driving because music influences affect and music distracts from the relative monotony of the driving task. The distraction provided by music might direct attention away from the sources of negative events in the road environment, thereby facilitating recovery from anger or frustration. Music may affect the mood state of the individual by influencing the level of activation or by inducing positive or negative changes in mood valence.

The current study was designed to examine how the emotional properties of music (energy and valence) may impact on the psycho-physiological status of an angry driver during a simulated journey. The study thus followed the dimensional approach of subdividing mood into two (valence and energy) dimensions (Russell, 1980; Wilhelm & Schoebi, 2007). Five groups of participants completed a short journey under time pressure during which they encountered a number of obstacles, such as traffic jams. Four of the groups were presented with music, which could be described as high energy/positive valence (i.e., activating, joyful music), low energy/positive valence (i.e., calming, relaxing music), high energy/negative valence (i.e., activating, angry music), low energy/negative valence (i.e., calming, sad music). A fifth group was included in the study as a control group who did not hear any music during the simulated journey.

7.2 Method

7.2.1 Participants

Each group of participants included 20 volunteers (10 males, 10 females) amounting to 100 participants in total. The mean age of the participants was 21.2 years ($s.d. = 4.7$ years). Each participant received a £ 20 voucher for taking part.

7.2.2 Design

The actual experiment consisted of two sessions. In the first session music was rated via the internet at the participants' convenience which took approximately 60 minutes. The control group also completed this session. The purpose of this initial session was to personalise the music choice of those individuals in the four music groups: HE/PV = high energy/positive valence, LE/PV = low energy/positive valence, HE/NV = high energy/negative valence, LE/NV = low energy/negative valence. The second session took approximately 60 minutes in a laboratory and involved a baseline measurement, a mood induction session, and driving in a simulated environment while attached to psycho-physiological sensors.

7.2.3 Music selection

Via an online questionnaire participants were asked to rate 80 songs (preselected on valence and energy levels using algorithms (Skowronek et al., 2006, 2007)) on their expressed valence (unpleasant to pleasant) and energy (without energy to energetic) levels on 7-point Likert scales. Participants were asked to listen to each song at different places within the song to get a good impression of the song. For each participant the 10 songs with the highest rating in their mood state were selected: i.e., for a participant in the positive high energetic HE/PV condition songs with the highest scores for valence and energy were selected. The average valence (V) and energy (E) ratings of the selected song stimuli per music state were as follows: LE/PV $E = 3.5$, $V = 5.1$, HE/PV $E = 6.6$, $V = 6.7$, LE/NV $E = 1.3$, $V = 1.8$, HE/ NV $E = 5.1$, $V = 1.8$.

7.2.4 Anger drive

To induce anger during the simulated drive the following manipulations were made, adapted from Van der Hulst et al. (2001). In the first place, drivers experienced time pressure during the simulated journey in that they had to complete the drive within eight minutes. In addition, they were told there was a monetary incentive to complete the journey in time (an additional £ 10 bonus). However, participants could be fined for speeding (i.e., exceeding the speed limit by 10 % incurred a £ 2 fine) and they were informed that they would lose 70 % of their £ 20 payment if they crashed the car more than twice. During the drive, participants were exposed to a number of discrete obstacles, such as traffic lights that always turned red on their approach; drivers also encountered a number of vehicles that accelerated and decelerated in a sinusoidal pattern at a certain point with traffic coming in the opposite direction, preventing any attempt to overtake. The drivers also encountered two traffic jams that effectively prevented them from completing the journey on time. The first traffic jam was encountered early in the drive and lasted approximately two minutes. The second traffic jam was encountered at the end of journey and lasted approximately two- to three minutes.

7.2.5 Dependent variables

The STAXI was used to verify anger induction (Spielberger, 1999). The UMACL was used to assess valence, energy, and calmness of mood dimensions (Matthews et al., 1990). The physiological responses of skin conductance were recorded continuously during the drive. Skin conductance measurements were taken using dry finger electrodes attached to Velcro strips. The electrodes were strapped around the index and middle fingers of the non-dominant hand (Cacioppo et al., 2007). Blood pressure was measured using a band around the upper arm. Blood pressure was measured after the baseline, after the induction, in the third minute, the sixth minute, and at the end of the drive.

7.2.6 Procedure

Prior to the experiment participants were randomly assigned to one of the five music conditions, although they were not aware of which condition. Awareness that musical mood induction would take place could have severely influenced the results. The music selection part took up to an hour prior to attending the laboratory. In the lab, after signing the informed consent form, participants were seated in the car and the physiological measuring equipment was attached. A baseline period then commenced in which the participants were asked to relax and watch an aquatic video for eight minutes (Piferi et al., 2000). The data acquired during this time provided the baseline measurements. The participants were then asked to listen to the music presented for six minutes. To ensure that the participants paid attention to the music they were told that questions would be asked about the music at the end of the experiment. After the baseline period and again after the music listening, participants completed the STAXI and UMACL. Participants were then given written instructions on the driving task on paper in which they were told that they had to take some children to school in an eight minute drive. It was emphasised that it was important to arrive on time as the children had an exam and they would not be allowed to start the exam if they arrived too late. The monetary penalties for road offences were made clear. If the participants had no further questions the drive began. During the drive music from one of the five groups was presented. After twelve minutes the drive was stopped and the STAXI and UMACL were presented for completion. Finally, there was a recovery period in which the participants were given the debriefing form and the money voucher. Participants were informed that the time pressure and driving offences did not affect their reward. Lastly, the physiological sensors were detached and the participants were thanked for taking part.

7.3 Results

A univariate ANOVA model with Music (HE/PV, LE/PV, HE/NV, LE/NV) as the within-subject factor in SPSS v.17 was applied to all the data to test for between-group differences. Reaction scores for the UMACL and the STAXI were calculated by subtracting the scores obtained after the baseline from the scores obtained after the induction or task performance. The baseline values were as follows: valence M=5.45 (SE=.007), energy M=3.37 (SE=.007), STAXI M= 1.03 (SE = .01).

7.3.1 Subjective self-report

The STAXI reaction scores obtained after the mood induction showed a significant main effect of Music ($F(4, 95) = 5.02$, $p < .01$, $\eta^2 = 0.18$). Post-hoc tests showed more anger in the High Energy/Negative Valence music condition compared to all other music types.

Analysis of the STAXI reaction scores obtained after the drive also revealed a significant main effect for Music $F(4, 95) = 5.02$, $p < .01$, $\eta^2 = 0.18$). Post-hoc tests showed that subjective anger was significantly greater in the High Energy/ Negative Valence music condition compared to either the High Energy/ Positive Valence or the Low Energy/ Positive Valence music types ($p < .05$). Mean values for the STAXI data are shown in Figure 7.1.

Analysis of the UMACL reaction scores obtained after the mood induction showed a significant main effect of Music ($(12, 285) = 9.37$, $p < .01$, $\eta^2 = 0.28$). Univariate effects showed significance for valence, energy, and calmness ($p < .001$). Post-hoc tests showed higher valence levels in the positive compared to the negative music

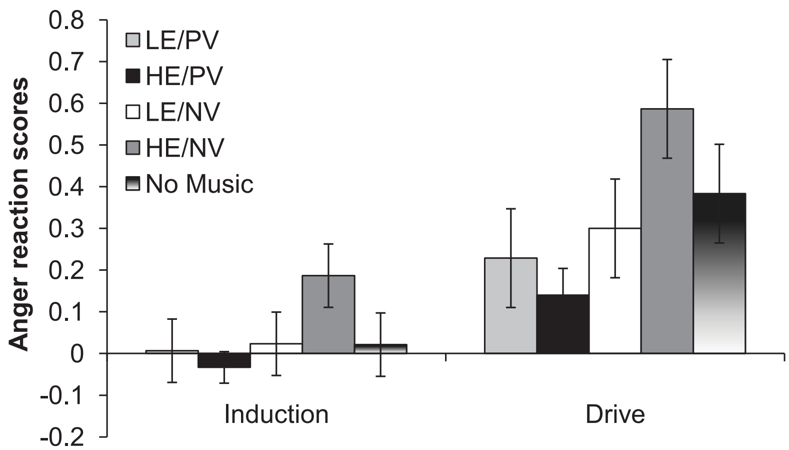


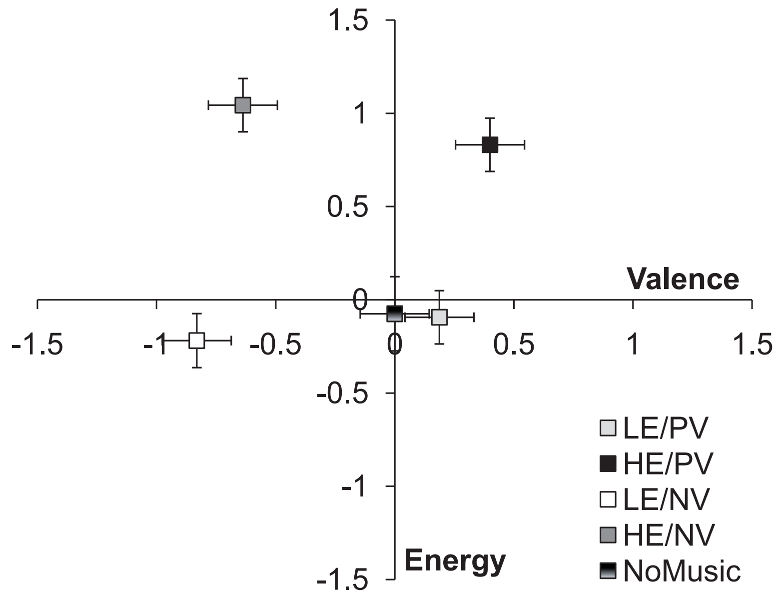
Figure 7.1 – The average STAXI reaction scores obtained after the mood induction and after the drive. Note: HE = high energy, LE = low energy, PV= positive valence, NV = negative valence. Error bars represent +- 1 standard error.

conditions. The no music condition also had higher valence levels compared to the negative music conditions (all $p < .01$). Energy ratings were higher in the high energy music conditions compared to the low energy music conditions and the no music condition (all $p < .01$).

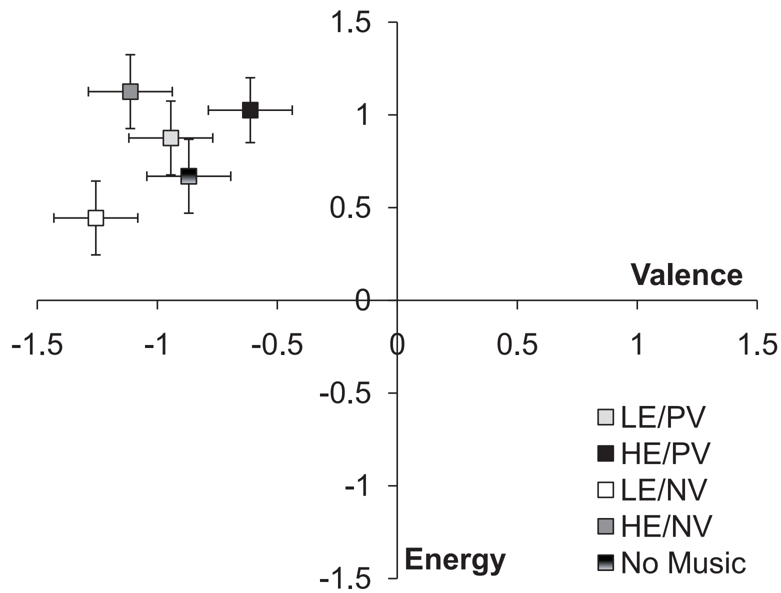
Analysis of the UMACL reaction scores obtained after the simulated drive showed a significant main effect of Music ($F(12, 285) = 2.37$, $p < .01$, $\eta^2 = 0.09$). No significant univariate main effects were found (valence $p = .11$, energy $p = .12$, calmness $p = .06$). Post-hoc tests revealed that High Energy/ Positive Valence music induced higher valence levels than High and Low Energy / Negative Valence music (HE/NV $p = .04$, LE/NV $p = .01$). Low Energy / Negative Valence music induced lower energy levels than High Energy / Positive and Negative Valence music (HE/PV $p = .04$, HE/NV $p = .02$). Calmness levels were lower during High Energy/ Negative Valence music compared to all other music types (HE/PV $p = .010$, LE/PV $p = .01$, LE/NV $p = 0.1$). Calmness averages were as follows; HE/PV $M = -1.16$, LE/PV $M = -1.06$, HE/NV $M = -1.89$, LE/NV $M = -1.08$, NoMusic $M = -1.34$. See Figure 7.2 for the UMACL reaction scores.

7.3.2 Autonomic variables

The skin conductance level and systolic blood pressure data were averaged across the mood induction and the driving task and an ANOVA analysis was carried out.



a) Induction



b) Drive

Figure 7.2 – The reaction scores of valence and energy obtained after mood induction and after the drive. Note: HE = high energy, LE = low energy, PV= positive valence, NV = negative valence. Error bars represent +- 1 standard error.

Skin conductance level

The skin conductance level was measured continuously throughout the experiment. The data was adjusted for the baseline measurement using a z-transformation. For this normalisation the mean and standard deviation obtained during the baseline were taken. An ANOVA with Music as the between-subject variable was applied to the normalised SCL values during the mood induction and showed a main effect of Music ($F(4,94) = 2.71$, $p = .034$, $\eta^2 = 0.10$). Post-hoc analysis showed that the High Energy Music states have higher normalised SCL values compared to the Low Energy Music conditions and the no music condition. The results of the ANOVA applied to the normalised SCL data obtained during the drive did not show a significant main effect of Music ($F(4,93) = .86$, $p = .49$, $\eta^2 = 0.36$). To more specifically investigate the effect of the energy mood dimension on SCL, a repeated-measures ANOVA with Music Energy (LE/ HE/ No) was applied to the SCL during the drive. The results did not show a main effect of Music Energy ($F(2,95) = .28$, $p = .27$, $\eta^2 = 0.27$). Pairwise comparisons showed that the High Energy Music resulted in marginally higher SCL compared to the Low Energy Music ($p = .11$). See Figure 7.3 for the means of the normalised SCL values obtained during the drive.

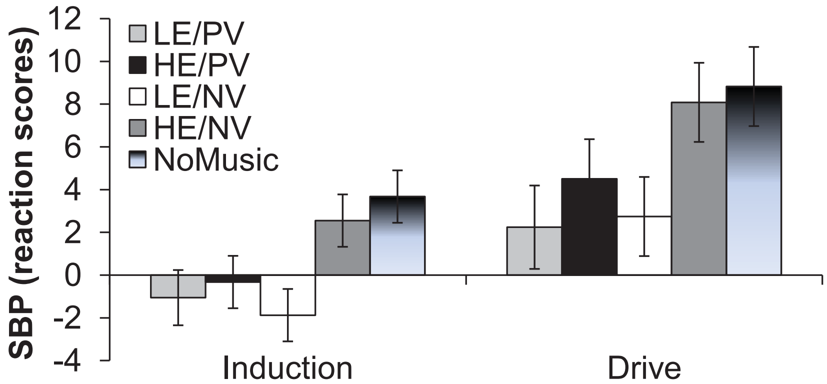
Systolic blood pressure

Blood pressure was recorded on several occasions during the simulated journey. The data from systolic blood pressure obtained during the simulated drive were adjusted for the baseline by subtracting the baseline values from that recorded after the induction and during the drive, i.e., positive systolic reactivity indicated increased blood pressure during the drive. Separate ANOVA analyses were applied to these systolic reactivity measurements. A main effect of Music was found on the systolic reactivity for the systolic data obtained at the end of the induction ($F(4,93) = 3.77$, $p < .01$, $\eta^2 = 0.14$). Post-hoc comparisons showed higher systolic reactivity in the no music condition and the HE/NV group compared to all other conditions (all $p < .02$), with the exception of the HE/NV and HE/PV conditions.

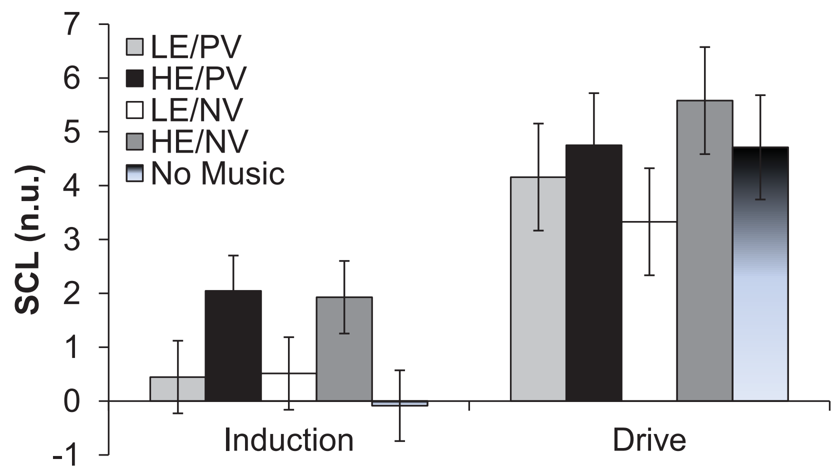
The analysis of systolic blood pressure reactivity during the drive revealed a significant main effect for Music ($F(4,93) = 2.61$, $p < .041$, $\eta^2 = 0.11$). Post-hoc tests showed that systolic reactivity was significantly higher for both HE/NV and No Music drives compared to either LE/PV or LE/NV ($p < .05$). This effect is illustrated in Figure 7.3.

7.4 Discussion

Anger is an emotion which occurs frequently while driving which can lead not only to antisocial behaviour on the road but also bring health risks. Music is known to influence mood and listening to music is also a popular activity while driving. The present study was designed to assess the impact of four categories of music and a no



a) Systolic blood pressure



b) SCL

Figure 7.3 – The average SCL and systolic blood pressure reaction scores obtained during mood induction and the drive. Note: HE = high energy, LE = low energy, PV= positive valence, NV = negative valence. Error bars represent +- 1 standard error.

music condition on psychophysiological and subjective markers of anger and mood while driving. The study showed that different levels of anger were activated during the simulated drives with different types of music. The sympathetic nervous system activity of the systolic blood pressure showed the activating effect of anger on the body while listening to high energy negative valence music or no music. The skin conductance level appeared to be most responsive to moods changes induced, and increases with high energy music. Hence, it was concluded that music can modulate the extent to which anger is induced while driving.

It should be noted that, depending on music type, music directs moods towards a different quadrant of the two-dimensional space representing valence and energy (Figure 7.2). However, moods were not directed towards each direction to the same extent. So, while the four categories of music were distinct and personalised to the individual, it was impossible to direct the valence and energy dimensions of the moods completely independently.

While driving, the induced moods all ended in the negative high energy quadrant implying successful induction towards a high energy negative valence state as was intended by the anger drive. Even though the range of the induced moods decreased from induction to the drive, the moods induced by the different types of music could still be discerned in the valence and energy levels. This result emphasises the ability of music to influence mood, even when music is only listened to in the background. An exception in the current situation is the low energy positive valence music: i.e., for this type of music slightly lower energy and higher valence ratings were expected during the driving. An explanation for this effect can be found in the mood congruency theory; as a more low energetic positive valence mood is the most opposite state to anger (a more high energetic negative valence state) this mood might have been perceived as incongruent to the situation and thereby seen as a negative stimulus. This finding reinforces the argument that the influence of music on mood should be interpreted in the situational context (DeNora, 2000).

The subjective measurement of anger (STAXI) obtained during the mood induction was at its highest during the HE/NV music compared to all other music conditions. The experience of anger during the drive was higher in the HE/NV music condition compared to the HE/PV music condition. The subjective anger also showed a trend towards reduction by HE/PV music relative to the no music condition. Both positive and negative categories of low energy music failed to make any substantial impact on subjective anger relative to the no music control condition. Although the effects of music on the autonomic nervous system were subtle, they were present. It is possible that the impact or stress of the driving task tended to overshadow and thus obscure any autonomic changes due to the different categories of music.

Systolic reactivity is a variable that has been closely associated with beta- adrenergic responses from the sympathetic nervous system (Cacioppo et al., 2007). The analysis of systolic reactivity revealed a significant increase during both the no music control condition and HE/NV music. The effect of the latter did not come as a surprise given the subjective results found. However, the elevation of systolic reactivity during the no music condition requires further explanation. It is proposed that systolic reactivity was increased for the no music control group because in other conditions (except for the HE/NV group) music either enhanced the simulated driving experience or acted as a distraction from the irritating events on the road and the stressful effects of the time pressure. Both categories of low energy music tended to reduce systolic reactivity relative to the no music condition (Figure 7.3), suggesting that beta-adrenergic activity was strongly influenced by the energy component of the music. This interpretation is supported by the trend observed in the normalised SCL data after mood induction, which is also considered as an index of activation, i.e., SCL was increased for both high energy activation categories of music. The relationship between subjective anger and mood, and psychophysiological responses to mood could be further supported and explored with pattern recognition techniques (Picard, 1997; Petta et al., 2011).

On the basis of this study, we conclude that music may alter the subjective experience of anger and mediate the magnitude of the psychophysiological response to anger. It is proposed that music has two effects in the context of this study: firstly, music acts as an overt source of distraction from negative events in the environment and secondly, music exerts a subconscious influence on psychophysiology. People may use music to distract themselves from a monotonous situation (as in the traffic jam scenario) and to divert themselves away from negative thoughts and feelings. It would appear that high energetic negative valence music tends to augment the latter, thus inflating subjective feelings of anger. With respect to the psychophysiology, categories of music with low energetic levels (regardless of valence) appeared to reduce the sympathetic response to anger, which may be a positive adaptation in terms of long-term health.

The study demonstrated that music can mediate the effects of anger in a simulated environment. These findings demonstrate the potential of music to manage mood states and influence those covert psychophysiological states that accompany different moods. It is suggested that music's ability to influence physiology at a subconscious level has the potential to reduce the impact of negative emotion on health in the long term.

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Chapter 8

Directing physiology and mood through music: validation of an affective music player

Music is important in everyday life as it provides entertainment and influences our moods. As music is widely available, it is becoming increasingly difficult to select songs to suit our mood. An affective music player can remove this obstacle as it can take a desired mood as input and then select songs that directs towards that mood. In the present study, an affective music player is validated for directing the energy dimension of mood. Firstly, user models were trained for ten participants based on skin conductance responses to songs from their own music database. Secondly, based on these results the songs that best increased or decreased the skin conductance level of the participants were selected to induce either a relatively energised or a calm mood. Experiments were conducted in a real world office setting. The results showed that a reliable prediction can be made of the impact of a song on skin conductance, that skin conductance and mood can be directed towards an energised or calm state and they remain in these states for at least 30 minutes. All in all, this study shows that the concept and models of the affective music player worked in an ecologically-valid setting. The results therefore show the feasibility of using physiological responses in real-life affective computing applications.

8.1 Introduction

Listening to music is a very popular activity among many people (Juslin & Sloboda, 2010). Music provides entertainment, it is readily available to everyone, can be listened to almost anywhere, and is one of the most popular ways to regulate mood (Gross, 2007; North & Hargreaves, 2008). The ability of music to direct mood is important, as positive moods enhance several cognitive functions (Isen, 2000), cause optimistic feelings to predominate (Gendolla, 2000) and, among other things, can enhance cognitive revalidation (Lesiuk, 2010). However, as our personal music databases increase in size, so the selection of songs to play becomes more difficult. On top of this, given that in industrialised countries, in particular the music listened to in everyday life is recorded music, the listener often does not know who the composer or performer of the music is (Juslin & Sloboda, 2010). Therefore it is not easy to select songs that directs you to a mood that you want at a certain point in time or that is consistent with the tasks that you are doing. To deal with this, music players have been proposed that help to direct affect towards a target state (Janssen et al., 2012; Oliver & Kreger-Stickles, 2006). In the present study, the affective music player (AMP) (Janssen et al. (2012)) will be extensively validated to show whether it can direct mood towards a desired state, and thereby facilitate personal music selection.

8.1.1 Music listening in everyday life

There are many types of responses to music, but the influence of music on mood is one of music's most palpable effects (Juslin & Sloboda, 2010). In this section we will briefly explain some important characteristics of the influence of music on mood. First of all, it is increasingly recognised that responses to music are personal and depend on preference (Cassidy & MacDonald, 2009; North & Hargreaves, 2008). This personal response to music may depend on several aspects such as age, gender, and culture (Juslin & Sloboda, 2010; North & Hargreaves, 2008). To further illustrate this, Cassidy and MacDonald (2009) found that self-selected compared to experimenter-selected high and low arousal music caused greatest enjoyment, reduction of tension and most efficient performance during a driving game. An explanation of the large differences between individuals in affect induced by the same music is that in everyday life, music is often listened to in the background to other activities, e.g., while driving or during work (Juslin & Sloboda, 2010). When attention is divided in this way between music and something else, this may cause differences in the affect induced by the same music (Juslin & Sloboda, 2010).

Secondly, arousal is an important effect of music because it is part of mood and may influence task performance. For the sake of clarity, arousal is one of the dimensions in which moods can be operationalised (Wilhelm & Schoebi, 2007). When music is listened to in the background to another activity, it has been found to influence task performance, but it has also been claimed that task performance influences the impact of music on mood (North & Hargreaves, 1999). It has been asserted, for example, that during task performance the influence of music on mood or music preference is determined by the interaction of musically-evoked arousal and the cognitive demand required to perform a task (Arousal-based theory, Konečni, 1982; Yerkes &

Dodson, 1908). The task characteristics cannot be changed by music but the arousal levels can be changed by music. One suggestion for obtaining optimum music preference was proposed by the psychobiological approach of Berlyne (1971). This approach describes that there is an inverted-U shaped relationship between music preference and arousal i.e., medium arousal levels would obtain optimal (highest) music preferences (Berlyne, 1971). However, the arousal levels required to achieve the optimum impact of music on mood and music preference during task performance are unknown. Nonetheless, it can be concluded that musically-induced arousal is an important aspect of influencing mood with music, even though it is also subjective to the individual listener (North & Hargreaves, 2008).

Thirdly, responses to music include changes in a variety of physiological responses (Hodges, 2010). Physiological changes have repeatedly been used to reflect changes in affect (Calvo & D'Mello, 2010; Janssen, Bailenson, IJsselsteijn, & Westerink, 2010; Picard, 1997). The physiological responses to musically-induced affect are primarily sensitive to a single mood dimension (Van der Zwaag, Westerink, et al., 2012). Skin conductance is a direct reflection of the sympathetic nervous system and therefore has been related to arousal (Cacioppo et al., 2007). Consistent with this, skin conductance is most clearly responsive to the energy of the music (Hodges, 2010; Krumhansl, 1997; Nykliček et al., 1997; Venables & Fairclough, 2009; Van der Zwaag & Westerink, 2012). For example, higher skin conductance levels have been reported with high percussive, more arousing, music compared to low percussive music, low arousing, music (Van der Zwaag, Westerink, & Van den Broek, 2011). The other mood dimension, valence (Wilhelm & Schoebi, 2007), has been repeatedly related to skin temperature (Janssen et al., 2012; Lundqvist et al., 2009; McFarland, 1985; McFarland & Kadish, 1991; Van der Zwaag, Westerink, et al., 2012). Changes in skin temperature reflect changes in vasoconstriction of the blood vessels near the skin (Hodges, 2010). Higher skin temperature values have been related to positive valence and decreases in skin temperature to lower valence (Lundqvist et al., 2009).

8.1.2 Affective music players

Several methods and systems have been described that help make song selection easier for a user. These are based on different systems of music recommendation, e.g., systems that find songs that sound similar based on the subjective input of the user or on music features, or systems that tag songs with an affect label based on song features and use these to recommend music (Chung & Vercoe, 2006; Kim & André, 2008; Skowronek et al., 2006, 2007; Van der Zwaag, Westerink, & Van den Broek, 2009; Wijnalda, Pauws, Vignoli, & Stuckenschmidt, 2005; Zhang, Tian, Jiang, Huang, & Gao, 2008). Most of these models, however, do not take into account that music preferences, and hence affective reactions, are highly personal (Juslin &

Sloboda, 2010). As a result, these music selection systems could be improved by taking the user's affective response to a song into account as well.

A couple of such systems have already been proposed that aim to direct mood to a target state based on physiological measurements to enable unobtrusive affect recognition. To start with systems have been proposed that adjust music characteristics, such as tempo, to intensity or stress levels while exercising (Oliver & Flores-Mangas, 2006; Wijnalda et al., 2005). The system of Wijnalda et al. (2005) takes into account the heart rate and exercise goal of the user by adjusting the music tempo to the user's heart rate, by adjusting the music tempo to the pace of a runner, or by selecting music with a constant tempo so that the users can synchronise their pace with the music. The system keeps track of heart rate history to predict how the heart rate will progress in the next 30 seconds, which in turn influences the selection of the next song.

The affective remixer system of Chung and Vercoe (2006) personalises music selection by re-arranging songs. It does so by taking the users' physiological measurements into account to detect the affective state. It then remixes the music using a predictive music-arrangement system that was trained based on previous physiological responses of various users to a song. If the user wants to be more aroused the music is remixed so that the most arousing parts of the music will be presented first.

The physiology and purpose-aware automatic playlist generation (PAPA) system incorporates physiological responses to determine which song to play next (Oliver & Kreger-Stickles, 2006). The PAPA system uses the physiological measurements to find a song with the correct music features to change the physiological responses in the desired direction. If heart rate is lower than the desired goal, for instance, a song with a higher tempo than the current song will be selected.

These music players mentioned so far do not keep track of the personal preferences or physiological responses to songs over time. The affective music player (AMP) as developed by Janssen et al. (2009), and Janssen et al. (2012) aims to direct affect and is specifically intended to create an individually tailored playlist. The AMP is an extended and more sophisticated version of the affectiveDJ (Healey, Picard, & Dabek, 1998). The affectiveDJ saves the song effect, which is the difference in skin conductance between the level of the last 30 seconds of the current song and the level at the end of the previous song. It then uses this information to select a song to either relax or arouse a user that moment. The affectiveDJ failed to perform successfully in a user test conducted by the authors, which they attributed to the high song repetition rate in a short period of time together with the fact that the songs were not individually chosen.

The AMP by Janssen et al. (2012) uses physiological responses as input to personalise music selection and direct the mood to a target state selected by the user. The AMP thereby uses an affective loop that uses the physiological changes to adjust the actuator (Calvo & D'Mello, 2010; Höök, 2008, 2009; Janssen et al., 2012, 2010). Thus, the behaviour of the closed-loop systems is described on the level of physiological change, and the AMP immediately selects songs based on the physiological input, without inferring the mood from the measures. After a song has been listened to, first the physiological responses of the last minute of listening to the song are normalised using z-transformations to correct for the variance over the last set time period (e.g., 30 minutes) of the session. Next, the song effect is calculated by subtracting the normalised physiological value during the last minute of the previous song from the last minute of the current song. The song effect is then corrected for the Law of Initial Values (LIV), the fact that the physiological change depends on the previous level (Geenen & Van de Vijver, 1993). This is done by regressing the physiological values of the song effect over the physiological values of the previous song. The song effect is corrected with this regression line by taking residuals (Janssen et al., 2012). This LIV corrected song effect is then tagged to the song, and together with the previous tags to the song, a prediction is made of how the song will influence the physiological state of the individual the next time it is played. The models of the AMP are based on accumulating probability density functions. These models can naturally deal with noise in the environment on top of the influence of the music. The more often a song is listened to the more reliable the prediction will be of it's effect on the physiology. In particular, the AMP can select a song which is known to increase or decreases skin conductance. Similarly a precise target level might be specified so that a song may be selected that makes the exact required change from the present state (Van der Zwaag & Westerink, 2011).

To overcome the fact that a new song in the user's database does not yet have a prediction, a bootstrap needs to be implemented. For example, the user can provide their own bootstrap by tagging the song with a mood label, the prediction of a user or group of users can be adopted, or music features can be used to make a general prediction in advance of how a song might influence a user's physiology (Skowronek et al., 2007; Van der Zwaag et al., 2009). There is no best bootstrap yet, however, and a combination of user input and music features to predict the mood that a song will induce would probably be most accepted by a user. The AMP is currently implemented in a working carrier application (see also (Schroeder, Van der Zwaag, & Hammer, 2008; Van der Zwaag & Westerink, 2011)).

The AMP has certain advantages over the other music players previously mentioned that aim to direct affect. Specifically, the AMP combines a wide range of design considerations based on previous research; 1) it recognises that music is personal, 2) it incorporates physiological sensors to allow unobtrusive mood measurement and personalisation of music selection, 3) it incorporates an affective loop so that the personal information on the user's physiological responses to a song can be updated after each song, 4) it uses probabilistic models to make a prediction of the influence of a song on the user's physiology, and 5) by implementing the law of initial values (LIV) it can accommodate for the effect that the influence of a song on physiological state depends on the physiological level at the onset of a song.

8.1.3 The present study

This study aims to further validate the affective music player developed by Janssen et al. (2012). Janssen et al. (2012) validated the affective music player for directing valence using skin temperature. For this they used three participants and 27 songs for each participants. The present study expanded on this validation in the following ways. Firstly, it tested whether the energy rather than the valence of a mood can be directed based on SCL. This is important as energy is an important feature in directing mood. Secondly, we used eight participants and included 36 songs for each of them. The songs were selected to direct mood towards neutral, high energy positive valence (happy) and low energy negative valence (sad) moods, as happy and sad are the most opposite moods in terms of both valence and energy (Calvo & D'Mello, 2010; Wilhelm & Schoebi, 2007). Therefore they result in the largest differences between the states. This is especially important in the present study because the good ecological validity of the study also introduces noise into the measurements. The validation process is also very time consuming as models have to be trained before they can be validated, thus the most opposite moods were chosen. Thirdly, tests were done over a longer listening time than those used by Janssen et al. (2012), to investigate whether moods can be induced and maintained over longer time periods. Finally, the SCL and mood were targeted to influence in one of three directions: relatively higher SCL, relatively lower SCL, and dynamically changing the SCL to a neutral state (i.e., in between the other two directions) based on real-time analysis.

To our knowledge, there have been no attempts to direct mood in a *dynamic* way by means of song selection based on the evaluation of physiological responses in real-time. In a slightly different domain, systems have been evaluated to adapt task difficulty to psychophysiological responses in an adaptive and real-time manner (Haarmann, Boucsein, & Schaefer, 2009; Novak, Mihelj, Ziherl, Olensek, & Munih, 2010). Haarmann et al. (2009) determined the task difficulty of a simulated flight on set thresholds of psychophysiological values. If the skin conductance was found to be above this threshold, for instance, the level of turbulence and therefore the difficulty of the test was lowered. Novak et al. (2010) used input from several physiological measurements, such as heart rate and skin conductance, and applied an adaptive threshold based on a discriminant analysis of these responses to determine whether the task is too easy or too difficult and then adapt it accordingly. This method of adaptive real-time estimation of the song to be played was also tested with the AMP.

First of all, as part of a training phase it was investigated for each participant individually to what extent happy, neutral, or sad songs can influence SCL in a certain direction each time that a particular song is presented. Based on the results of the training phase, a prediction was made for each song of how it would influence

SCL the next time it was presented, following the methods of Janssen et al. (2012). Secondly, in an evaluation phase the songs with the highest prediction to increase, decrease, or to not change SCL were used to validate the affective music player. Accordingly, the songs for one of the following directions (up, down, or no change in SCL) were played successively in one session. Higher SCL was expected with happy songs compared to sad songs. In a dynamic neutral session, SCL was expected to be directed to a neutral state, in between the relatively happy and sad moods, with both happy and sad songs. The selection of the songs in this session was chosen automatically and dynamically. The training phase and the evaluation phase are described separately.

8.2 Part 1: Training phase

8.2.1 Method

Participants and design

Ten employees (five male/ five female, age M= 26.5 years, SD= 3.5 years) of Philips Research received € 100 in vouchers for taking part in both the training phase (part 1) and the evaluation phase (part 2) of the experiment. Participants were unaware of the research goals. For the training phase a within-subject design was employed so that all participants followed a set of nine sessions listening to 36 songs in each session. During the experiment the order of the songs within each session was counterbalanced based on the nine first rows, one for each session, of a 36×36 digram balanced Latin square (Wagenaar, 1969). In this way, each song was played once every session, each song occurred only once in a certain place in the list of songs, and each sequence of two songs in a row did not occur more than once.

Music stimuli

Music was selected per participant based on a music rating procedure. Participants rated 200 songs that were randomly selected from the participants' own music database. Participants rated their songs in terms of the perceived influence on energy (low energy to high energy) and valence (unpleasant to pleasant) on 7-point Likert scales. During the music rating, participants could listen to the song if they wished. Based on the music ratings, twelve songs were selected for each participant for each of three mood categories, resulting in 36 songs in total. The songs with the highest valence and energy ratings were selected for a happy (high energy positive valence) category, intermediate valence and energy levels for a neutral category, and songs having the lowest valence and energy values were chosen for a sad (low energy low valence) category. To prevent the experiment taking too long per session the selected songs were shortened, if necessary, to four minutes and faded out at the end of the song using the Audacity software (version 1.2.6).

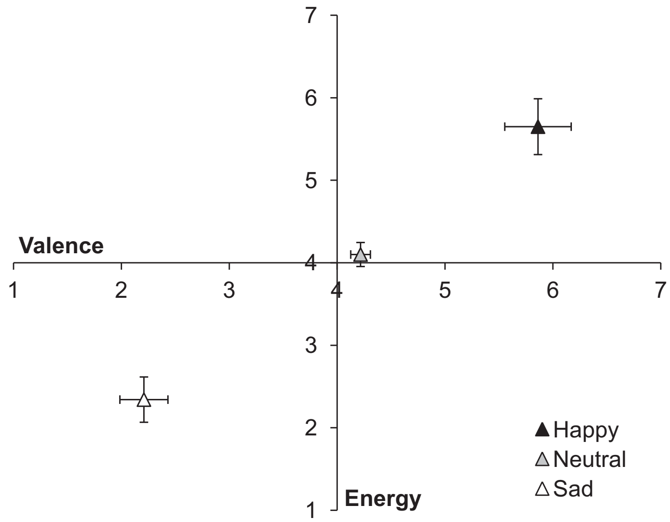


Figure 8.1 – The average valence and energy ratings for the individually selected songs of the training phase of the experiment.

A repeated-measures MANOVA with Mood (Happy, Neutral, Sad), was applied on the valence and energy ratings of the selected songs to verify that songs in the three categories differed in subjective ratings. Multivariate results showed that the selected songs differed significantly in Mood ($F(2, 4) = 27.16$, $p = 0.001$, $\eta_p^2 = .948$). Univariate tests showed that both valence and energy ratings significantly differed for the three Moods (valence ratings $F(2, 18) = 48.70$, $p < 0.001$, $\eta_p^2 = .844$; energy ratings $F(2, 18) = 42.19$, $p < 0.001$, $\eta_p^2 = .844$). Pairwise comparisons revealed that all the moods (Happy, Neutral, Sad) significantly differed from each other in valence and energy ratings in the expected way (all $p's < .001$). Means and SEs are depicted in Figure 8.1.

Physiological measurements

The Nexus-10 (Roermond, MindMedia B.V., the Netherlands) was used to measure the participants' physiological signs of skin conductance. Skin conductance measurements were obtained using dry Ag-AgCl finger electrodes, attached to Velcro strips (sample frequency 128 Hz). The participants strapped the electrodes around the lower phalanxes of the index and middle fingers of the non-dominant hand. To make sure the wires would not distract the participant from their work activities, the participant taped the wires of the sensor to the wrist with medical tape.

Procedure

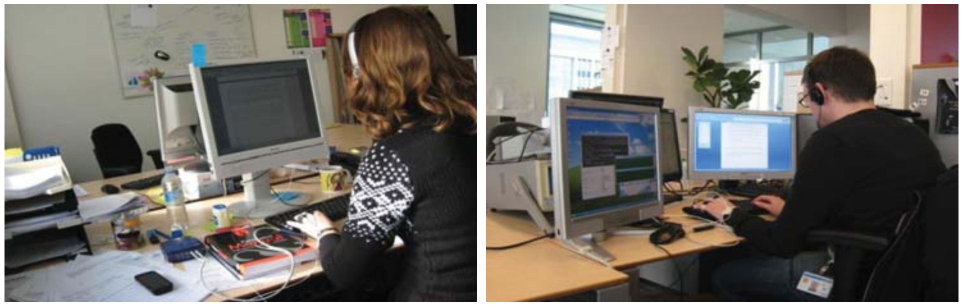
Each of the nine experimental sessions took place while the participants conducted their normal office work activities at their desk. Each participant received one desktop PC to record the physiological measurements and run the experimental sessions. In this way the participants could easily start a session themselves, and their work on their normal work PC would not be disrupted by the experimental programs. Participants could start a session whenever they liked, with a maximum of one per day. Participants were encouraged to complete a session without too many interruptions. Participants were asked not to start a session when they did not feel like doing it. In an introductory session the participants were shown how to connect the physiological sensors to themselves and how to start the measurement and the music listening. None of the participants felt that the sensors disrupted their work activities, like typing, despite the presence of the physiological sensors. See Figure 8.2 which shows the setup of the experiment with two of the participants, while they are running an experimental session during their normal work activities.

During each experimental session participants first attached the skin conductance sensor to their fingers. They then started the experiment by clicking on a 'start session' icon on the desktop. The physiological recording then began and the first song started to play. The first song was a two minute silent period for data analysis which is explained in the data analysis section. Music was listened to via a circum-aural headphone. The participant could press a 'break' button if anyone or anything interrupted the music listening. The music listening could be continued by pressing a 'continue' button, and the session was resumed from the last minute of the song that was interrupted, and this song was also put at the end of the playlist. This ensured that all the songs were fully played during each session. When all the songs had been played, the session ended and the participants could disconnect the sensors. Lastly, the participants reported in a diary whether there were any circumstances that might have influenced their physiological state, e.g., a very short night of sleep, extreme stress, etc. Each session had a maximum duration of 2 h 22 min if no breaks were taken. As the participants were only allowed to conduct one session a day, the total training phase took at least nine days. In practice, participants preferred to spread the sessions over about three weeks, having about three sessions a week.

8.2.2 Data preprocessing and results

The data processing of the training phase followed the method described by Janssen et al. (2012, 2009). We have summarised the most important steps below and refer to Janssen et al. (2012) for specific mathematical descriptions.

The SCL of the last minute of each song was normalised using a z-transformation. For this normalisation, the mean and standard deviation of the SCL per session (i.e., listening to 36 songs) were taken. For each song, the average of the last minute of the SCL of the previous song was subtracted from the average of the last minute of the SCL of the song. This difference in the song (delta SCL) best describes the effect of the song on SCL taking into account the influence of the previous song.



a) b)

Figure 8.2 – Two participants taking part in the experiment during their normal office work activities. The SCL sensors were connected to the fingers of the non-dominant hand.

The data were then corrected for the Law of Initial Values (Geenen & Van de Vijver, 1993; Wilder, 1967), to correct for the initial value of the SCL. Accordingly, first the delta SCL of the current song was regressed over the SCL of the song preceding the current song. The regression line was determined per participant based on the data points of each song in each session, resulting in 324 data points (i.e., 36 songs x 9 sessions). Then the delta SCL of the current song was corrected for the regression line by subtracting the value of the regression line from the song, resulting in delta SCL residuals. Figure 8.3 shows an example of the regression line of one participant and one residual indicating how the effect of a song is corrected for the LIV. Over the ten participants, the average slope of the regression line was $-.39(SD = .12)$, and the intercept was $.04(SD = 0.03)$.

Next, the delta SCL residuals per song were used to create a probability density function (PDF), which was implemented using Kernel Density Estimation (KDE) to make a prediction of the song's effect on the SCL (Silverman, 1986). The KDE fitted a Gaussian distribution to every delta SCL residual of a song and averaged over these distributions (see Figure 8.4 for an example of four songs with different impacts on the SCL of one participant). The probability that a song will increase the SCL is represented by the size of the area below the curve in the range > 0. The probability that a song will decrease the SCL is represented by the area below the curve in the range < 0.

To determine whether a song can increase or decrease the skin conductance level the PDF was divided into three areas. We calculated the probability that a song will increase SCL as the area under the PDF curve for residual sizes greater than .25 ($[.25, \infty >$). Similarly, we calculated the probability that a song will decrease SCL as the area under the PDF for .25 ($< \infty, -.25]$), and the probability for a neutral effect as the area under the PDF curve between residual sizes of ($< -.25, .25 >$). The results showed that per participant, on average 9.2 songs could be selected

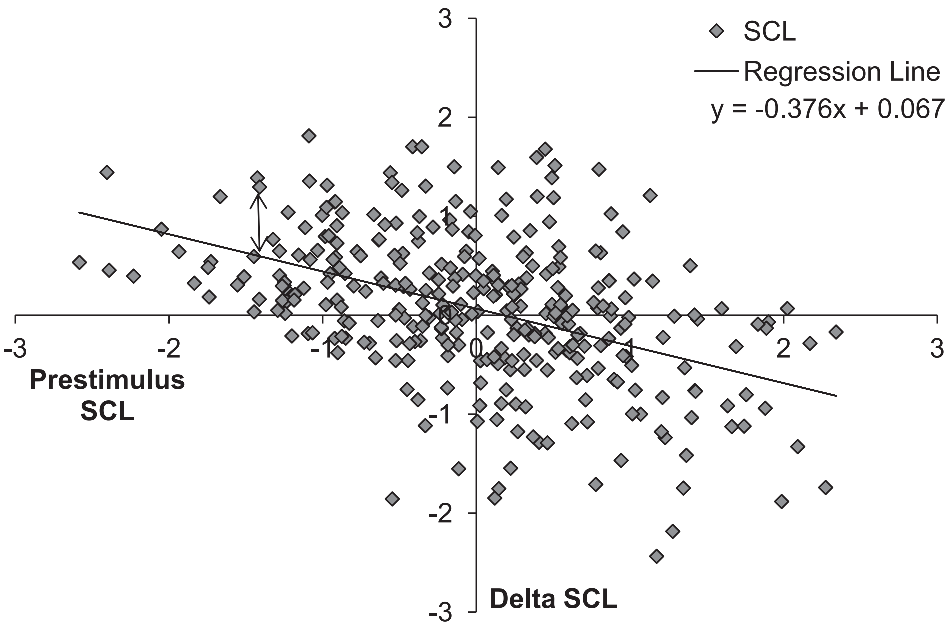


Figure 8.3 – The delta SCLs (i.e., the normalised SCL of the song minus the normalised SCL of the preceding song) of one participant for all songs played during all sessions of the training phase plotted against the normalised SCLs of the preceding song. The regression line is determined per participant to correct for the Law of Initial Values. The vertical arrow shows one delta SCL residual indicating the effect of that song corrected for the LIV.

Table 8.1 – Confusion matrix of the SCL direction probabilities of the eight selected songs per participant per state for the evaluation phase. The values represent the average distributions of the residual values for all participants.

	Probability directing SCL to interval		
Range of selected songs	$< \infty, -.25]$	$< -.25, .25 >$	$[.25, \infty >$
Down	**.47**	.38	.15
Neutral	.20	**.57**	.22
Up	.15	.42	**.42**

within the decrease SCL range, 12.4 songs within the neutral SCL range, and 7.6 songs within the increase SCL range. This already suggests that songs can be used to direct SCL of the listener, but we will explicitly test this in the next phase.

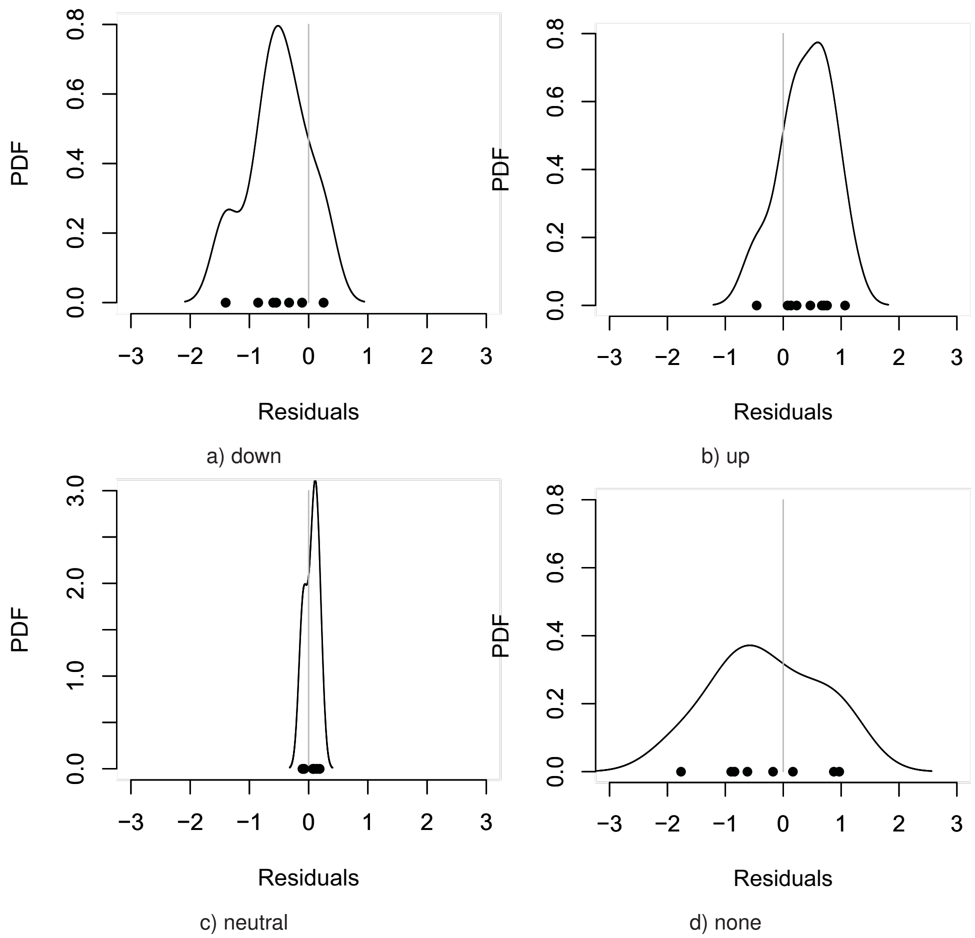


Figure 8.4 – The probability distribution of four songs. Each dot in the figures A-D represents the delta residual SCL value of a song when presented once. Panel A shows a song most likely to decrease SCL, panel B shows a song most likely to increase SCL, panel C shows a song most likely to not change the SCL, and panel D shows a song where reliability is low in terms of predicting how the song will influence SCL.

8.3 Part 2: Evaluation phase

The aim of this phase of the experiment was to consistently direct skin conductance in a target direction (relatively up / neutral / down) using music that in the training phase of the experiment was demonstrated to consistently influence SCL. Due to an expected time-on-task effect we expect that it will be difficult to lower the skin conductance, because following the time-on-task effect we would expect a tonically increasing trend in the SCL. We therefore expect that the ‘up’ direction will accelerate the upward trend, the 'down' direction will inhibit this trend, and the 'neutral' direction will follow the trend.

8.3.1 Method

Participants and design

Eight of the ten participants who took part in the training phase continued with the evaluation phase of the experiment. Two participants dropped out because they were not located at the Philips Research premises during the evaluation phase. In the evaluation phase we employed a within-subject design in which SCL was directed in each of three directions: up, neutral, or down. During each session 8 songs targeting one mood state (energetic, neutral, calm) were presented. Each mood state was presented six times, resulting in a total of 18 sessions. The order of mood state was counterbalanced over the 18 sessions with the constraint that one target mood state would not immediately follow the same state. The order in which the songs were presented within each mood state followed an 8 × 8 diagram balanced Latin square (Wagenaar, 1969); the last two rows of the Latin square were not used as there were six sessions per mood state.

Song stimuli

Songs were selected per participant where the prediction was that they would direct his/her SCL up, down, or not change the SCL at all. This was done based on the results from the training phase. The eight songs with the greatest probability of increasing or decreasing were selected for the up and down states. The eight songs with the highest probabilities that they would not change the SCL, the mid-ranges, were selected for the neutral condition. The total number of songs used in this session was 24 in total (i.e., 3 × 8) songs. In line with the individual selection of the songs in the training phase, the songs in the evaluation phase were also different for different participants. Table 8.1 provides the average probability distributions of the eight songs per direction up, down, and neutral.

A repeated-measures MANOVA with Direction (up / neutral / down) was then applied to the valence and energy ratings of these selected songs to determine whether the song ratings (provided at the beginning of the experiment) were different for the different directions. The results showed a significant univariate effect of Direction for the valence ($F(2, 18) = 3.58$, $p = .025$, $\eta^2 = .285$) and energy ratings ($F(2, 18) = 4.09$, $p = .017$, $\eta^2 = .312$). Pairwise comparisons show that the ratings in the up condition were significantly higher in energy ratings ($p = .015$) and marginally higher in valence ratings ($p = .063$) compared to the down ratings, while these scores were marginally higher compared to the neutral songs (energy $p = .095$; valence $p = .080$). The neutral songs did not differ from the down songs. The average valence and energy ratings of the subset of songs selected for the evaluation phase were follows: Mean (Standard Error), Valence Up $M = 4.75(.24)$, Neutral $M = 4.08(.23)$, Down $M = 4.02(.24)$; Energy Up $M = 4.67(.16)$, Neutral $M = 3.98(.14)$, Down $M = 3.97(.265)$.

Materials

The UWIST Mood Adjective CheckList (UMACL) was used to obtain a subjective indication of valence and energy levels (Matthews et al., 1990). The two mood dimensions concerned were valence (ranging from unpleasant to pleasant) and energy (ranging from tired/without energy to awake/full of energy). The UMACL contains eight unipolar items for each mood dimension, starting with 'Right now I am feeling..', and with answers ranging from 1: 'not at all' to 7: 'very much'. Skin conductance and skin temperature measurements were recorded with the Nexus-10 (Roermond, MindMedia B.V., the Netherlands). Skin temperature was added in this phase to show a possible relationship with mood valence (Janssen et al., 2012). The skin conductance sensor was attached to the fingers in a similar way as in the training phase. A thermistor skin temperature (ST) sensor was attached to the lowest phalanx of the little finger of the non-dominant hand using adhesive tape (sample frequency 128 Hz). The temperature sensor records temperature changes with a resolution of 0.001 °C in a range of 10 °C to 40 °C.

Procedure

Similar to the training phase of the experiment this evaluation phase took place at the participant's own desk, and the participant was asked to listen to music while doing normal office work during several sessions. The participants were unaware of the aim of the experiment; they were solely told that the aim was to collect physiological response measurements when listening to music while working. The participants could start a session whenever they felt like it, with a maximum of two sessions a day. Before each session, the participants attached the skin conductance and skin temperature sensors to their non-dominant hand. The participants then started the experiment by pressing the 'start session' icon on the desktop of their experiment PC.

Each session began with a baseline period in which four of the eight neutral songs were presented. The eight neutral songs used for the baseline period were counterbalanced over the sessions. The music then stopped and the participants filled out the UMACL questionnaire which was presented on the experiment PC, after which they continued to listen to another eight songs. During this period, the SCL was directed to one of three states: up, down, or dynamically to a neutral state. In the up or down sessions the eight songs of the related SCL change direction were presented successively. By contrast, the playlist of eight songs in the dynamic state was adjusted in real-time based on the current SCL. The aim of this condition was to direct the SCL to a neutral state. The neutral state for a session was defined as the normalised mean SCL, using z-transformation, of the SCL obtained during the baseline period. The song to be played next was automatically selected based on the average normalised SCL of the last minute of the preceding song (i.e., if the SCL was higher than the neutral state an SCL-down song was chosen, otherwise an SCL-up song was selected). The songs of the dynamic state were equal to the songs of the up and down SCL directions. In order to start this state in the same way each time, the first song of this dynamic state chosen was always an SCL-up song; this was an arbitrary choice and could equally have been a down song. After eight songs had been presented, irrespective of the state, the participants filled out the UMACL questionnaire again on the experiment PC and the session was ended. Each session lasted a maximum of 48 minutes: 16 minutes for the baseline period and 32 minutes for the SCL direction part. On average the participants took about four weeks to finish this evaluation part of the experiment, having about one session a day.

8.3.2 Data processing

Subjective data

Chronbach's alpha values for both the valence and energy items of the UMACL questionnaire were larger than 0.8, which indicated good reliability of the two mood dimension scores. Next, mood reaction scores were calculated by subtracting the ratings obtained after the baseline period of a session from the ratings obtained after the mood induction of the same session.

SCL and ST data

As with the data processing of the training phase data, the average SCL of the last minute of each song was calculated. These values were then normalised with z-transformations using the mean and standard deviation of the SCL obtained during the entire duration of the baseline period. Next, the delta SCL was calculated by subtracting the previous normalised SCL from the current normalised SCL. The average SCL was calculated per SCL Direction (up/ down/ dynamic neutral) over the six sessions of each mood direction per participant. The data processing of the ST data was similar to that of the SCL data. There was missing data for two participants due to equipment failure: for one session of a participant the SCL for one song in the up and dynamic conditions was missing and for one session of another participant data from one song in the down and dynamic conditions were missing. The missing data points were replaced by average residuals of the song.

8.3.3 Results

Subjective data

The average values during the baseline period were 4.64 ($SE = .069$) for valence and 3.97 ($SE = .067$) for energy. To investigate whether the mood direction influenced the subjective mood ratings, a one-tailed repeated-measures MANOVA with

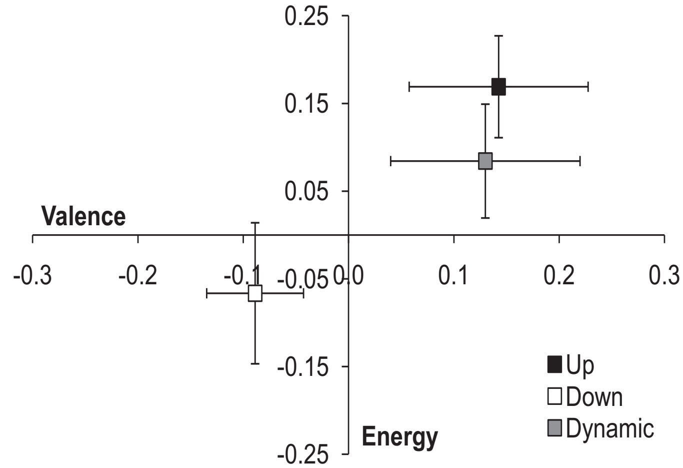


Figure 8.5 – The average energy and valence reaction scores over all participants and sessions in the up, down, and dynamic SCL directions. Error bars represent standard errors.

Table 8.2 – The real-time song choices per song number (SN), show how often (as a percentage) a song was chosen to either increase or decrease the SCL to a dynamic neutral state.

SN	1	2	3	4	5	6	7	8	average
Up	100	25.00	25.00	16.67	20.83	18.75	16.67	20.83	20.54
Down	0	75.00	75.00	83.33	79.17	81.25	83.33	79.17	79.46

Direction (up, down, dynamic) as the within-subject variable was applied to the valence and energy reaction scores. Significant main effects were found for Direction on valence ($F(2, 14) = 3.145$, $p = .037$, $\eta^2 = .310$) and a marginally significant effect on energy ($F(2, 14) = 2.72$, $p = .056$, $\eta^2 = .280$). Pairwise comparisons of the main effect showed significantly higher energy levels for the up SCL direction compared to the down condition ($p = .009$). The energy levels of the dynamic condition were not significantly different from the down or up conditions (all $p > .10$). Furthermore, the valence levels of the down condition were significantly lower compared to the up ($p = .041$) and dynamic ($p = .047$) directions. The valence levels of the up and dynamic directions did not significantly differ ($p > .10$). Means and standard errors are given in Figure 8.5.

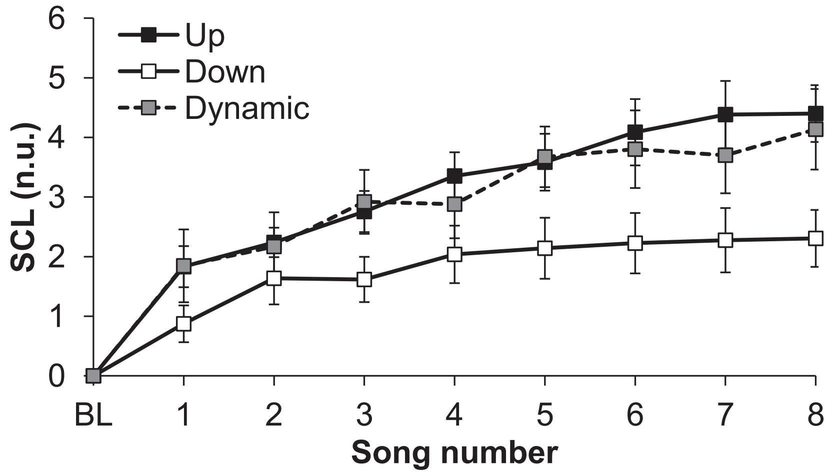
SCL and ST data

To verify whether the SCL differed for the three mood directions and to see how this pattern evolved over time, a repeated-measures ANOVA was applied to delta SCL residuals with Song number (1, 2, 3, 4, 5, 6, 7, 8) and Direction (up/ down / dynamic) as the within-subject factors. The results showed significant univariate main effects of Direction ($F(2,14) = 6.39$, $p = .006$, $\eta^2 = .48$), Song number ($F(2,14) = 21.32$, $p < .001$, $\eta^2 = .75$), and an interaction between Direction and Song number ($F(2,14) = 1.95$, $p = .015$, $\eta^2 = .22$). Pairwise comparisons of the Direction with Song number interaction showed that the SCL in the up condition was significantly higher compared to the down condition from the first song onward (all $p < .05$), with the exception of the second song. During the dynamic SCL direction, the SCL was marginally significantly higher than the down SCL direction from the fifth song onward (all $p < .05$). The SCL did not differ significantly between the up and the dynamic conditions. Figure 8.6 shows the mean SCL averaged over the participants and sessions for each mood direction.

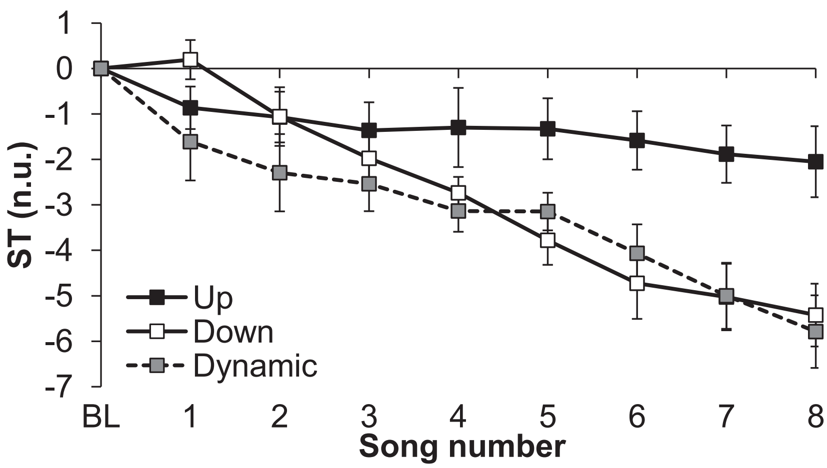
In the dynamic session on average 20.5 % of the song choices included a song directing the SCL upwards. The first song choice was not included in this estimate as the choice of the first song was set by default to increase the SCL. Table 8.2 shows the percentages of the song choices to increase or decrease the SCL for each decision moment averaged over all participants.

To investigate whether the ST differed between the three SCL directions and to see how this pattern evolved over time, a repeated-measures ANOVA was applied to ST with Song number (1, 2, 3, 4, 5, 6, 7, 8) and Direction (up/ down / dynamic) as the within-subject factors on the delta ST residuals. The results showed significant univariate main effects of Direction ($F(2,14) = 6.96$, $p = .004$, $\eta^2 = .50$), Song number ($F(2,14) = 13.26$, $p < .001$, $\eta^2 = .65$), and an interaction between Direction and Song number ($F(2,14) = 4.13$, $p < .001$, $\eta^2 = .37$). Pairwise comparisons of the Direction with Song number interaction showed that the up direction has higher ST compared to the down direction from the fifth song onward (all $p < .010$). The ST was significantly higher in the up direction compared to the dynamic direction from the second minute onward (all $p < .05$). The ST did not differ significantly between the down and the dynamic directions. Figure 8.6 shows the ST values for each direction.

To obtain the relationship between the subjective mood ratings of the three directions and the physiological responses, Pearsons' correlations (r) were calculated. The average SCL and ST data obtained during the eighth song were used as input ($N = 18$). The results showed a significant correlation between SCL and energy ratings (energy $r = .362$, $p = .041$; valence $r = .174$, $n.s.$). The ST shows marginal significant correlations with both the valence and energy ratings (energy $r = .330$, $p = .057$; valence $r = .292$, $p = .083$) The valence and energy ratings were furthermore positively correlated with each other ($r = .488$, $p = .008$). All in all, SCL was mostly related to energy, and ST to both valence and energy.



a) SCL



b) ST

Figure 8.6 – The average SCL and ST values for each song number for the three mood directions (up / down / dynamic neutral). Error bars represent standard errors, BL= baseline.

8.4 Discussion

This user test further evaluated the feasibility of the affective music player (Janssen et al., 2012) in a real office environment. Participants first listened to a variety of songs taken from their own music databases during normal office activities while skin conductance (SCL) was continuously measured. Based on the output of this training phase, a prediction of the influence of each song on the SCL was made. The results indicated that songs can influence skin conductance level in a direction which is predictable even in a noisy environment where music is listened to in the background. The evaluation phase showed that a playlist lasting for over 30 minutes generated to direct the SCL in a predefined direction has the intended effect; the SCL was higher when aimed at relatively higher SCL levels and lower when aimed at relatively lower SCL levels. The subjective mood ratings validated higher energy levels with higher SCLs and lower energy levels with lower SCLs. In the dynamic neutral situation we aimed to keep the SCL measure in between the lower and higher SCL conditions. The results showed that the SCL increased in this condition, and therefore songs to decrease the SCL were automatically selected most often. All in all, based on the physiological responses to a song, a prediction can be made about the influence which a song will have on physiology. This study therefore validates and builds on the models of the AMP as presented by Janssen et al. (2012). It further shows the ability of the affective music player to direct mood energy.

The valence and energy ratings of the songs selected for the evaluation phase were closer to each other than the ratings from the initial song set in the training phase. This implies that the initial ratings provided by the participants themselves were not necessarily the same as the extent to which they induce moods. This is in accordance with the literature which indicates that what is mostly rated is the affect expressed by the music, which is not necessarily the same as the mood induced by that music (Juslin & Sloboda, 2010; Van der Zwaag, Westerink, et al., 2012). This result also shows the added value of the affective music player; song ratings and people's own reflections on the influence of a song on their mood are not always accurate. The results of this study therefore imply that mood can be more accurately directed to a predicted state by using physiological responses, thereby making a prediction of the song's effect and selecting music accordingly, rather than using subjective ratings.

The evaluation phase of the experiment tested the influence of a playlist of songs that aimed to either relatively increase or decrease SCL. First of all, as expected the SCL increased in every session, including the down session, compared to the baseline. This effect could most possibly be assigned to a time-on-task effect, and was also found in Chapters 2, 3 and 4. The time-on-task effect is a well known effect showing that physiological signals, mostly in cardiovascular studies, tend to change over the course of time irrespective of the experimental conditions (Fairclough & Venables, 2006; Mulder, Dijksterhuis, Stuiver, & Waard, 2009). From the SCL data obtained during the baseline period (four neutral songs) it also appeared that the SCL gradually increased over time during this period. Nevertheless, irrespective of this effect the results showed that after two songs the SCL was significantly higher in the up compared to the down condition. The results also show that with these same playlists the mood, as measured by valence and energy, was also directed towards a predefined state. Increased energy levels when SCL was higher are consistent with previous research which has shown that SCL is generally related to arousal

(Boucsein, 1992). In addition, the current results indicate that the difference between the two directions lasts for over 30 minutes. This is a new finding because this long duration of the induction of moods with music (over 30 minutes) has not been reported before.

We have to point out that although the mood difference scores in the evaluation phase did significantly differ between the SCL up and down conditions, their absolute differences were only small. Therefore, it can be questioned whether the mood changes found are relevant. The results of the present study indicated, however, that the changes in mood did correlate with changes in SCL. Hence, even though changes in mood were maybe not always conscious to the user, the bodily changes validated that music had an effect on the user.

The skin temperature decreased during the course of the evaluation phase irrespective of the SCL direction. This effect can be attributed to the small amount of movement of the fingers during desk work which cools the lateral parts of the body including the fingers. Moreover, although the evaluation phase was not targeted to direct the skin temperature, it did: higher skin temperature was found in the SCL up condition and lower skin temperature was found in the SCL down condition. This result can be explained by the difference in valence induced by the music, i.e., higher valence levels correlate with higher skin temperatures and lower valence levels with lower skin temperatures. This result is in line with previous research that has shown a positive correlation between skin temperature and valence (Lundqvist et al., 2009; Van der Zwaag & Westerink, 2012). Janssen et al. (2012) also show in their validation of the affective music player that directing skin temperature to a relatively higher level goes together with higher valence levels compared to when the skin temperature was directed to a relatively lower level.

The skin temperature showed differentiation between the two induced moods from the fifth minute onward, and thus reacts more slowly to music mood induction than SCL. Janssen et al. (2012) showed that the skin temperature differentiated between up and down from the fourth song. This small difference may be explained by the fact that Janssen et al. (2012) aimed to direct the ST rather than the SCL as in the present study, hence songs targeted to adjust ST were presented in that study.

The dynamic condition in the evaluation phase shows a different picture than in the up and down conditions. In this dynamic condition, the SCL followed the pattern of the up condition, while the skin temperature followed the pattern of the down condition. This different result of directing physiology in the dynamic condition might be explained by the playlist in this condition. In this playlist songs with different characteristics were alternated, i.e., with extreme differences from each other. This might have lead to some stress, which is a high energy state, as reflected in higher SCL, and also is a negative valence state, as reflected in low skin temperature. These results do not indicate that it is impossible to direct SCL to a neutral state. It is still possible that when only neutral songs are presented, as opposed to alternating songs in a dynamic neutral state, this might still lead to a neutral state, however this was not tested in this experiment.

The present study explored and validated the possibilities for the affective music player. The findings resulted in a number of future research ideas which can show not only the feasibility of the affective music player in different contexts, but also other possible adaptive affective support systems. Firstly, physiological responses are most sensitive to one affect dimension. By integrating SCL (representing arousal) and ST (representing valence), for example, the extent to which the affective music player can direct mood towards each quadrant of the valence-arousal model could be tested. Secondly, in this study the SCL was directed in a relatively up or down direction. Ideally, the SCL should be directed to a precise target value (including a neutral state), instead of only in a direction, which could possibly be done by calculating the change in SCL needed to reach the target level and select the song whose prediction is closest to bringing about that change. Thirdly, the scope of the context could be extended to environments that have been shown to benefit from the influence of music on mood, for example, while driving a car (Van der Zwaag, Fairclough, et al., 2011; Van der Zwaag, Dijksterhuis, et al., 2012; Van der Zwaag, Janssen, et al., 2012), or to reduce patient anxiety (Van der Zwaag, Tijs, Westerink, & Molegraaf, 2011; Van der Zwaag, Tijs, & Westerink, 2011). Fourthly, the affective music player improves its performance each time a song is played. However, a bootstrap is needed for new listeners or for new songs. This bootstrap could be explored but could, for example, also be obtained from music features that predict a song's effect (Skowronek et al., 2007; Van der Zwaag, Westerink, & Van den Broek, 2011): if song B is new, and similarity algorithms based on audio features indicate that it is similar to song A which is already known to the user, then song B can be initiated with the same prediction as song A.

To sum up, the present user test successfully validated the concept of the affective music player. In the training phase a variety of songs were presented so that an individual prediction of the influence of a song on the SCL could be made per participant. Successively, the results were validated in the evaluation phase. The results validated that the predicted influence of a song on the SCL based on our models is reliable; both the SCL and the subjective mood ratings were directed relatively up or down as expected. All in all, the current results demonstrate the feasibility of the affective music player in the highly ecologically-valid setting of office work. Hence, we have provided evidence for the proper functioning of an affective music player in everyday life music listening situations. Our study therefore indicates that the outlook for the feasibility of other physiologically-driven affect-oriented systems is promising. Undoubtedly, there will be some challenges to be overcome in the development of the affective music player, such as the need for unobtrusive physiological measuring equipment. However, as unobtrusive affect monitoring devices are developing rapidly (Ouwerkerk, 2011; Poh, Swensen, & Picard, 2010), it will be only a matter of time before people can buy an affective music player.

To conclude, music is an important means of regulating mood in various everyday situations. It is readily available to everyone and can be listened to almost anywhere. It is often used to direct mood and there is, therefore, extensive application potential for music players that support this ability to direct mood. Such devices need to incorporate unobtrusive affect measurements and personalise music selection accordingly to be able to direct mood to a target state. The extensive user study described in this paper validated the affective music player and shows that music can be used to reliably direct mood to a desired state during office work.

Chapter 9

General discussion

The affective music player enables automatic, tailored music selection to direct mood towards the user's desired state. The affective music player may benefit many people because mood influences our mental and physiological state and therefore may have an impact on health in the long term. The work described in this thesis provides an improved understanding of the relationship between music, mood, and physiological state. In this chapter we will discuss how this knowledge supports assumptions underlying the affective music player and how it may be applied in the affective music player. We also reflect on the theoretical implications and the methods used, present ideas for future research, discuss the ethical implications, and provide a general conclusion.

9.1 Overview of the most relevant research results

The first three chapters in this thesis showed to what extent music can influence mood and physiological responses during office work activities. As the physiological correlates of mood are relatively under-investigated in comparison to the physiological correlates of emotions, the findings of the first three chapters provided many new insights. First of all, Chapter 2 revealed that a wide variety of physiological responses adapt differently to happy and sad music in two minutes, on average. The chapter further showed that the physiological variables stabilise to the new mood-dependent levels in three to five minutes. This time period can thus be seen as the minimum duration necessary to induce a stable shift in mood through music. Chapter 3 showed that musically induced moods and the accompanying physiological variables can be maintained when music is continuously played in the background to an activity. Chapter 3 showed also that music can be used to induce moods towards the four dimensions of the valence-energy model and that during musical mood induction physiological measurements correlate to the valence or the energy mood dimension. Skin conductance, for example, is related to the energy dimension, and skin temperature is related to the valence dimension. In Chapter 4 we showed that moods can be induced with background music while doing a task. The physiological responses of skin conductance and EMG activity of the zygomaticus major facial muscle were equally sensitive to mood induction in the background compared to traditional musical mood induction methods. From this study we can therefore infer that it is not necessary to first induce a mood with music listening as a primary activity but that mood can also be induced with background music.

The results of the first three chapters had several consequences for the development of the affective music player. The first three chapters showed that physiological patterns relate to mood which implies that the affective music player could be used to influence mood to a wide variety of directions. This result is important, as the ability of music to influence mood and physiological responses is crucial to the feasibility of the affective music player. The results also implied that music can induce and maintain moods in all of the following scenarios: when music listening is the primary task, in the background to an activity, or when switching between music listening as a primary and a secondary task.

The next three chapters investigated the influence of music on changes in mood and physiological variables during driving tasks. In Chapter 5 it was investigated how music listening while driving influences mood, physiological responses, and driving performance. The results showed that music can induce and maintain positive and negative moods in ecologically valid settings such as driving. We showed also that a musically induced different moods do not necessarily impact driving performance during low or high demand driving tasks. Chapter 6 tested how music can be selected to most efficiently regulate an uplifting mood downward during high demand driving. The study showed that the manner in which music is selected to affect moods can influence physiological state and behaviour. We further showed that in high demand driving situations calm music can best be selected immediately rather than gradually increasing the calmness of the songs. This music selection calmed drivers most efficiently and resulted in better driving performance. Chapter 7 aimed to show whether music can be used to prevent the build-up of anger while driving under annoying circumstances. The study revealed that positive valence music, either high or low in energy, best prevents anger induction compared to no music or negative valence music. These findings demonstrate the potential of music to adapt mood and influence the physiological states that accompany different mood states while driving.

These three chapters also presented important information for the design and feasibility of the affective music player. Firstly, the results implied that the affective music player can be used to induce moods and physiological variables during a driving task. The results also suggested that the affective music player could take the cognitive demand of the driver into account to increase the efficiency with which mood can be changed during high demand driving. The affective music player could also play (or suggest) positive valence music in anger inducing situations.

Chapter 8 describes a validation of the affective music player while conducting office work. This study put together the lessons learned from the earlier chapters. Firstly, a training phase revealed that music can be selected to relatively decrease, maintain, or increase skin conductance level. An evaluation phase then showed that this individually selected music can be used to direct energy level and the related skin conductance level in these desired directions. The study showed that it takes about two songs to induce a difference in physiology and mood energy levels during office work. This study provided further evidence that the concept of the affective music player is feasible and likely to be effective in everyday situations.

9.2 Theoretical implications

All in all, steps were taken to show the relationship between music, mood, and physiological measurements. As there was some overlap between the studies, most of the results were replicated. These replications strengthen our view that music is indeed able to influence mood and physiological states, and that the effects we found were not due to chance. It is likely that these results can also be generalised to other contexts besides office work and driving scenarios, such as reducing anxiety during medical interventions. In the following paragraphs we will reflect on the methods used and describe the theoretical implications of the results.

Firstly, the music mood induction procedure evolved over the course of the experiments. We started with the traditional music mood induction procedure in which mood changes were induced while music listening was the primary activity (Chapter 2). Then we investigated whether induced changes in mood persisted when music was listened to in the background (Chapter 3), and finally we concluded that difference in moods can be induced with music even when music listening is not the primary activity (Chapter 4). Further support for this finding was provided by the driving task studies and by the extensive evaluation of the music player, which showed that mood can be induced with music while another task is being performed simultaneously. These findings introduced a new mood induction procedure that can save time in the experimental procedures and in practical use.

Secondly, we used the dimensional approach to operationalise mood measurements (Russell, 1980). The mood valence and energetic arousal dimensions were used most often as they suited our research questions best. Although these two mood dimensions are described as orthogonal (Matthews et al., 1990), the current results showed they are not completely orthogonal. Significant correlations between the indicated valence and energy ratings after music mood induction confirmed this. This means that for musically-induced moods higher valence levels occur together with higher energy levels (e.g., being happy), and lower valence levels occur together with lower energy levels (e.g., being sad). Our findings are supported by the fact that happy and sad moods are considered to be the most opposite moods

(Wilhelm & Schoebi, 2007). For the affective music player this finding implies that in normal circumstances it will be difficult to select songs that direct a mood towards a low energetic positive valence or towards a high energetic negative valence mood. The results of our studies also implied that these two difficult moods are easier to induce if the situation is congruent with the mood to be induced. For example, in Chapter 7 we showed that a high energetic negative valence mood can be induced in a context that is congruent with this mood (i.e., anger induction). It cannot be argued, however, that the dimensional approach is inadequate as we did not conduct research that was specifically designed to answer the question of how these two dimensions relate to each other precisely when music is the mood inducer. These results demand further investigation of the relationship between mood dimensions when music is the mood inducer. For example, it could be investigated whether moods can be captured by one single dimension, or whether an extra dimension is needed to find influences of music on mood that remained hidden during our research. Moreover, it could be investigated to what extent the context influences the relationship between the dimensions of musically-induced mood. This relationship might be different for mood naturally experienced in everyday life compared to moods induced with music.

Thirdly, the music selection procedure used in our experiments was new, and allowed for song selection per individual. As described in Chapter 1, songs selected to test the influence of music on affective phenomena are often chosen by the experimenter (Juslin & Sloboda, 2010). The song selection in our studies was based on a combination of mood labels provided by automatic classification using music features, and on music ratings provided by individuals. If both methods put a song in the same quadrant of the valence-energy model, that song was considered for the experiment. Our method proved to be very useful and accurate as the mood changes that were intended to be induced with the music were actually achieved, and this was replicated several times. Hence, individual song selection is an important step in taking individual differences in music preference into account. Our approach achieved similar affective impacts on people with different musical preferences and could therefore help to explain the contradictory results that were found in earlier music and emotion research (Juslin & Sloboda, 2010; North & Hargreaves, 2008). We believe that the field of music and emotion could mature rapidly if this step of individual song selection is included. Nevertheless, individual song selection also has its limitations, as all participants listened to different songs. However, this limitation is only relevant when the reaction to a specific piece of music is of interest, or the influence of music characteristics on affective phenomena or physiological responses is under investigation, but is not relevant when the influence of the affective type of music is being investigated. Therefore, depending on the research question, a researcher should carefully consider whether individually-selected music or otherwise selected music would be more desirable.

9.3 Implications for future research

The research described in this thesis provides a step towards a better understanding of the relationship between music, affect, and psychophysiological state. Music and emotion research is a growing field which would benefit from a standardisation of research methods and terms used for affective phenomena. A valid theoretical model of how music influences affect, together with its neural correlates, would also be very useful. In this way, research can be better directed and integrated, and hypotheses better specified. A start has already been made on such a model (Juslin, Liljeström, Västfjäll, & Lundqvist, 2010). This thesis delivered some new findings in the field of music and emotions, but also yielded many new research questions. We have already indicated further research topics and some will be mentioned here below.

We limited the scope of this research to a situation in which people were seated. The results showed that music can consistently direct mood and psychophysiological state to a desired state while seated. The affective music player would be very useful in situations where people also have this type of constraint, in a hospital, for example. The affective music player could then be used to reduce patient anxiety or stress and potentially be used as a competitor or supplement to pharmacological interventions (L. A. Mitchell, MacDonald, Knussen, & Serpell, 2007). The affective music player could improve patient comfort and potentially the medical outcome too (Van der Zwaag, Tijs, & Westerink, 2011). During a PET-CT scan, for example, the medical outcome can be improved with increased relaxation due to reduced muscle tension which improves the scan results. To be able to generalise our results, the next step would be to investigate whether similar results are found in situations when people do not have the constraint of remaining seated. For example, when people use the affective music player while walking along the street, in their homes, or during exercise.

Another aspect for further research is the input signals which the affective music player can use to derive mood. At the moment the affective music player is validated to direct skin conductance (Chapter 8) and skin temperature (Janssen et al., 2012). Other physiological, posture or gesture measurements could potentially be used instead or as a complement to increase the robustness of the prediction made by the affective music player. Facial muscle tension of the zygomaticus or corrugator muscles, for example, have been found to relate to valence. Several body posture measurements, such as bending of the spinal cord and the position of the head, have also been related to happy and sad music mood induction (Thrasher, Van der Zwaag, Bianchi-Berthouze, & Westerink, 2011). These signs could be employed as input for the music player as well. However, the feasibility of this in everyday life situations would have to be validated first.

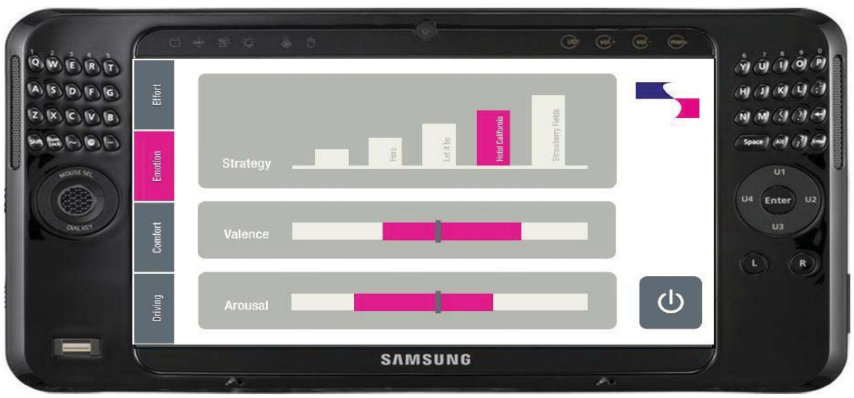
9.4 User interface of the affective music player

For the European FP7 REFLECT project we worked on building a working prototype of the affective music player (Van der Zwaag & Westerink, 2011). An example of this prototype can be seen in Figures 9.1 and 9.2 implemented in a Ferrari California car. The prototype consists of three screens, one shows the raw physiological signals, the second indicates the current state, and the third shows the user interface. For the design of the user interface some choices had to be made. For example, the choice of mood states that could be selected by the user. Currently, the user can select from three target mood states, i.e., relaxed, neutral and energised. These worked properly in initial test runs but they have not been extensively investigated. Besides this design consideration, several other design and functional aspects were considered for the affective music player, which we will discuss next.

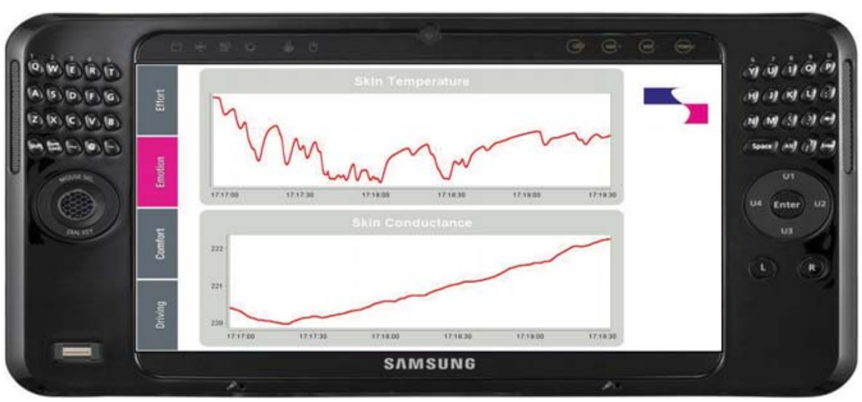
First of all, the autonomy of the affective music player needs to be considered. Chapters 6 and 7 of this thesis describe how the affective music player could select music to most efficiently calm the driver or to prevent anger induction and improve driving performance. One consideration is whether the affective music player should overrule the users' selected target mood (adaptive automation) or whether the user should be in control of the target mood at all times (adaptable automation; Opperman (1994)). With adaptive automation, the affective music player would follow its own recommendations. In some situations the target mood that was initially selected by the user would thus be overruled by the choice made by the affective music player. Even though this choice could be beneficial for both the driver and road safety, the affective music player essentially disregards the decision-making capabilities of the user. The user could then feel that they are no longer in control of the system which could have an impact on acceptance of the system (Norman, Ortony, & Russell, 2003). To overcome such issues, the affective music player could use adaptable automation (Opperman, 1994). In this situation, the user has total control of the system. This method provides the user with a sense of control, while the affective music player can still suggest music to direct the user to a state that is healthier in the long run or safer in a specific situation. To optimise these functional aspects the affective music player could provide the user with the option of either adaptable or adaptive, and the music player would respond accordingly. An extra option could be added to the affective music player such that if the affective music player detects that the user is in an undesired state, it suggests only music for the most optimum target state but does not automatically switch to it.

Secondly, different arguments can be used to persuade the user of the necessity and benefits of the mood suggested by the affective music player in certain circumstances. The success of the persuasive style in influencing the user will dependent on the user. The affective music player could be combined with adaptive persuasive profiling tools to increase the likelihood of a user following the advice of the

a The user interface



b The logic interface of the estimated mood



c The raw data interface of the skin conductance and temperature

Figure 9.1 – Deliverable of the REFLECT project. Emotion loop carrier deployed on three Samsung Ultra Mobile PCs. The first screen (a) shows the user interface, the second (b) shows the processed signals, and the third screen (c) shows the raw data input.

Figure 9.2 – Deliverable of the REFLECT project. The affective music player deployed during a user test in a Ferrari California, January 2011, Maranello, Italy. The first two screens of the user interface can be seen in the car.

affective music player (Kaptein, Duplinsky, & Markopoulos, 2011). In adaptive persuasive profiling, the persuasive strategy that the user is most susceptible to can be used to motivate a user to do something. For example, it could use the strategies of authority (expert opinion is provided) or consensus (do as other people do). Using an individual strategy may be important because if the advice of the affective music player is followed it could potentially be beneficial to the users bodily state (e.g., physiological stress) and in the event of driving, for road safety too (see also Chapters 5, 6 and 7).

9.5 Ethical implications

After asking the question: can an affective music player be created? To which the answer is: yes, we will now discuss the reciprocal question: should an affective music player be created? This question is more difficult to answer as ethical issues in the affective computing domain touch upon important and very personal aspects of human life, and how solutions in this domain affect our place in the environment (Cowie, 2010). The ethical issues of the affective music player are less severe than those of the affective computing field in general, as the affective music player does not judge the mood of the user, it only assumes a relationship between physiology and mood. This difference is subtle but important, as the affective music player does not impose a mood on the user. Nevertheless, the ethical considerations should not be overlooked. We will now identify some of these ethical considerations and offer suggestions on how to deal with them effectively. It is a matter of personal ethics not to misuse any ethical consideration raised that could have a negative impact on the user rather than helping them.

The first consideration has ethical importance but is a design choice at the same time. To illustrate, Chapter 3 shows that music can induce mood changes towards every quadrant of the valence-energy model. It could be questioned, however, whether the affective music player should allow the user to select all these possible moods, including the high energetic negative valence mood that could induce health problems in the user in the long run or can cause unsafe road situations while driving. A reduced affective grid could be used in the affective music player to give a user a sense of choice in targeting the mood they select without having the feeling that some important moods are missing. The moods that the affective music player proposes need to be carefully considered. The affective music player could also suggest choosing a different set of moods depending on the situational context. Possible mood suggestions which the affective music player could offer, for example, are energised, neutral, happy, relaxed, and calm.

The next ethical concern deals with data protection. The data that the affective music player saves could hypothetically be used by third parties for positive as well as negative purposes. On the positive side, the data of several users could be compared to improve the performance of the affective music player. In this way, an initial prediction for a song could be provided when a new song is added to the user's database. The data could also be used to recommend new music to a user that is expected to direct mood in a certain way. This could be done by comparing the data of users listening to similar music, or data of users with a similar profile. On the negative side, the data of several users could be used for various commercial or insurance purposes. Thus, it is important to ascertain that the data of the affective music player are properly protected and the user is asked to give their consent before this data are used for other purposes than the intended one.

9.6 Conclusion

This thesis began by pointing out that music is extremely important to many people. The importance of music is related to the mood inducing properties of music. Using a new method of individual song selection, we experimentally proved that music is indeed able to consistently change mood and several physiological variables in different ecologically-valid circumstances, and towards a variety of states. The studies showed that moods and differences in the physiological state were induced after two songs and these induced mood changes lasted for more than thirty minutes. During musical mood induction, physiological measurements correlated to the valence or the energy mood dimension. We further showed the feasibility of inducing moods in the background of an activity and thereby not only introduced, but also validated this new mood induction procedure. Finally, we showed that there are songs that predictably influence physiology and we proved that the models applied in the affective music player are able to direct physiology and mood towards a desired state in an ecologically-valid setting. In this way, the thesis established experimentally the feasibility of a tailored affective music player which provides a means to automatically direct your physiological state and mood towards a desired state using music. Hence, we offer a means to make better use of the powerful influence of music and facilitate music selection for optimum performance and a sense of well-being.

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Samenvatting

Muziek is een krachtige methode om onze stemming te beïnvloeden in het dagelijks leven. Omdat stemming belangrijk is om ons optimaal te voelen en optimaal te functioneren, zullen methoden die automatisch muziek selecteren om die stemming naar een gewenste toestand te sturen voor veel mensen nuttig zijn. De affectieve muziekspeler (AMP) selecteert automatisch muziek nummers die de stemming in de richting van een gewenste stemming sturen. Welke stemming dat is, kan worden ingesteld door de gebruiker. De AMP doet dit door aan te nemen dat veranderingen in de stemming gerelateerd zijn aan veranderingen in fysiologische reacties. Elke keer dat een nummer gespeeld is slaat de affectieve muziekspeler de invloed van het nummer op de fysiologische reacties van de gebruiker op. Aan de hand hiervan maakt de AMP een voorspelling van het effect dat het nummer op de fysiologie zal hebben de volgende keer dat het gespeeld zal worden. Dit proefschrift probeert het inzicht in de relatie tussen muziek, stemming en fysiologische reacties te verbeteren en gebruikt deze kennis om experimenteel aan te tonen dat een affectieve muziekspeler haalbaar is.

De eerste drie experimentele hoofdstukken in dit proefschrift geven inzicht in de mate waarin muziek onze stemming en fysiologische variabelen kan beïnvloeden. We laten zien dat fysiologische reacties primair reageren op een enkele stemmingsdimensie, ofwel de positiviteit ofwel de energie van de stemming. Verder laten we zien dat stemmingen die geïnduceerd zijn door muziek blijven bestaan wanneer de muziek wordt gespeeld op de achtergrond, en dat stemmingen zelfs geïnduceerd kunnen worden met achtergrondmuziek. Daarnaast blijkt dat het minder dan 2 minuten duurt totdat muziek een stemming geïndiceerd heeft, en dat de bijbehorende fysiologische reacties stabiliseren in drie tot vijf minuten afhankelijk van het niveau.

De volgende drie hoofdstukken onderzoeken de invloed van muziek op stemming en fysiologische variabelen tijdens auto rijden. Deze hoofdstukken laten zien dat muziek stemming en fysiologische staat beïnvloet bij zowel lage en hoge rijinspanningen, zonder noodzakelijkerwijs de rijprestaties te veranderen. Daarnaast

wordt aangetoond dat, in overeenstemming met de stemmings-regulatie theorie, muziek efficiënt kan worden gebruikt om bestuurders te kalmeren tijdens veeleisende rij-taken. Bovendien hebben we bewijs gevonden dat positieve muziek in staat is om de opbouw van de woede en de daarbij behorende fysiologische effecten te voorkomen tijdens ritten die normaal boosheid oopwekken.

Hoofdstuk acht, ten slotte, beschrijft een uitgebreide gebruikers test van de affectieve muziekspeler. Het laat zien dat muziek kan worden geselecteerd om voor een periode van zeker 30 minuten huidgeleiding in een gewenste richting te sturen. Zodoende kan de muziek gebruikt worden om een relatief energieke of rustige stemming op te wekken, terwijl mensen hun normale kantoor-werkzaamheden uitvoeren. Deze resultaten bewijzen dat het mogelijk is om met muziek onze stemming automatisch relatief in de gewenste richting te sturen tijdens dagelijkse werkzaamheden.

In Hoofdstuk 9 wordt al het experimentele werk samengevat, en bediscusseren we hoe de resultaten de aannames van de AMP ondersteunen. Verder bespreken we de theoretische implicaties, de gebruikte methoden en etische implicaties van het onderzoek beschreven in dit proefschrift. We sluiten af met een algehele conclusie.

Summary

Music is a powerful means of influencing mood in daily life. As mood is important to optimum functioning and a sense of well-being, methods to automatically select music to direct mood towards a desired state would benefit many people. The affective music player (AMP) automatically selects songs that direct mood towards a target state set by the user. It does so by assuming that changes in mood relate to changes in physiological responses. The affective music player stores the influence of a song on the physiological responses of a user each time a song is played and makes a prediction of the effect the song will have on physiological responses the next time the song is played. This thesis aims to improve understanding of the relationship between music, mood, and physiological responses. This understanding was then used to find experimental evidence for the feasibility of an affective music player.

Chapter two to four, the first three experimental chapters, provide insights into the extent to which music influences mood and physiology. Physiological responses appear to be primarily reactive to a single mood dimension, either mood valence or mood energy. We also show that musically induced moods persist when music is played in the background and moods can be induced with background music only. Lastly, we find that music induces moods in two minutes on average and physiological responses stabilise to their new mood dependent levels in three to five minutes.

The next three chapters investigate the influence of music on mood and physiology while driving. These chapters reveal that music influences mood and physiological state in low and high demand driving situations, without necessarily impairing driving performance. Additionally, it is shown that, in accordance with the mood regulation theory, music can be effectively used to calm drivers during high demand driving situations. Evidence is also found that positive music can prevent anger building-up during anger-inducing drives.

Chapter eight, finally, presents an extensive user test of the affective music player. It shows that music can be selected to relatively steer skin conductance in a desired

direction. This music is used to induce an energised, neutral, or calm state for over 30 minutes while people are conducting their normal office work activities. These results therefore demonstrate the feasibility of the affective music player and provide a method which uses music to direct mood towards a desired state in everyday life.

In Chapter nine we discussed how this knowledge supports assumptions underlying the affective music player. We also reflect on the theoretical implications and the methods used, present ideas for future research, discuss the ethical implications, and provide a general conclusion.

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Marjolein van der Zwaag
Eindhoven, December 15th, 2011

Curriculum Vitae

Marjolein D. van der Zwaag was born in Sneek on February 23, 1984. In 2002 she obtained her VWO diploma from the Lorentz college in Arnhem. In the same year she started her artificial intelligence study at the Radboud University Nijmegen. In September 2007 she obtained her MSc in Artificial Intelligence (bene meritum) with a specialization in Cognitive Research from the Radboud University Nijmegen. The graduation project was carried out at the Media Interaction Department at Philips Research. There she investigated how music features can direct affect and psycho-physiology. This work lead to a journal paper, a patent application, and two conference contributions.

After 101 days of traveling through south-east Asia, in February 2008 Marjolein started her PhD project at the Brain, Body, and behaviour Department at Philips Research in affiliation with the faculty of behavioural and social sciences at the University of Groningen. The current work lead to several journal publications, patent applications and conference contributions. During her project, Marjolein was involved in several extracurricular activities; supervised four students, had a consultancy role on physiological research, data analysis, and research design for psychological research, was a visiting scholar at the Stanford University and at the Liverpool John Moores University, and was the co-founder and chair of the Philips PhD and postdoc community. Her research interests include personalized human computer interaction, health science, psychophysiology, and affect.

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