EMOTIONAL EFFECTS OF CAR PASSENGER ACTIVITIES ON PHYSIOLOGY AND COMFORT: AN EMPIRICAL STUDY

A THESIS SUBMITTED TO
THE GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES
OF
MIDDLE EAST TECHNICAL UNIVERSITY
AND
THE FACULTY OF INDUSTRIAL DESIGN ENGINEERING
OF
DELFT UNIVERSITY OF TECHNOLOGY

BY

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IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR
THE DEGREE OF MASTER OF SCIENCE
IN
DESIGN RESEARCH FOR INTERACTION

OCTOBER 2012

Approval of the Thesis:

EMOTIONAL EFFECTS OF CAR PASSENGER ACTIVITIES ON PHYSIOLOGY AND COMFORT: AN EMPIRICAL STUDY

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ABSTRACT

EMOTIONAL EFFECTS OF CAR PASSENGER ACTIVITIES ON PHYSIOLOGY AND COMFORT: AN EMPIRICAL STUDY

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October, 2012, 64 pages

There are lots of elements involved in the design of a car. This study, which is inspired by the brief of BMW group, explores the seating unit of cars with regard to prototypical activities, such as, listening to music, working, looking outside etc. The current study proposes that these external stimuli have an effect on comfort experience and felt emotions. So, this study explores the relationship between types of music and activities typically performed by car passengers and emotion and comfort perception, through performing a within subject design empirical study. A car seat provided by BMW group was used to test the above mentioned relationships. Data was collected through a self-report questionnaire, heart rate equipment, a pressure mat and analyzed separately for each condition. Results of the study show that there is a successful emotion induction by task and music individually, and partly on task*music interaction. A comparison of

congruent and non-congruent situations, i.e. high arousal music and high arousal task or low arousal music and low arousal task, showed that differences occur in subjects' reported level of arousal. Furthermore, the results of the study indicated that comfort is related to valance factors, independent of arousal levels. Lastly, physiological measurements showed that only task has a significant effect on heart rate, implicating for the complexity of linking physiological data to emotion and comfort.

Keywords: Emotion, comfort, music, activity, car seat

ÖZ

ARABA YOLCUSU AKTİVİTELERİNİN FİZYOLOJİ VE KOMFOR ÜZERİNE DUYGUSAL ETKİLERİ: AMPİRİK BİR ÇALIŞMA

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Eylül 2012, 64 sayfa

Araba tasarımına dahil birçok eleman vardır. BMW grubun sağladığı tanımdan esinlenen bu çalışma, yolcuların, müzik dinleme, çalışma, dışarıyı seyretme gibi, tipik aktiviteleri üzerinden araba kotuğunu inceliyor. Çalışmada bu bahsedilen tipik aktivitelerin komfor deneyimi ve hissedilen duygular üzerinde etkisi olacağı öne sürülüyor. Bu sebeple, bu çalışmada, bir ampirik çalışmayla, müzik çeşitleri ve araba yolcularının tipik aktiviteleri ve duygu ve komfor algısı arasındaki ilişki ele alınıyor. Bu ilişkileri test etmek için BMW grup tarafından sağlanan bir araba koltuğu kullanıldı. Öz-bildirim anketleri, kalp ritmi cihazi ve basınç matından toplanan veri, her durum için ayrı ayrı analiz edildi. Çalışma, duygunlanım yaratma üzerinde müzik ve aktivitenin ayrı ayrı ve iki durumun, yani müzik*aktivite etkileşiminin de, belli bir seviyede başarılı sonuç verdiğine işaret etmiştir. Uyumlu, yani yüksek seviyede duygulanim yaratan müzik ve aktivite veya alçak seviyede duygulamın yaratan müzik ve aktivite durumları, ve uyumsuz durumların karşılaştırmasında ise katılımcıların duygulanım raporlarında farklılıklar olduğu gözlenmiştir. Ayrıca, sonuçlar, komforun duygulanım faktorlerine bagli olduguna işaret

etmiştir. Son olarak, fizyolojik ölçümler, sadece aktivitenin kalp ritminde anlamlı bir etkisi olduğuna işaret etmiştir. Bu da fizyolojik data, duygu ve komfor kavramları arasındaki karmaşık ilişkiden keynaklanmaktadır.

Anahtar sözcükler: Duygu, komfor, müzik, aktivite, araba koltuğu

ACKNOWLEDGEMENTS

Firstly, I would like to thank my supervisors Prof. Dr. Peter Vink, Assist. Prof. Dr. Valentijn Visch and Assoc. Prof. Dr. Owain Pedgley, for their guidance, advice and criticism throughout this graduation project. Also, I would like to examining committee members; Inst. Dr. Canan E. Ünlü, Assist. Prof. Dr. Çağla Doğan and Assist. Prof. Dr. Elif Özcan Vieira.

Furthermore many thanks to Ir. Alexa-Sibylla Wagner and BMW group for providing me with the opportunity to perform a research that can be used in industry and for all comments and advice. Moreover, my thanks to Dr. Ir. M.P. Netten, Dr. Ir. Irene kamp and Dr. Gaël Laurans for their comments on the topic and sharing their thoughts with me. Also, many thanks to Ir. Bertus Naagen, for sharing his expertise and offering support on the many technological challenges in equipment. These insights were very valuable and motivating for me.

I would like to thank my parents and brother for always believing in me, keeping me calm and opening new perspectives which broadened my vision. Tommy and Jelle, my study mates and sports buddies, thank you for the inspiring discussions and late night talks on our graduation projects. Also, many thanks to Jaap, Anne and Odiel for their moral support. Bart and Frank, thank you for supporting me and being patient in our friendship.

Also thanks to my friends Floris, Tirza, Gonca and Nur, whom I started this master adventure together. Senem Turhan, Hakan Boğazpınar, Aslı Günay and Ercin Okursoy for their help on practical issues. Damla, for her enduring help on numerous administrative arrangements of hundreds of institutions, but moreover, for being my personal star. Without your light I would get lost, without your love and trust I would fall.

Thank you all for supporting me.

Time for a new challenge.

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CHAPTER 1

INTRODUCTION

1.1 Background

The automotive sector is a competitive environment that is fed from the neighboring domains of technology, ergonomics and design. These domains help to improve automotive sector by contributing through different perspectives that are derived within their expertise. Technology expands the possibilities; ergonomics dictates the compatibility with man. Design appears as a bridging element among these different expertises. Designers and design research by approaching to the automotive sector and the product: car, from different aspects contribute to the design of cars that are better suited to users' expectations and that have better interaction with their users, by understanding its users better.

Innovation is crucial. Moreover, there are several challenges that the automotive sector faces with. For example, as Kamp (2012, p.329) states "not only does the industry [the automotive industry] have to keep up with competitors but also has to maintain (or expand) market share and meet increasingly stringent emission regulations." While regulations limit the space for product design and innovations are needed to keep up with competitors, product development is under continuous pressure. Yet, the maintaining and expanding of market share is directly related to the people who are purchasing and using thesis cars which emphasizes the importance of the user component in product design.

In automotive design there are multiple examples of driver-focused interfaces and interactions, such as a safety oriented 'eye-blinking monitor' monitoring alertness of a

driver (Toyota news release 2008, accessed on 2nd Sept 2012) or a more hedonic oriented 'driving dynamic control' that addresses the driver's perception thus product experience by giving a more dynamic, sporty feeling of driving (BMW technology guide, accessed on 2nd Sept 2012). These show the currently existing search for applications in which various aspects of product experience are measured and the elements of a car are adjusted for the betterment of the emotional or physical state of a driver.

As Vink (2010) states, comfort is related to expectations and emotion, which emphasizes the importance of the product-user interaction. In the context of interaction, emotions have multiple functions on both shaping and evaluating the interaction (Forlizzi and Battarbee, 2004). Therefore, from a design perspective, the interaction between the car as a product and the passenger/driver as user should be the focus point to maximize positive emotions and thus enhance comfort.

1.2 BMW

BMW group, which has a long lasting established place in the automotive market, realizes these dynamics well. In their vision "Safety, comfort and driving pleasure should not be compromised by increasing sustainability regulations (Kamp, 2012, p. 10), implicates their understanding of the car is beyond just technical innovation and meeting regulations. It can be understood from this vision that the user is BMW's foremost concern in car context.

The idea for the here presented research originated via existing communication lines between DUT and BMW. BMW's brief, matching their current research portfolio, asked a study which focuses on passengers and tries to explore passengers' activities in the car context and the relationship between these activities and emotion and comfort. The author designed the study based on existing research and technical possibilities, which was reshaped in several iterations with supervisors and contact with BMW. Selection of independent and dependent variables was made in collaboration (see acknowledgements and 'independence of study'). Furthermore BMW provided a budget

for the materials in the research setup and financial compensation of participants (see method). Pilot, preliminary and main study were built, performed and analyzed by the author under supervision of the supervisory team.

1.3 Aim and Research Question

Applications and research on passenger experience are relatively limited in number. As an example Kamp (2012) in her study, which aimed for the improvement of the rear seat experience, proposed a game design which showed to contribute to a fitter and more refreshed feeling compared to other activities such as reading a book, performing tasks on laptop or playing games on tablet pc. Based on this study can be argued that there is a relationship between emotional feeling (such as 'refreshed') and performed activities.

Likewise, the here presented study inquires into ordinary activities of passengers in a car context, such as listening to music, watching out of the window, working on tablet or laptop etc. and searches for the relationship of these activities to emotion and comfort. Furthermore, the brief of BMW questioned whether emotional state and/or comfort perception of a user, can be read from unobtrusive measurements such as posture and other physiological measurements and/or read from activities such as listening to music. The objective of this study is to explore these relations as well as possible ways in which those relations can be used in future product design.

Therefore, the main research question is: 'what are the effects of typical passengers' activities on emotion, comfort perception and physiological response?'

Four sub-questions are posed to help answer the main question, as follows.

1. ‘What are the effects of activities on emotions?’
2. ‘What are the effects of activities on comfort perception?’
3. ‘To what extent do activities have an effect on posture?’
4. ‘To what extent does emotional incongruence of activities have an effect on posture, comfort experience and emotional feeling, compared to congruent situations?’

1.4 Structure of the Thesis

This thesis is composed of five chapters: introduction, theoretical framework of emotion and comfort, method of empirical study, results and discussions of empirical study, and conclusion with implications for product design and future study.

CHAPTER 2

THEORETICAL FRAMEWORK

This chapter aims to ground the concepts used in this study and the hypothesis that are built on these. First the emotion concepts are discussed, which are followed by discussion of comfort concepts. By introducing the embodied cognition theory, emotion concepts are linked to physiological phenomena. Finally emotion induction processes are described, to substantiate the independent variables of the study which will be explained in the next chapter

2.1 Appraisal and Core Affect

When people are faced with a product, their interaction with the product follows certain steps. As mentioned before emotions play a key role on shaping and evaluating this interaction (Forlizzi and Battarbee, 2004). The fundamental point of working on emotions is perhaps to define how emotions are built in an interaction.

Commonly used explanation is that emotions occur through a process of 'appraisal'. Appraisal is defined as "a quick evaluation of a situation with respect to one's well-being" (Demir et al, 2009). From this definition it can be understood that appraisal is a personal evaluation of one's relationship with a given situation. Furthermore, as the multi component model of Sander et al. (2005) describes, the appraisal mechanism consists of several stimulus evaluation checks ("SEC's", p. 319) that through an iterative process form the total appraisal process resulting in emotion and possible action tendencies. Therefore, it can be understood that both the fact that this process is individual specific and even a slight change in initial stimuli can change the whole appraisal process thus outcome of it, portrays the appraisal process as a complex web of

various dynamics. In other words, a change in core affect will have an effect on the end result, the affective state of this interaction.

There are also different approaches to explaining for affective states exist. Yik et al. (2011) classify three types of structures; 1. Categorical structures, which are based on everyday folk lexicon; 2. Dimensional structures, which place affective states in a two dimensional, bi-polar (pleasure-displeasure and activation-deactivation) space, and; 3. Circumplex Structures, these are derived from dimensional structures, thus defining a multi-dimensional space on which affective states can be plotted. Categorical structures use emotion concepts from everyday folk lexicon such as 'fear' or 'anger' which are typically "about something", i.e. an intentional object or subject (Russell, 2003).

As explained there are various dynamics acting on affective states. Therefore measuring them is also multi-faceted. However, methods that focus on categorical structures, which try to address affective states in folk lexicon are mostly used methods. Since using words is also ambiguous, scholars have found a way of addressing these everyday categories in various ways. Often used models are the categorical emo-cards by Desmet (2001) (Figure 1), and the dimensional model using (self-) assessment manikins (Figure 2). In both models participants are expected to select the option that applies to them.

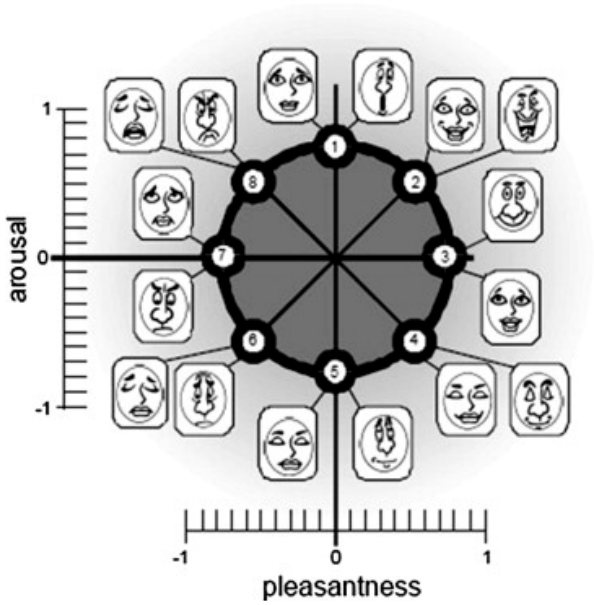

Figure 1 Emo-cards (Desmet, 2001)

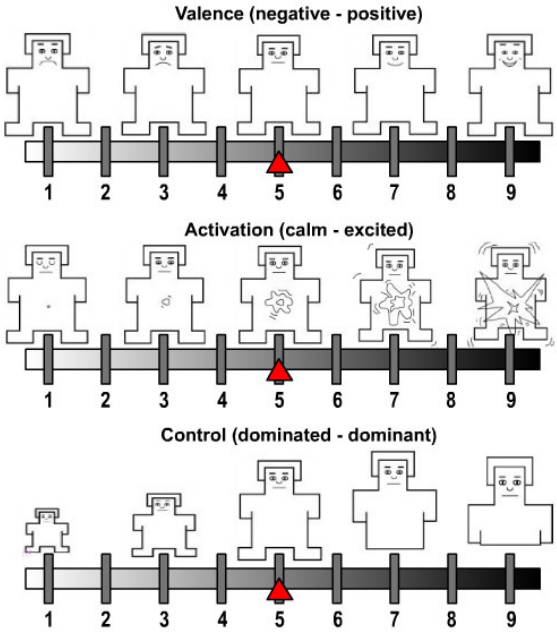

Figure 2 Self-assessment manikins (TRUE, SAM. 'www.salle.url.edu/tsenyal/true', Sept 2, 2012)

These methods might appear beneficial for solving the ambiguity of cultural and linguistic processes. However, these graphic methods disregard the difficulty of assessing the meaning of the icons. Moreover, these methods are difficult to link to a situation where multiple emotions exist simultaneously, which, as Russell (2003) points out, is often the case.

The multiple stimulus evaluation checks (Sander et al.) and iterations explain the difficulty of predicting the outcome of the appraisal process. Especially in an experiment setting where only a limited amount of components (e.g. stimuli and environment) can be influenced and measured. Therefore, an approach on emotions at a very fundamental level, i.e. 'The Approach of Core-affect' (Russell, 2003, figure 3) is preferred as a way to measure affective states in this study. The approach of core-affect describes core affect as the continuous assessment of one's current state, similar to the definition of 'appraisal' of Demir et al (2009), but more fundamental and focused on the state of a person.

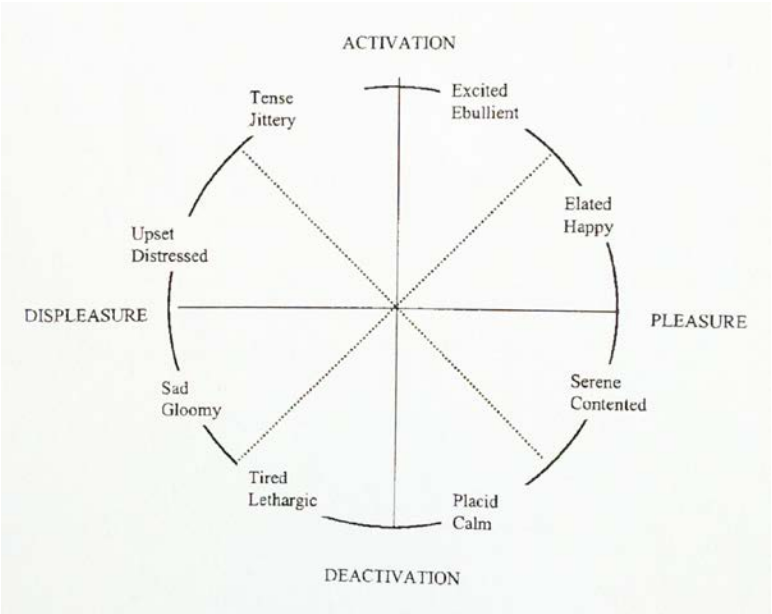

Figure 3 Russell's Approach of Core-Affect (Russell, 2003)

Perception of any affective quality of a stimulus can lead to a change in core-affect, which in return can lead to an attributed affect, e.g. emotional feeling (Russell, 2003). Russell adds to this that multiple changes in core affect can occur at the same time, which further justifies the use of a multi-dimensional approach, in which subjects rate all elements of a circumplex rather than specific emotion labels.

2.2 Emotion

There are several terms that are used to define different affective states such as emotions, moods, attitudes or preferences. Scherer (2005) addresses this issue of multiple terms and makes a clear distinction among these states based on their 'design features' (Figure 4). Distinguishing emotions from other states, Scherer describes 7 design features on which emotions are built. Those are described below;

- Event focus. Emotions are related to an event in specific which can be external or internal to a person. For example, fear is often related to an external event (being feared of a snake). But emotions can be also elicited by one's own actions, of which pride and shame are examples. Emotion is thus not a flee-floating state nor is it a structural decision of a person towards an event or other person.
- Appraisal. The process of validation of the relevance of an event or person to an appraiser. This can be intrinsic, i.e. based on genetic or learned preferences, or transactional appraisal, evaluating relevance of an event or person to for example 'salient needs' or 'goals of the appraiser'. The more relevant an event is evaluated, the more likely it is that the appraiser will react to this event, i.e. the emotion leads to action tendencies.
- Response synchronization. The process, in which the response to an event or person is prepared, based on the analysis of the presumed implications of the event. Thus, emotions prepare responses to relevant events. Synchronization is referring to the fact that most cognitive subsystems are

involved in this process of ‘response preparation’ and thus should be synchronized to give a uniform response which fits to the appraisal.

- Rapidity of change. The speed in which changes of emotional responses to an event occur, based on an adaptation process to the event or changes in context. Emotions are considered to have a relatively high rapidity of change.
- Behavioral impact. This refers to the impact on ‘emotion consequent behavior’ and possible motor expressions referring to bodily state.
- Intensity. The intensity of a state related to the response patterns and size of behavioral impact, i.e. to which degree a person’s behavior is adjusted. Emotions are considered to have a high intensity when compared to other affective states.
- Duration. This is the length to which response patterns to an event or person take place. Emotions show to be relatively short-lasting since response patterns can change rapidly.

Design features Type of affect	Event focus	Intrinsic appraisal	Transactional appraisal	Synchronization	Rapidity of change	Behavioral impact	Intensity	Duration
Preferences	VL	VH	M	VL	VL	M	L	M
Attitudes	VL	L	L	VL	L	L	M	H
Moods	L	M	L	L	M	H	M	H
Affect dispositions	VL	L	VL	VL	VL	L	L	VH
Interpersonal stances	H	L	L	L	VH	H	M	M
Aesthetic emotions	H	VH	L	MH	H	L	L–M	L
Utilitarian emotions	VH	M	VH	VH	VH	VH	H	L

Note: VL = very low, L = low, M = medium, H = high, VH = very high.

Figure 4 Different types of affective phenomena (Scherer, 2005)

It is important to note that those features are not describing subsequent steps in which emotions are build, but are referring to different elements that can be used to describe different affective states among which 'emotions'. Scherer (2005) produced a table (Figure 4) in which different affective states are compared on the before mentioned features. In this, Scherer distinguishes aesthetic and utilitarian emotions. Aesthetic emotions such as fascination, bliss and rapture, refer to the experience of visual art or listening to a music piece, which is not formed by a transactional evaluation of one's goals. Utilitarian emotions such as anger, fear and joy, are considered as a state which facilitates one's adaption to events. This distinction might also refer to relaxing versus working situations that can be seen in a car context.

In existing automotive research related to users there is often made use of the word 'mood' referring to a user's; emotional state (for example Van der Zwaag, 2012). Scherer exemplifies moods by being cheerful, depressed or gloomy. Preferences, i.e. 'unspecific positive of negative feelings' (p703) and attitudes as 'liking', 'desiring' and 'love' (interpersonal), are considered as diffuse states and are less used as concepts in automotive studies. This because of their stability and endurance, thus extreme difficulty to change or induce, especially in experimental research.

As can be seen from Scherer's division, moods are rather long lasting, slowly changing states with high behavioral impact. This would implicate that research focused on mood would have a long time span containing multiple measurements of mood as well as a search on behavioral changes. However, this is not always the case as Van der Zwaag encompassed 4 relatively short-lasting sessions (8 minute induction followed by two*8-minute simulation drives), but also a different mood induction for each session. It could therefore be argued that this is more referring to emotion induction than to mood induction, explaining the doubled use of the concepts 'mood' and ' emotion' in research. Thus, 'mood' implies for a considerably long term interaction. Therefore, 'emotion' will be used as a term defining the outcome of appraisal process.

2.3 Emotion Induction by Music

The main research question of this research focusses on the relation between performed activities by passengers and passenger emotions. It is therefore interesting to look at emotion induction, to use this knowledge in experimental setup. This paragraph discusses emotion induction through music which relates to passengers activity of listening music.

Literature shows that emotion induction through music is approached from many terrains such as psychology, musicology and comfort studies. From emotional perspective, Scherer and Zentner (2001) describe several features of music (i.e. structural, performance, listener and context features) to aim for a componential approach searching the effects of specific features. However, Scherer and Zentner argue that the possible way in which music might generate emotion is not necessarily the same way as the earlier described appraisal route of emotion. Furthermore they argue that more subtle words should be used to describe the 'music-specific' emotions, which indicates the existence of subtle differences in emotional responses to music. This argues for a personal and phenomenological approach, in which subjects select music from their own playlist and is validated through self-report ratings.

Many studies exist on the emotional and physiological effects of music, also regarding the automotive industry. One distinction between these studies is that the music listening is either a primary or peripheral task.

Also Khalfa et al (2008) proposes a componential approach through a study searching physiological effects of respectively fast/slow rhythm and tempo. Significant differentiation of happy and sad music is found, showing importance of 'tonal variations', while rhythm and tempo versions did not elicit these differentiation. However, other emotional categories are in this study not taken into account. Contradicting Khalfa (2008), Lundqvist et al (2009) does show a relation of happy music and presence of fast tempo, high sound level and major mode and the opposites for sad music.

2.4 Measurement of Emotion

The phenomenal descriptions of emotions, makes it even more debatable to induce emotions and to measure these. Furthermore, according to Zentner et al. (2008), present studies on musical emotion induction are often based on discrete emotion theories or to arousal and valence dimensions from the affective circumplex. As argued in previous paragraph those 'utilitarian emotions' are high intensity and encompasses mobilizations of bodily systems due to events or persons (stimuli) that have obvious effect on an individual's well-being. As Scherer's (2005) distinction from these to aesthetic emotions which have low behavioral impact, Zentner et al. (2008) propose a theory of 'emotion refinement' which makes a similar division between "coarse" and " refined" emotions (Frijda & Sundararajan, 2007, from; Zentner et al.).

Moreover, Zentner et al. show several inconsistencies in methodologies of past research on music induction over the 20th century. First is the discussion which Lundqvist et al. (2009) describe an enduring methodological issue in research on music with self-reports as measurement tool for emotional 'feeling'. Core of this discussion is whether to speak about music contagion (cognitivists) or music induction (emotivists). Referring to Rigg's comparative study (1994), Zentner et al (2008) explain that early research running into 70's, focused on perceived characteristics of music, e.g. not to asking subjects for feelings but ask subjects to describe the music using emotional terms, thus a cognitivist approach. On this approach Sloboda argued that its relevance to emotional experience is not proven (in; Zentner et al, 2008, p.496). The emotivist approach is empirically supported in later research, e.g. Kallinen & Ravaua (2006, from Zentner et al. 2008, p. 496) who showed that fearful and sad music can elicit a positive affect. A second methodological inconsistency according to Zentner et al. lays in unclear ways of selecting music excerpts used as stimuli. Selection criteria are not standardized. Moreover, this results in unclear procedures of processing and validating gathered data. These inconsistencies led to fragmentation of the research area which makes results of one study difficult to compare and validate to another study.

Opposing emotion models with arousal and valence as basic dimensions (e.g. Russell (2003)), Zentner et al. propose a more qualitative and phenomenological approach to emotions induced by music. In a series of studies differentiating perceived and felt emotions to music, they construct the Geneva Emotional Music Scale (GEMS) containing 9 emotion 'musical emotions' and their associated 'feeling terms'. Although this is a promising theory which addresses a large part of the methodological issues in research, it is important to realize that these emotions may be "just one example of a much larger category of emotions relating to aesthetically appraised day-to day objects, situations, and experiences, which, as a whole, occupy much space in human lives" (Zentner et al, p. 515). This also seems to argue for an approach that does not break music down into separate elements such as timbre, tempi and major or minor tone, but approach as a more phenomenological construct. Furthermore, critical issue concerning the here presented research is not solely focusing on emotional responses to music, since listening music is only one of the activities performed in a car-context. Interestingly, Yik et al (2001) elaborated on the circumplex model of core-affect proposed by Russell (1980, 2003), with a similar intension of clarifying the emotion concept (compared to models with few dimensions) to be used in self-report methods. Yik et al. provided a series of studies in which current emotion models were merged and validated in an empirical study asking subjects about a 'specific moment'. Furthermore, the study compares three different response formats, i.e., "adjective", "agree-disagree" and "describes me" format on their 'fit' to the circumplex. Although the 'fit' of these formats is only merely differentiated in some of the 12 segments of the circumplex, the 'agree-disagree' format seems to show the most evenly spread result over the whole circumplex, and seems to be less biasing the results on reported emotions. The statements that Yik et al. (2011) use in their 'agree-disagree' format are different, and perhaps stronger related to concrete emotion labels compared to the 'aesthetic' adjectives of Zentner et al. Yet, statements of Yik et al. do also address the 'negative' semicircle on pleasantness, i.e. left side of the emotion circumplex (see Figure 3).

With the theory of earlier paragraphs in mind, it remains a question how emotions can be best measured. In this, it is important to remember the valence and arousal components, which are the basis of the dimensional emotion models mentioned earlier. According to Scherer and Zentner (2001) self-report is 'the only method that allows to the subjective emotional experience'. In this, Scherer mentions different checklists and scales to be used, a part of which Yik et al. (2011) has discussed and validated on the circumplex model described earlier. However, Scherer also stresses that self-report, and 'verbal report' in specific, bring a fundamental difficulty which is the influence of experiment design including the artifacts used, 'demand characteristics' and possibly even social desirability. Fitting with the multi componential model of Scherer (2005), Scherer and Zentner (2001) argue that measurement of emotion should at least encompass the components of physiological arousal, motor expressive behavior, subjective feeling, and possibly also a motivational component in the form of action tendencies and a cognitive component consisting of emotion-constituent appraisal and reappraisal. Therefore it is also interesting to look at possible physiological measurements to indicate emotion, and the earlier explained change in core affect in specific. Since this study is aimed at the relation of those measurements to music, elements of music literature are discussed below.

2.5 Physiology of Emotion

Stating Gendolla (2000), Van der Zwaag et al. (2012) argues that primary listening to music is not resulting in physiological responses on heart rate and respiration rate (RR). On the other hand Van der Zwaag (2012), referring to Cacioppo et al. (2000), and Van der Zwaag and Westerink (2011), argues that skin conductance and facial muscle tension are shown to differentiate between moods. Also Lundqvist et al. (2009) found a significant effect of both skin conductance and finger temperature between happy and sad music. Furthermore, Lundqvist et al. did not find a significant relation towards heart rate, but does report a significant U-shaped pattern in deceleration-acceleration in the first 15 seconds of the music, regardless of Valence.

Scherer and Zentner (2001), discussing and comparing multiple existing studies on music- mood induction, conclude that it is difficult to argue that 'prototypical' physiological response patterns have been found distinguishing 'discrete' emotions. This shows that results in studies differ in outcomes, especially on physiological effects. On one hand this is may be due to differences in experiment setup, such as differences in stimuli, duration, on the other hand it shows that conclusions on correlations between reported physiological effects and elements of music should be taken with care. Laurans (2011) concludes after reviewing existing studies on measuring affect "(e.g. self-report and physiology) do not always allow any clear conclusion about the magnitude of the correlations but those that are reported also tend to be quite modest" (Laurans, p. 136). Furthermore, since literature does not show consensus on the route in which music-mood induction takes place, it is important to show that aim of the study is to search for relations to comfort and emotional experience, rather than explaining the music mood induction itself.

Lastly it is also important to realize that some of the physiological measurements like ECG are quite obtrusive (e.g. skin has to be cleaned from old skin particles and then sensors need to be placed) and therefore unsuited for this research, since comfort is also one of the variables.

2.6 Comfort

In a new comfort model (Figure 5) which elaborates on existing comfort models, Vink and Hallbeck (2012) indicate that comfort (C) is related to product interaction (I) through perceived body effects (P) and expectations (E). Yet, this new model is partly based on a comfort model of De Looze et al (2003) in which emotion is named as factor of comfort as well. Together this implies that the emotional state of a user can have an effect on and can be affected by the interaction with a product, which in the end might affect comfort.

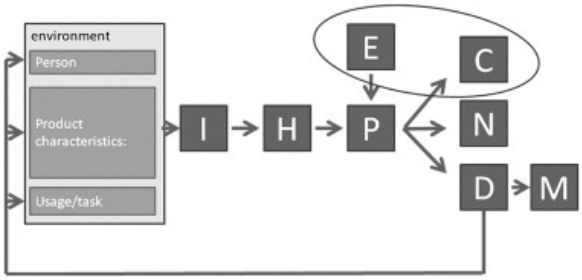

Figure 5 New Comfort Model (Vink and Hallbeck)

Related to airplane seats Vink (2010) states that "comfort is related to experience, emotion, unexpected features, and luxury", which stresses the importance of knowledge on these elements. For the present study the emotion component of comfort will be explored.

Moreover, Vink (2010) states that discomfort is not the opposite of comfort, meaning that taking away discomfort does not necessarily leads to a higher comfort level, which can be also seen in the new comfort model of Vink and Hallbeck placing both discomfort (D) and comfort (C) as outcome.

This has its effects on the way of measurement of comfort, as well. Kyung et. al. (2007) concluded, as a result of their comparative study on different subjective rating methods, that overall vehicle comfort is not only the sum of comfort and discomfort ratings. In addition to this, Kyung et. al. (2007) showed that, especially regarding the car seats, comfort ratings are best suited to distinguish seats. Adding to this, Kyung et. al. (2007) found that comfort ratings are more oriented to pleasure where discomfort ratings relate more to pain prevention. Therefore, in this study, as part of the self-report questionnaire, an overall comfort rating scale will be used. Following Kyung (2007), Vink (2003), Vink and Hallbeck (2012) it is hypothesized to see a significant relation between comfort and pleasantness, i.e. valence scores which is one of the emotion factors of dimensional emotion models.

2.7 Embodied Cognition

Besides the comfort model of Vink and Hallbeck (2012), which explains that emotion and comfort are linked, there is also existing empirical evidence for the link of emotion and 'bodily state' (e.g. physiological posture, movement, blood pressure, heart rate etc.) that is clustered under theories of embodied cognition (Niedenthal, 2007). As Niedenthal (2007) explains, perceiving an emotion involves perceptual, as well as motoric re-experiencing (i.e. 'embodiment'), of the felt emotion. Adding to this, Barsalou et al. (2003) explain that the cognitive systems that are responsible for perception, action and emotion, are also constructing the conceptual representations i.e. knowledge about a 'category', e.g. car seat or car. These views add to the embodied cognition theory that 'body' and 'mind' are not working parallel, but interrelated. Therefore it is interesting to take physiological measurements on bodily state into account when studying emotion.

Embodied cognition contains a 'body feedback' and 'cognitive feedback' direction, indicating two possible relations between 'body' and 'mind'. Body feedback, or the embodiment process, describes which sensory-motor systems (like bodily state, facial mimicry and posture) relate to cognitive emotion processes (Niedenthal, 2007). An example of this relation is shown by Strack (1988) who assigned participants to stabilize a pen between their lips. This action of stabilizing requires a tensioning of the same muscles ('corrugator supercilii', see also Lundqvist et al. 2009) of the mouth that are also involved in faces which correlate to negative emotions as 'anger'. Participants were significantly less amused by a cartoon compared to compared to holding a pen between their teeth activating muscles that are also used for pleasant emotions('zygomaticus major', see also Lundqvist et al., 2009). This showed that muscle activation resulted in a change of appraisal.

The opposite direction, called 'cognitive feedback', is describing the effect of cognitive processes on sensory-motor systems. Empirical arguments on cognitive feedback are mainly from linguistic and semantic studies. Glover et al (2003) showed for example that when hearing words related to the size of objects ('apple' vs. 'grape'; large vs. small)

subjects had a different orientation of the fingers correlated with the kind of grip ("power grip", i.e. grasping with the hand; vs. "precision grip", i.e. grasping with finger tips). Thus, the cognitive processing of the words changed the position of the hand, i.e. the sensory motor system. In other words, this shows that positions of the human body (linked to posture) are related to cognitive processes as emotional appraisal. This funds the hypothesis that after successful music emotion induction, changes in body posture occur that are congruent with the type of emotion that is induced. Related to seating in a car, this would suggest changes in posture (e.g. upright vs. slumped).

The empirical arguments supporting the embodied cognition theory relate bodily state to emotion. Since comfortable feeling is built on an emotional feeling of personal well-being (Kamp, 2012; Vink and Hallbeck, 2012), it is hypothesized that comfort is related to bodily state as well as emotional state. Furthermore, the embodied cognition theory refers to bodily state as 'state', 'posture' and even to movements of the human body. Thus, the physiology of the human body encompasses for example heart rate, as well as posture of the human body. Therefore 'physiological measurements' is used as term in thesis encompassing both heart rate and posture.

The here described literature relates to a research studying the effects of music induced emotion and task on both comfort experience and emotion. This is done by measuring comfort, emotion and posture. Based on the above discussed fundamental literature, the following list of independent and dependent variables is selected for experiments. The variables in the preliminary study/main experiment are;

- Chair position (preliminary study); BMW provides a car seat which is manually adjustable. A pilot study will be performed to determine a valid position of the seat. This position will be used as standard position in the main experiment.
- Music (main experiment, independent variable); To induce the arousal level, participants are asked to select and rate 4 songs from their own playlist, resp. two high- and two low aroused. Participants will also rate their songs on arousal level, forming a measurement to be used as validation of other results.

- Task (main experiment, independent variable); Counterbalancing the music variable, two activities are used to bring people in a resp. low and high aroused state. These activities are related to the context of car travelling (as passenger). Looking outside to the environment is selected as low arousing task and working in the form of a cognitive brain trainer game on iPad, is selected as high arousing task.
- Posture (main experiment, dependent variable); Posture will be measured using camera recordings as well as pressure mat recordings to capture the pressure distribution on the seat.
- Emotional feeling (main experiment, dependent variable); As the main dependent variable, the two main components in which emotions and other affective states are described, i.e. arousal and valence, will be tested through a self-report questionnaire on core affect.
- Comfort experience (main experiment, dependent variable); as main dependent variable, comfort is asked using a questionnaire, which is a common method in comfort measurement.
- Heart rate (main experiment); As physiological reference for emotional feeling, heart rate changes will be recorded using Polar Heart rate equipment.

The next chapter will explain the method of the performed study in which these variables are applied.

CHAPTER 3

METHOD

A passenger car seat provided by BMW Group was used as the seating unit of the experiment. This chapter describes first a preliminary study which was performed to define the backrest angle of the seat. In a following pilot study the research setup and equipment was tested. Lastly, the method of main study is described.

3.1 Preliminary Study

BMW Group provided a BMW 3-serie passenger seat, for use in the experiments. Due to practical constrains of transportation (e.g. proportions of a whole rear-bench) and difficulty of using standalone (e.g. attachment of rear-bench in a setup and electrical equipment in high-end passenger seats), use of this mechanically adjustable seat were preferred above use of a whole rear-bench or high-end passenger seat. However, angle of the backrest had to be determined. Moreover, pressure distribution is used as one of the physiological measurements to test the hypothesis that bodily state, e.g. posture, is related to emotion as hypothesized in paragraph 2.6 on embodied cognition. To be able to detect differences in pressure related to the experimental conditions rather than being caused by a variance in backrest angle, a fixed chair position including backrest angle is needed. This formed a second argument for a preliminary study on the backrest angle, not to induce posture changes or negatively influence comfort ratings due to unrealistic backrest angles.

The car seat provided by BMW was mounted on a dais to provide a seating height of 440 mm, an average of seating height that can be found in public transport and between

heights in automotive industry, see figure 6. To differentiate between length, i.e. morphological groups, additional footrests are used to decrease seating height of respectively 18 (seating height: 422mm) and 75mm (seating height: 365mm). Stickers were placed on the side of the backrest indicating the place of the hinge (bottom) and three stickers on the side of the backrest, as a reference for the backrest angle, figure 6.
Subjects were asked to adjust the backrest angle according their preference and to let the researcher know when the preferred angle was decided. The following verbal instructions were given;

- "you are not driving but traveling in a car, the backrest can be adjusted using the handle at the left bottom. Can you please adjust the angle of backrest as you would prefer for a relaxing position?";
- "you are not driving but traveling in a car, the backrest can be adjusted using the handle at the left bottom. Can you please adjust the angle of backrest as you would prefer for working on an iPad?"

A photo of each perpendicular side-view was made for both the situation of working on iPad as the situation of relaxing, the tasks that are used in main study.
Angles of each backrest position, i.e. the angle of red markings to vertical, were taken from the photo's using modeling software (Rhinoceros 3d, version 4.0) and analyzed using SPSS (IBM SPSS Statistics 19) to find the ideal angle for the backrest.

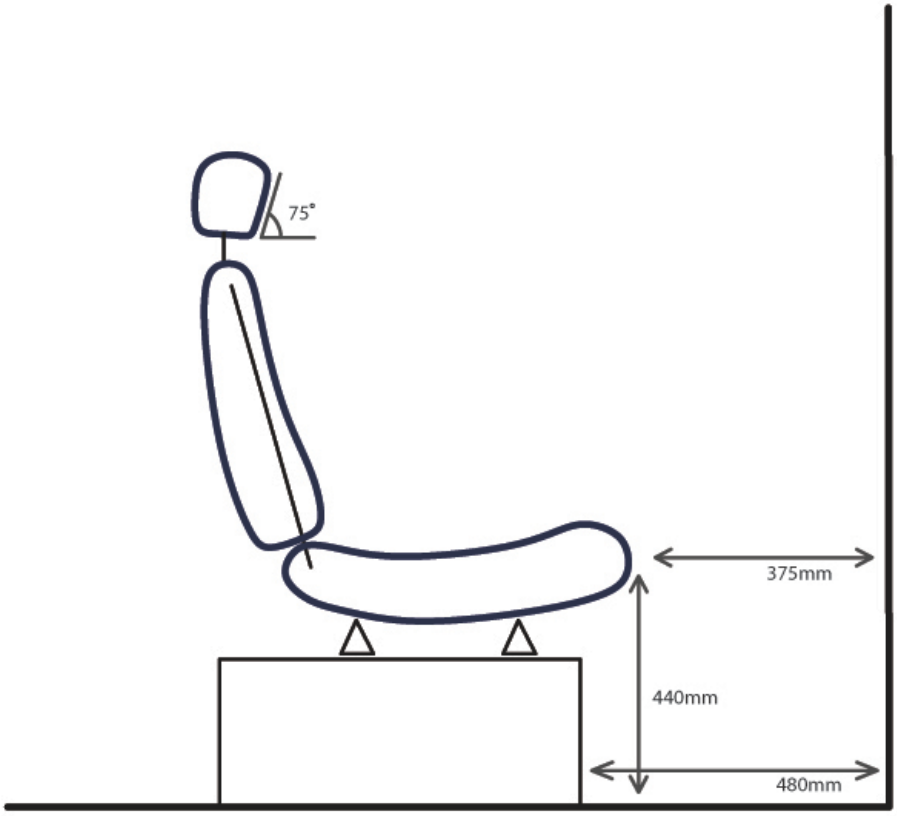

Figure 6 Illustration of car seat measurement in preliminary study

Figure 7 Picture of used car seat with red markings on backrest

Mean values of the angles (e.g. angle on the line of red markers compared to vertical) are relaxing 26,2^0(sd: 4,4^0) for relaxing and 23,3^0 (sd: 4,1^0) for working on iPad, with a mean difference of 2,83^0. A paired samples T-test showed significance of this difference (t<0,01) on 95% confidence interval. However, since the mechanism of the seat is not continuously variable in angle, the backrest angle was set to 24,9^0 which is the possible

midway between the mean values for angles in each task. The chair is used in this state throughout the pilot and main study.

3.2 Pilot Study

To test the protocol and apparatus of the main study, a pilot study was performed with 6 subjects, students at the Delft University of Technology that did not take part in the main study. Specific apparatus is described in appendix A. Goal of this study was to evaluate the research setup, defined dimensions and stimuli. The place of the panels, i.e. the leg space, and the position of the screen are the main elements that set the dimensions of the setup.

Referring to the physical setup, feedback of subjects showed that the screen which was placed perpendicular to the seat (like a car window is to the seat) caused strain in the neck. Therefore the screen was adjusted by placing it more in front of the car-seat, meaning that subjects would turn the head approximately 40^0 degrees to the left to see the screen frontal. Furthermore the distance of the screen appeared too close (approx. 70cm) for the video size to look at pleasantly, after which the size of the video size was decreased to 69,7*34.5 cm (width*height) for the main experiment.

Main criteria for selection of stimuli is the intended induction process as described in paragraph 2.3, but moreover it is preferred to choose stimuli that are related to activities of passengers in daily life. In the theoretical background is shown that music induction processes are stronger in distinguishing arousal levels than valence (pleasantness) levels as well as physiological phenomena that appear to be more related to levels of arousal compared to valence levels. Furthermore, as explanation for non-corresponding results in this field, Lundqvist et al. (2009, p.64) argue that personal 'predominance' for an 'experience-arousal'-, 'experience-expression' link and situational and individual characteristics influence emotion components. This tension field argues to distinguish stimuli based on arousal level, since emotion induction showed to be successful on this dimension in existing research (see paragraph 2.3 on emotion

induction). Therefore the stimuli that are chosen, have been tried to be neutral in valence.

Concerning the cognitive, high arousing game (discussed in following paragraph on main study), a Sudoku puzzle was used in the pilot study as energizing task, in which a combination of numbers is used to create a pictogram. However, a majority of subjects did not understand the game, and left the paper blank. Therefore this game task was replaced by the 'unblock me' (Kiragames, 2009-2012). game on I pad in the main study, which proved to be more understandable and where multiple subjects were familiar with. The IPad with screenshot of the 'unblock me' game is shown in figure 8.

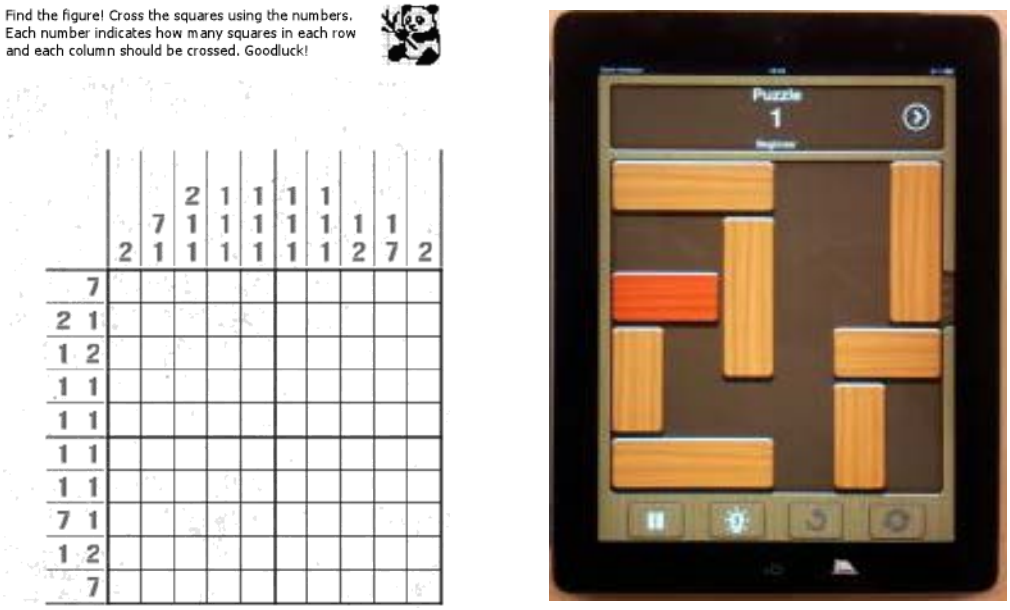

Figure 8. Original Sudoku game and view on iPad with game

As low aroused task, subjects were watching a movie taken from Dutch landscape. Three movies were recorded from the rear seat view of a car driving on a provincial road, in

the Netherlands. All movies were captured in the same landscape at one day thus with similar weather conditions, and were therefore very similar but slightly different. To expand the feeling of looking outside a car window, a left view was recorded, capturing the opposite driving lane with passing cars occasionally. The pilot study gave no results motivating a change of stimuli for low arousing tasks. Impressions of the final research setup including screenshot of movie are given in figure 9-12.

Figure 9. Impression of research environment, right view

Figure 10. Impression of research environment, rear view

Figure 11. Impression of research environment, top view

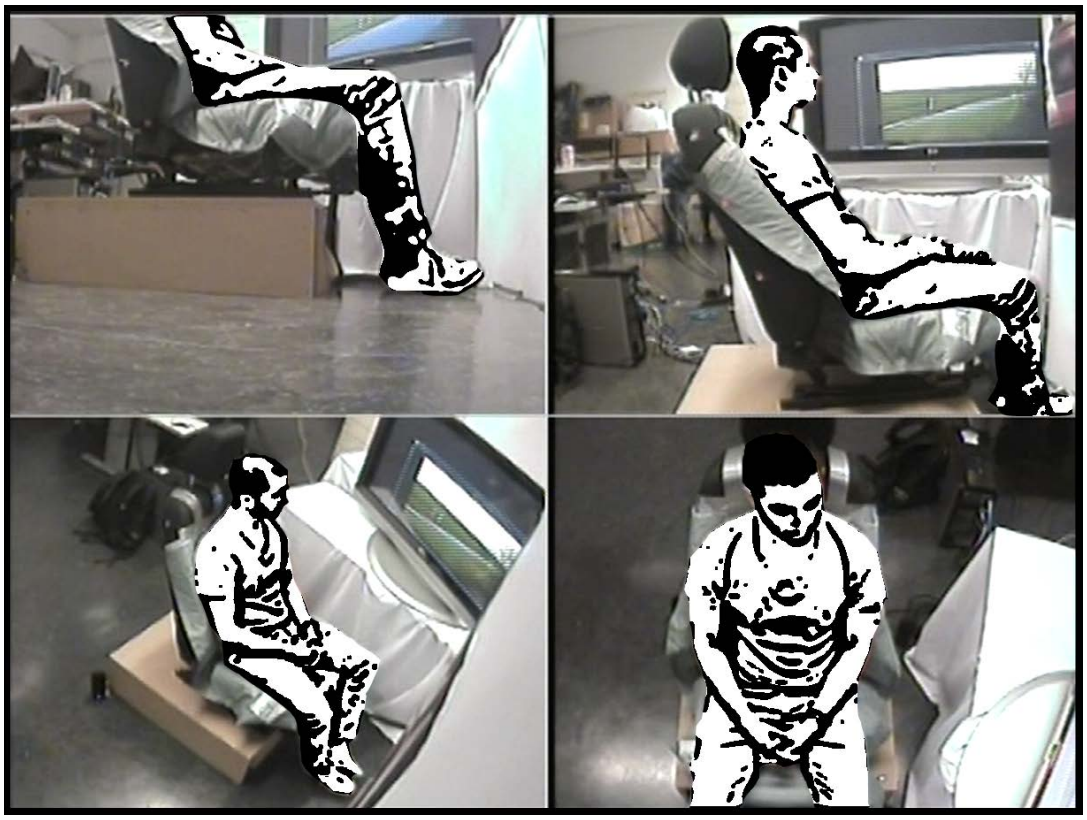

Figure 12. Impression of research environment with subject

3.3 Main Study

A total of 24 healthy subjects (12 female, 12 men) participated in the experiment. All subjects were students at the Delft University of Technology, between the ages 20 and 28 with an average of 24,13 years old. The length of the subjects ranged from 1479-1900mm with a mean of 1726mm and their weight varied between 46,9-95,8kg with a mean of 70,34kg.

In order to study the effects of effects of typical rear-seat passengers' activities on emotion, comfort perception and physiological responses -see the research question in introduction chapter- the activities form the independent variables of the experiment. As discussed in the theoretical background, the emotion circumplex constituted by

arousal and valence axis, gives a basis for dividing task traits in high/low activation or high/low pleasantness. Obviously, non-pleasant activities will not be preferred activities by users in daily life, justifying a distinction of activities on arousal level, also supported by the earlier mentioned argument on existing empirical evidence for relations to arousal level.

Concerning the activities, looking outside is considered as low arousing activity and a cognitive game, related to a concentrated working-task, is considered as high arousing. Listening to calm music are activities that do not involve any fierce bodily movement or cognitive processing (given instruction is not asking specific attention to the music), these are assumed be low arousing activities. Furthermore, taking interpersonal preferences into account, subjects were asked to select music from their own playlist, 2 songs that are 'calming' and 2 songs that are 'energizing'. Participants rated each song on a 10 point bi-polar scale, from 'calming' to 'energizing' as a control for the arousal level that was attached to the selected songs (see form in Appendix B). Furthermore, when music selection is not individually, there is the possibility of unintended emotion induction by the "Darling, they're playing our song' phenomenon" (Davies, 1987, from Lundqvist, 2009, p.). By asking people to select specific songs from their own playlist, and rate those songs on a fixed scale, it is possible to work around 'personal liking' (preventing to negatively induce emotion by playing disliked songs) but still having comparable results by personal rating of the selected songs.

Working on a cognitive task on an IPad and listening to energizing music are expected to be high arousing activities. To create a baseline for main effects of music, a non-music control condition was added. A non-task condition, i.e. sleeping, has been omitted since this cannot be practically combined with listening music, energizing music in specific. Furthermore, inducing sleep is considered out of scope of this research. Together this results in a 2*3 (task*music) = 6 conditions which are depicted in figure 13.

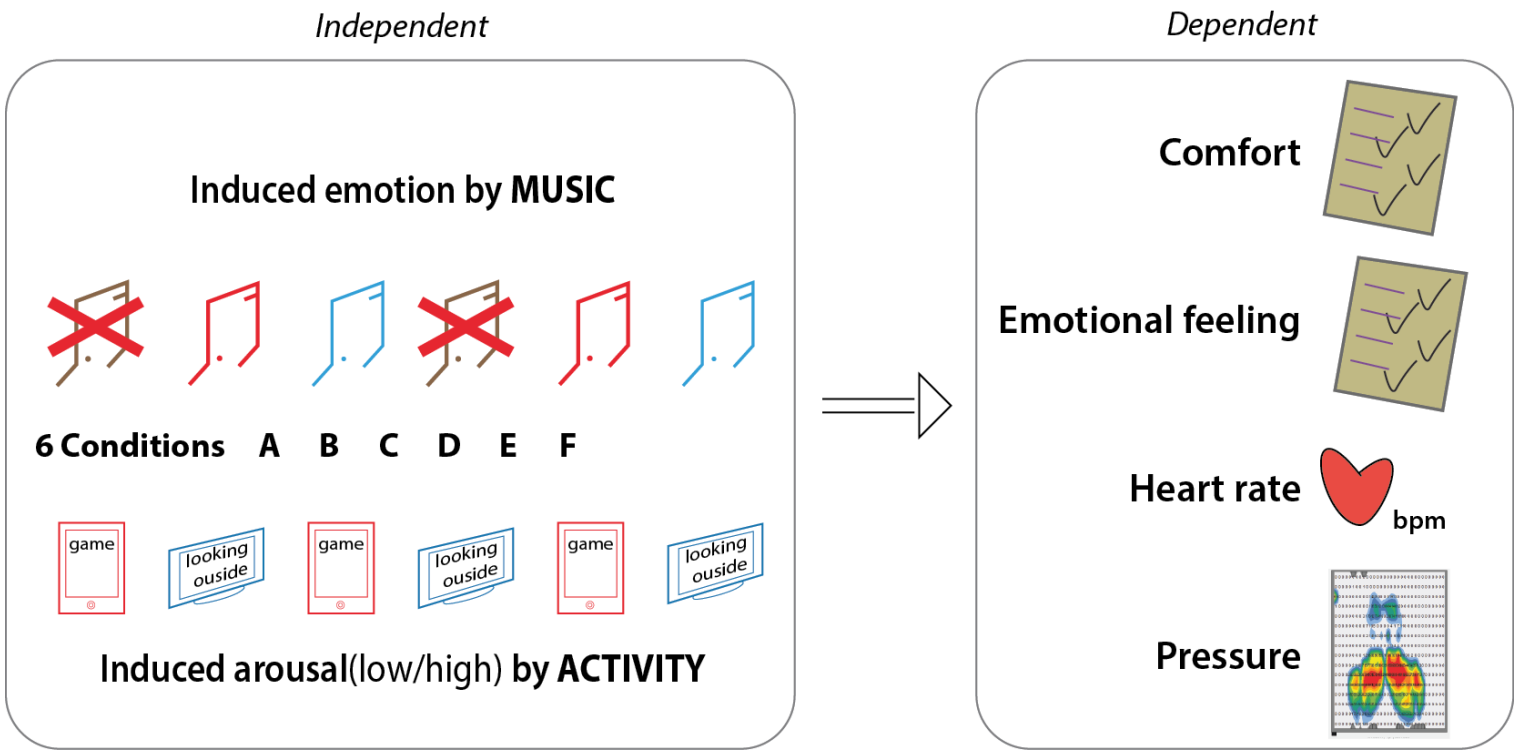

Figure 13 Research overview

The six conditions 'A-F', were systematically spread over subjects in a within subject design using a 'latin square', attached in Appendix D. The conditions, thus combinations of activities, are ordered as follows;

Condition A; Brain teaser game + Energetic music

Condition B; Brain teaser game + Calm music

Condition C; Brain teaser game + No music

Condition D; Watching landscape + Energetic music

Condition E; Watching landscape + Calm music

Condition F; Watching landscape + No music

As argued in the theory part, emotion induction by music showed to be effects after 30 seconds induction time. However, since physiological measurements are taken of which it needs multiple intervals to draw conclusions, a larger time of measuring is needed. The duration of each condition was set on 5 minutes of which the first minute is considered as induction time. The overall duration of each experiment was approximately 1 hour.

In the game conditions subjects started the game at level 1 and continued in following 'game conditions' from their last point onward. For each movie condition, one of the three movies was shown, fixing the combination of movie- and condition number between subjects.

The self-report questionnaire adapted from Yik and Russell et. al. (2011), used to measure emotion and the overall comfort rating, was distributed to participants after each condition (Appendix C). This questionnaire contains emotional statements (e.g. "I feel blissfully at ease" and "I feel energetic and jittery") which subjects rated on 5 point Likert (disagree – agree) scale. To have each of the 12 emotion segments equally represented, two statements per emotion segment were selected and combined in self-report questionnaire. To keep the amount of data manageable and out rule individual effects of statements related to ambiguity, the scores of the 3 segments in each emotion

quarter (e.g. 'Aroused pleasantness') were merged to one score on 1-5 scale. These scores are used for analysis.

3.4 Instructions

The recruitment statement explained the experiments as part of a graduation research in cooperation with BMW on sound and sound speakers, not to cause bias for the subjects through an emphasis on mood and comfort.

After entering the lab room, situated in the faculty of Industrial Design (DUT), Subjects received a verbal introduction in which the recruitment statement was repeated and the number of conditions was explained. Furthermore subjects were informed of the heart rate-, pressure mat-, camera- and sound recording as well as the stickers placed for analysis of posture (see apparatus in Appendix A). After signing the informed consent (Appendix B) subjects placed the chest band for heart rate measurement in a private area in the lab room. Then apparatus was switched on, heart rate connectivity was tested, and reference stickers were applied. Subjects received a 10 euro compensation for participation.

When sitting in the car seat, subjects were asked to indicate whether the height of the chair was satisfactory and when preferred, one of the two footrests (resp. height. 18mm and 72mm) was placed.

The task (game or watching outside) of the first condition was explained to the subject. On the moment of start, also the music was started matching the condition thus calming, energizing or none. After each condition the researcher came to the subject in the seat handing the pen plus self-report questionnaire, picking it up when subject was finished.

When taking back the questionnaire, the researcher gave an explanation of the new task. After finishing all 6 conditions, subjects were asked to stand up from the chair. All recordings were then ended by researcher and body stickers and heart rate band were removed. Finally, providing morphological data, length and weight of each subject were measured.

In the game-task, i.e. high arousing, subjects were instructed to solve as many levels as possible in the given time. Before the watching outside task, subjects were informed that a 'watching outside video will be shown' and were instructed to watch the video.

3.5 Method of Analysis

As the first minute of each condition is considered as emotion induction time, the first minute is not taken into account for analyzing heart rate and pressure mat data. Also, since subjects might get a feeling for the 5 minute condition time, and therefore might have thoughts as 'this condition must be over soon' which can influence their emotion, also the 5th minute is left out of the analysis. Based on these decisions and to keep the amount of data manageable, analysis of heart rate and pressure mat data are limited to the 2nd and 4th minute of each condition. For every condition a mean value of heart rate and posture was calculated for analysis.

CHAPTER 4

RESULTS AND DISCUSSIONS

Firstly the dataset is evaluated to detect patterns of missing values using a missing value analysis. Since patterns of missing values might bias the results these should be recognized and corrected when possible. Thus, a missing value analysis was performed on the answers to Yik and Russell's (2011) questionnaire on emotion, to see if there is a pattern in missing values. It showed that 16,67% (4 cases) had at least one missing value, in total 0,9% of the data appeared missing. One case showed 50% missing values in condition E (Arousing task*Energizing music), and this case was therefore excluded from further analysis on emotion. The quantitative data analysis was done using IBM SPSS Statistics 19 and results are reported significant at $p<0.05$ unless stated differently.

Results of the analysis are explained in four parts. The first part explores the results of the emotion induction process with respect to task and music. As described in methods chapter, different types of tasks and music were used to induce different levels of arousal. Therefore this part indicates to what extent emotion induction was successful. In the second part, the effects of emotion on physiological responses i.e. heart rate and posture are described. The third part reports the effects of congruence of task and music, i.e. high arousing activity and high arousing music, or low arousing activity and low arousing music, on emotion induction. A fourth part elaborates on the third, discussing comfort ratings, with respect to congruent compared to non-congruent situations.

4.1 Exploration: Main Results of Induction

Subjects rated each of the selected four songs from their own playlist on a visual bipolar 10point Likert scale (see Appendix B) from 'calming' towards 'energizing'. A T-test showed that on average calm music (m=2,73, SE= 0,29) were significantly rated calmer than exciting music (m= 8,34, se=0,12), t(23)=-17,10, p<0,01, r=0,96

A Task*Music factorial repeated-measures analysis of variance (ANOVA) was performed to find the effects of task and music on emotional feeling.

For both task and music, the assumption of sphericity is met at all 4 emotion quarters of the circumplex model that was explained in the theoretical background (Figure 13). However, this assumption is violated for the Task*Music interaction in the 'activated unpleasant' (top left) emotion quarter, $\chi2(2)=11,77$, p=0,003. This means that the variance of the differences between the scores in the 6 conditions is not equal in this emotion quarter, which is necessary for statistical comparison. Therefore these values were corrected using 'Greenhouse-Geisser estimates of sphericity' (A. Field, 2009, pp. 539-626). However, no significant interaction effect of Task*Music on emotion was found. This will be further discussed in part 4.3 related to congruence and non-congruence of Task*Music.

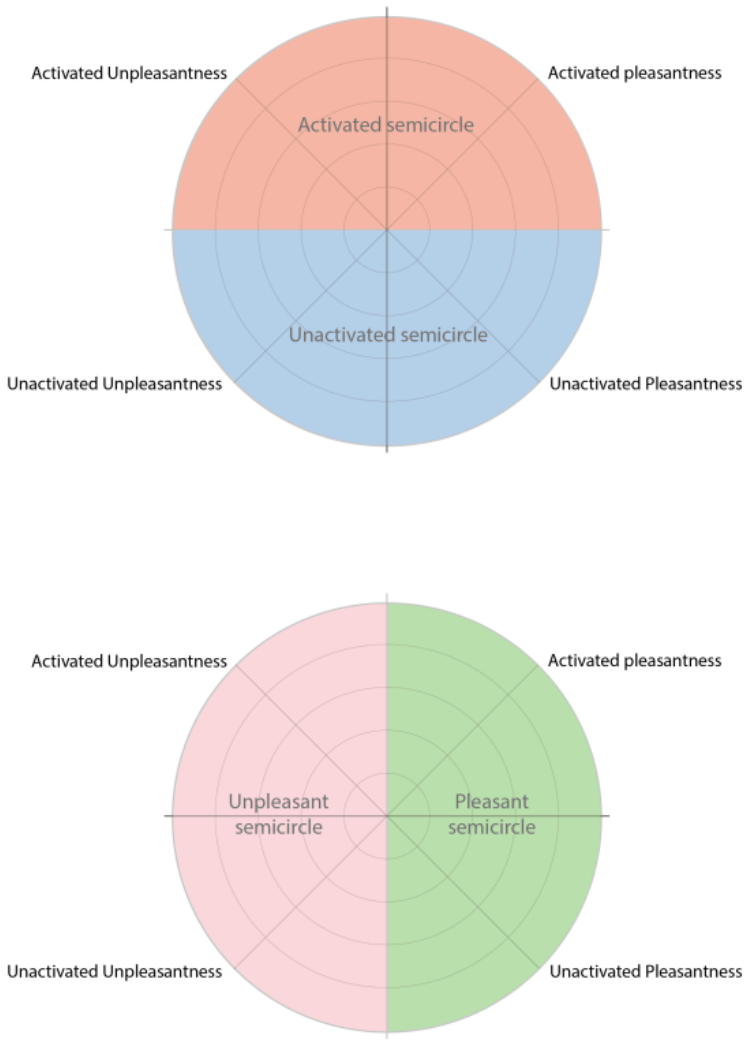

Figure 14 Arousal and valence semicircles

A significant main effect of music verified the hypothesis that music induces emotional feeling. A significant main effect is found for the quarters 'activated pleasant' $F(2, 44)=68.64$, 'unactivated pleasant' $F(2, 44)= 12.12$ and 'unactivated unpleasant' $F(2, 44)= 16.43$ (Figure 14). As expected based on existing studies, listening to music, did not show a significant main effect on the 'activated unpleasant' quarter. This can be due to the fact that participants were asked to select their own music, which is by principle a music

that is liked rather than disliked. Therefore, in this case(high arousing) music is generally not an unpleasant task, which explains why 'activated unpleasant' emotions are not reported.

When it comes to the level of music (calm, energizing, none-), a distinction seems to exist between the high aroused semicircle and low aroused semicircle (Figure 14). For the high aroused semicircle; energizing music scores highest with significant difference ($p<0.01$) to both calming ($F(1, 22)= 83.86$, effect size $r=0.89$), and no music situation ($F(1, 22)= 97.53$, effect size $r=0.90$). In the activated unpleasant quarter no significant effect was found. Nonetheless this shows that energizing music induced a high level of arousal and calm music induced a low level arousal.

In the low aroused semicircle, as expected, high arousing music scores lowest. In the unactivated pleasant quarter of this semicircle, music correlates with the level of arousal since calming music scores highest with significant difference ($P<0.01$) to both energizing ($F(1, 22)= 11.51$, effect size $r=0.58$), and no music situation, ($F(1, 22)= 23.75$, effect size $r=0.72$). However it is important to note that the effect size 'r' is a value showing a relative effect of one 'level' (e.g. 'calm' music) with respect to another level (e.g. 'energizing'- or 'none' music).

In the unactivated unpleasant quarter of this semicircle, calm and no music situation have equal scores ($F(1, 22)= 36.91$, effect size $r=0.79$), and as expected both score higher than energizing music $F(1, 22)= 21.88$, $r=0.71$.

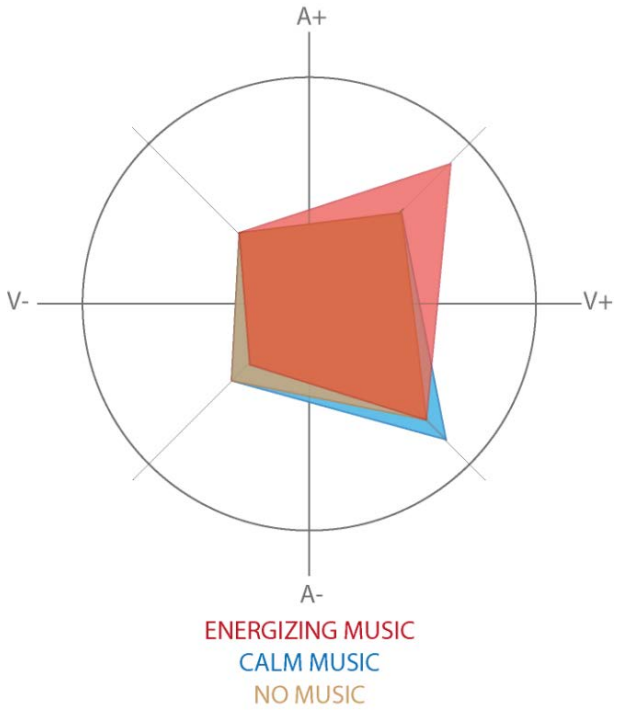

Figure 15 Emotion induction of music levels

For the intended emotion induction, it can be concluded that the self-reported levels of arousal match the arousal level of the played music. Yet, the fact that calm music and no music scored equal in the unactivated unpleasant quarter but differently on the pleasant quarter, indicates that the presence of music contributes to pleasurable emotions (figure 14). This confirms recent research which showed that negative emotions are experienced very rarely as response to music (from: Zentner et al, 2008, p 500).

Task showed a significant main effect on all quarters of the emotion wheel,. Contrasts confirm the hypothesis that game scores significantly higher than movie in 'activated' semicircle; quarter activated pleasantness',(F1, 22= 40.22), effect size r=0.80; as well as quarter 'activated unpleasantness' F(1, 22)= 20.89, effect size r=0.70 (figure 15). Vice versa, the movie (watching) task scores significantly higher than game in the 'unactivated' semicircle (encompassing the quarters 'unactivated pleasantness' F(1, 22)=

9.32, r=0.55, and 'unactivated unpleasantness' F(1, 22)= 26.17, r=0.74). This shows that, as intended, game induced a high level of arousal and movie induced a low level of arousal.

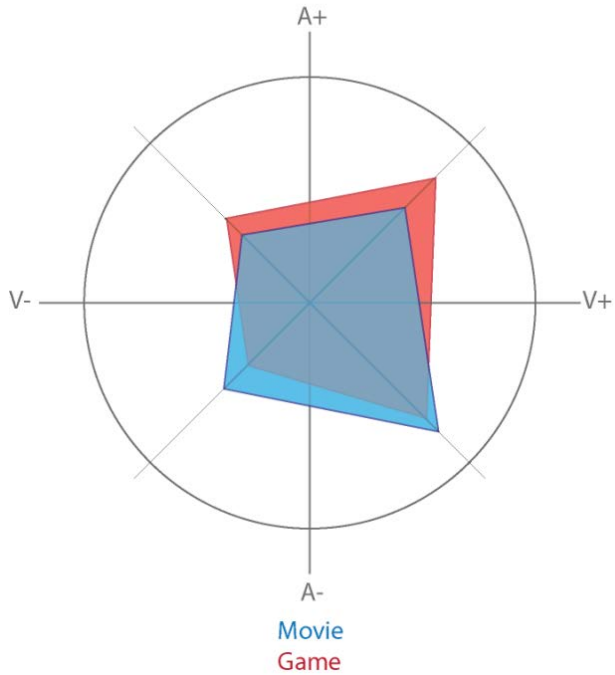

Figure 16 Results of task on emotion

Above mentioned results show that both task and music successfully induced emotion related to level of arousal. A significant main effect of condition on arousal/valance scores was found ($F(20, 528)= 5.29$, $p<0.01$) indicating that the type of condition, thus combination of task- and music types, resulted in different arousal and valence scores. Follow-up Anova's showed that this main effect is significant on all distinguished semicircles, thus the type of condition had an effect on positive/negative arousal as well as positive and negative valence scores. This means that the different conditions induce different arousal and valence scores. Furthermore, regarding music in general, presence of music was expectedly rated more pleasant (V^+) than absence of music.

4.2 Effects of Task*Music on Physiological Responses

A factorial repeated-measures ANOVA has been performed to find the possible effects of Task, Music and Task*Music interaction on heart rate and posture.

For both Music and the interaction Task*Music, the assumption of sphericity is met, $\chi2(2)=2,85$, $p=0,241$; $\chi2(2)=0,942$, $p=0.637$, which means that the variance of the differences between the scores of pairs of each 6 conditions is roughly equal. Therefore no correction for F-values is needed. Results show that the task, regardless of the type of music, has a significant effect on heart rate ($F(1,16)=11,99$, $p<0,01$. Contrasts show that the significant main effect of task reflects a significant difference (difference =2,68, $p<0.01$) between movie and game tasks. This means that participants had a higher heart rate in the high arousing task when compared to the low aroused task. However, music shows a non-significant effect of the heart rate [($F(2,32)=0,570$, $p>0,05$]. Furthermore there is no significant interaction between the type of task and the music listened to, [$F(4, 32)=0.920$, $p>0.1$]. This shows that the heart rate is related to the type of task rather than type of music.

On position of seating, based on the data that is derived from pressure mat, no significant result was found. However, considering the mean values of the different conditions, a tendency towards more active, upright position can be seen in energizing conditions occurs. This tendency was close to significance, $p<0.1$.

4.3 Congruent vs. Non-congruent Activity Situations

This paragraph discusses the comparison of effects of congruent versus non-congruent activities (Task*Music) on Emotion and Comfort. Contrast analysis shows no significant difference in both arousal and valence score between the two non-congruent conditions, movie+energetic music or game+calm music ($p>0.05$). This means that their effect of non-congruent situations on arousal and valence was similar. As expected,

following the earlier repeated measures analysis on emotion quarters, the congruent energizing conditions (game+energetic music) score significantly higher that the congruent calm (movie+calm music) conditions on the arousal axes ($p<0.01$). This is in line with the main induction effect which showed that both task and music individually induced the intended levels (low/high) of arousal. Also, game-energetic congruence is significantly higher in score on positive valance ($p<0.01$) when compared to movie-calm congruence, thus rated more pleasant.

A following contrast analysis was performed to compare non-congruent and congruent conditions. Strikingly, no significant difference was found on valance scores on any of the four comparisons ($p>0,05$). Yet, all comparisons showed significant differences on arousal scores. [Movie-calm is significantly less arousing than movie-energetic (non-congruent) and significantly less arousing than game-calm (non-congruent situation), $p<0.01$)]. Also, the game task-energizing music condition is significantly more arousing than movie task-energizing and significantly more arousing than game task-calm music condition ($p<0.01$). This posts the idea that non-congruence leads to ambiguous feeling, not related to specifically high or specifically low scores on arousal and valence.

4.4 Comfort

Comfort ratings show a deviation of normality on all levels of task and of all levels on music. Due to z-scores above 2,58, indicating significant outliers, two cases were excluded from the analysis. A condition*comfort*HR*pressure mat multivariate analysis of variance (MANOVA) showed no significant effect of type of condition, thus task*music combination, on comfort rating. Based on this it can be concluded that congruency between music and task did not show significant different rates of comfort in comparison to non-significant situation. This is rejecting the hypothesis that proposed congruence would have an increasing effect.

Yet, follow up ANOVA on the whole data set (n=24) revealed a significant individual effect of music on comfort ($F(2, 137)= 3,67$, $p<005$). This is caused by a significant higher comfort rating when listening energizing music compared to none-music condition. The individual effect of music might be explained by the results of emotion induction (part 1) in which presence of music increases valence, i.e. seems to induce 'pleasant emotions'. A possible explanation for this effect is the rating of positive valence attributed to music. The induction effects reported in part 1 showed that the presence of music seemed to be linked to pleasant emotions e.g. the pleasant semicircle, next to arousal. This seems to imply that comfort is more related to pleasantness, thus valence, than to level of arousal. From product design perspective, which aims for high comfort perception of users, it is thus interesting to develop ways to increase levels of valence, i.e. pleasantness. Another lesson that can be taken from this result is that levels of arousal seem less related to comfort, and are thus less indicative for the perceived comfort level by a user.

In addition to this, congruent conditions differed from non-congruent conditions only on the level of arousal. The fact that comfort ratings were not positively affected in congruent music*task situations (opposed to non-congruent), can have multiple explanations. Referring to the comfort model of Vink & Hallbeck (2012) again, which suggests that comfort is related to experience, the results show that comfort is related to other parts of the experience rather than music and task combinations, e.g. the interaction between user and car. Although it could be argued that hypothetical effects of music and task on comfort could have been overshadowed by the unavailability of armrests, a table supporting the arms or the lack of a footrest, these are physical aspects that will be more related to discomfort ratings than low comfort ratings, as explained when discussing Vink & Hallbeck's model (2012) in chapter 1.

CHAPTER 5

CONCLUSION

5.1 Concluding Remarks

After explaining the background for the research questions in the introductory chapter, in the theoretical framework (chapter 2) embodied cognition theory has been proposed as a valuable approach to link emotion to physiology as well as to comfort. Related to the context of traveling in a car as passenger, prototypical activities (watching outside, working on iPad and listening music) have been described and proposed as conditions in the present research. Existing research shows successful emotion induction processes through music, although types of stimuli differ and variations can be seen in the reported effects. Also, examples of existing research were mentioned that show effects of music on physiology such as heart rate. Based on the prototypical activities and existing research, two tasks (watching outside, working on IPad) and three levels of music (none, calm- and energetic) have been proposed as stimuli and hypothesis were formed regarding the dependents comfort-, physiology and task*music congruency. In the method chapter a preliminary study was described in which the measurements of the car seat were determined. Furthermore the setup of the within subject design empirical study encompassing 6 task*music conditions was described (n=24). The results show a successful emotion induction by task and music individually, but not via task*music interaction.

The individual effects of music that appeared strong enough to induce emotion independent from activity. The fact that no significant interaction/combination effect on emotion was found might imply that task and music have a different underlying principle of induction. This is elaborated on in part 4.3 where congruent conditions differed from

non-congruent conditions and not on valence i.e. pleasure ratings but only on arousal ratings.

Comparing congruent and non-congruent situations it is concluded that differences occur in subjects' reported level of arousal which seems to imply that non-congruent situations lead to an 'ambiguous state' which has a neutralizing effect on arousal level. A correspondence has been found between part 4.3 and 4.4 of the results and the main research question, which is used to hypothesize that comfort is related to valance (pleasantness) factors, separate from arousal. This seems to be supported by a found significant individual effect of music on comfort.

5.2 Implications and Future Research

This study should be seen as an exploration of relatively new field of research combining fields of comfort and emotion. From design perspective it deserves attention to valence factors of user-car interactions. It are those factors that can improve comfort by meeting expectations. What these expectations are might differ per user group, and is therefore an interesting field for future research.

The used self report method of Yik & Russel (2011) showed sufficient in distinguishing different arousal- and valence levels related to emotion induction. The decision to cluster the individual statemtents to 'emotion quarters' proved helpfull in keeping amount of data manageable as well as strong enough to distinguish the different quarters. However, it should be noted that it might be necessary to validate the statements in future study used by Yik and Russel on their emotional value, which would relate to the field of linguistics/semiotics as well as the lexicon people use describing their (in this case) current emotional state.

Part one of the results showed a successful emotion induction by music and task individually. For task this result was expected, though it is important to realize that the tasks were not selected by subjects themselves. This shows that playing a game on iPad,

which simulates working on iPad, is related to high arousal levels when compared to watching a movie, which simulates watching outside in a car context. Elaborating on this, too high levels of arousal might have negative effects on the concentration and alertness that can be needed, or preferred, by a user performing a task. For product design this result asks for further understanding of the car as working and relaxing environment.

The fact that this study proved only merely effects on physiology, supports existing theory, and shows the complexity and interpersonal differences. Designers should therefore be cautious when using physiological measurements, since validity is unclear. Moreover, the practical constraints of using physiological measurements (e.g. use of sensors on the body or thin clothing), ask for a skeptical approach using these measurements. Yet, position of seating might be a promising straw for car-design since mean values showed a tendency to differentiate in arousal levels. Further research on the relation between position of seating and affective state is needed to validate the strength of this relation. For this, it is advisable to take different seats into account, to be able to find relations between specific characteristics e.g. softness, tactility and adjustability, of car seats.

Results indicated a strong but personal relation between music and emotional state. This should therefore be considered for use in future product design. However, existing studies on music-components in relation to affective states, showed difficulty in assigning effects to specific music features (e.g. timbre, speed), thus a difficulty for use in product design. It seems valuable to consider music more phenomenally (as done by Zentner et al, 2008) which means that individual and context factors should also be considered. Congruency between activity and music, which are partly shaping users context, showed to strengthen emotional feeling. This argues for development of affective interfaces in which user experience and context elements are taken into account. Congruency between context factors can become a promising design tool, increasing emotional feeling. Use of posture and/or bodily gestures can be considered as

option for offline ‘tangible’ interfaces, to induce positive emotions and improve user’s experience.

5.3 Independence of the Study

The author would like to state that the collaboration with BMW did not influence the outcome of the here presented study in any way. The collaboration consisted of financial support to build the research setup and collaborative decision making on the scope of this research. Scientific quality has the highest priority and this research was approached as independent exploration on which further research and product design might be inspired.

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APPENDIX A Apparatus of the Main Study

The following components were used in the experiment setup. The first three have been explained in the method chapter, the remaining parts are described here.

- Car seat;
- Footrests (resp. height 18mm and 75mm)
- Panel walls;
- Cameras;
- Microphone;
- Speakers;
- Flat screen;
- 32*16 Pressure mat;
- Heart rate equipment;
- Body stickers

Cameras

Four cameras (ELRO; model: CS73Q) were mounted on the partitioning panels. Connected through a digitizer the camera footages were shown and saved using the program on a lab pc. The cameras were providing respectively a top front view, a '3/4' view, right sagittal view at ankle height, and right sagittal view at shoulder height. The video recordings were useful for two reasons. First, camera views were used by the researcher –sitting out of sight for the subject- during testing to have view on participant. Second, the recordings aid in synchronization of measurement tools.

Microphone

A microphone was mounted on the frontal partitioning panel connected to the same digitizer as the cameras. A continuous recording was made during the whole experiment, to be used as future reference in analysis for synchronization of test equipment.

Speakers and Music

Music was played using computer speakers (Logitech, model S-120) connected to a pc. To prevent inconvenience due to ergonomic concerns and to prevent inconvenience of loudness, headphones were not used. Speakers were placed at the left and right side at the back of the chair, similar to speakers in cars. Music was streamed through an online music streaming program (www.grooveshark.com, accessed; May 2012).

Flat Screen

A flat-screen was used to screen the landscape movies (see figure 3). The screen was placed on a table covered with a sheet. To simulate the situation of staring out of the window but to prevent strain in the neck, which was a feedback received in the pilot study, the screen and table were placed in an angle placing it perpendicular on the view-direction when turning the head 40degrees leftwards from straight.

Furthermore, to give the hint of the car environment, the height of screen was placed having the screen midpoint at eye height when sitting. The flat-screen was connected to the frontal panel in such a way that the edge of the screen was matching the poster in height.

Pressure Mat

To measure pressure distribution, an Mflex (Mflex FSA4, model UT4010-7000, sensor matrix: 32*16) pressure mat was placed over the chair. Since the size of the pressure mat did not match the measurements of the chair, the sides of the pressure mat were sticking out and should not be bent over chair edges to prevent distortions in pressure recordings. To ensure fixation of the pressure mat, the front edge was slightly folded around the front of the seat, to be sure the pressure could also be measured at the edge. Reaching to the top area of the backrest the mat was mounted using tape, both at the top of backrest, and front bottom of the seat pan.

Furthermore, using Flex software, the pressure mat was calibrated, with an approximate accuracy of 3 mm/Hg. Connected to a separate pc, using Flex software, the pressure mat was recording and saving the pressure distribution with a log time of 5 frames a second. Recording was switched on before subjects were sitting, and switched off after ending of the last condition. Calibration with condition times was done using the 'moment of sitting' as reference.

Heart rate Equipment

To analyze differences in heart rates between conditions, heart rates were measured using Polar heart rate equipment (model "Polar Xtrainer", figure 17). Subjects placed the chest band on their skin, after instruction by the researcher. A wristwatch receives and stores the heart rate data, and when recording was running, subjects were asked to wear the watch on one of the wrists to keep connectivity throughout the experiment.

Figure 17 Polar heart rate equipment

APPENDIX B Informed Consent

Informed consent

By participating in this research you are contributing to an academic study. Results will be processed and reported anonymously, and individual results are taken as confidential. Participating is voluntary, but as compensation you will receive one 'vvv-cheque' with the value of €10,- after completing the whole experiment.

An overview of the experiment:

- The duration of the whole experiment will be maximum 1 hour.
- The research encompasses 6 'conditions' in total.
- Each condition has one task and lasts 5 minutes followed by a short questionnaire of approximately 1 minute.
- There are two tasks; 1) watching a video and 2), doing a brain teaser game. Each task will be done three times.
- Every condition will be shortly explained by the researcher.

Furthermore, video footages will be made of different angles on the sitting position, as well as pressure mat measurement on the seat, and take heart rate recordings. These are used for data analysis and as comparison to previous studies.

For the heart rate recordings you are asked to wear a "polar" band during the research. For video analyzing you are asked to wear 9 small stickers on your clothes at the side towards camera.

Therefore we ask your approval:

I ***do / do not*** give irrevocable permission to take the measurements and use the results as stated above.

I declare by signing that I have been informed correctly and sufficient and agree to these terms and conditions.

Name: Signature:
Address:
Postal code:
City of residence:

Age:
Nationality:

APPENDIX C Music Rating Questionnaire

MUSIC RATING

1. Song title:
   Artist:

What effect does this song have on you?

Calming Energizing

2. Song title:
   Artist:

What effect does this song have on you?

Calming Energizing

3. Song title:
   Artist:

What effect does this song have on you?

Calming Energizing

4. Song title:
   Artist:

What effect does this song have on you?

Calming Energizing

APPENDIX D Self Report Questionnaire

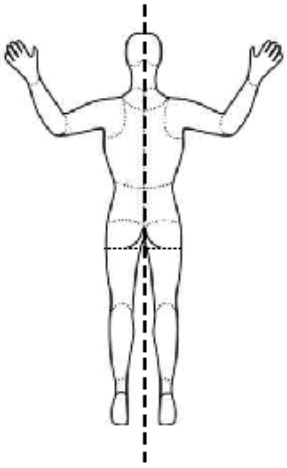
QUESTIONNAIRE

All questions are about how you felt DURING the last condition.

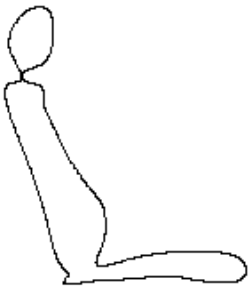
Question 1					
Below are 24 statements about how you felt during the condition. Please indicate how much you agree or disagree with each statement.					
	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
I was happy	☐	☐	☐	☐	☐
I was serenely at peace	☐	☐	☐	☐	☐
I felt energetic and vigorous	☐	☐	☐	☐	☐
I felt content	☐	☐	☐	☐	☐
I was blissfully at ease	☐	☐	☐	☐	☐
Everything seemed depressing	☐	☐	☐	☐	☐
My mind was quick and alert	☐	☐	☐	☐	☐
I was feeling "jittery"/"stressed out"	☐	☐	☐	☐	☐
I felt worried	☐	☐	☐	☐	☐
I felt sad and blue	☐	☐	☐	☐	☐
I was dissatisfied	☐	☐	☐	☐	☐
For some reason, I had been feeling sort of nervous	☐	☐	☐	☐	☐
I was filled with energy and tension	☐	☐	☐	☐	☐
I was feeling lively and cheerful	☐	☐	☐	☐	☐
I felt tense	☐	☐	☐	☐	☐
I felt droopy and drowsy	☐	☐	☐	☐	☐
I was feeling placid/peaceful	☐	☐	☐	☐	☐
I was unhappy	☐	☐	☐	☐	☐
My body felt activated	☐	☐	☐	☐	☐
Everything seemed boring	☐	☐	☐	☐	☐
I was feeling energetic and positive	☐	☐	☐	☐	☐
All of me felt at rest	☐	☐	☐	☐	☐

Question 2									
On a scale from **1 to 10**, how do you rate your comfort in this position?									
Not comfortable at all ---------- **Very comfortable**									
☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7	☐ 8	☐ 9	☐ 10

Question 3
On the human figure aside, please tick the part(s) of your body which were the less comfortable.



Question 4
On the chair figure aside, please tick/sketch the part(s) of the chair, where improvements should be made.



Question 5					
Please indicate how much you agree or disagree with each statement on the played music or missing of music.					
MUSIC played	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
The music was disturbing	☐	☐	☐	☐	☐
I prefer another volume	☐	☐	☐	☐	☐
The sound quality was poor	☐	☐	☐	☐	☐
I would prefer silence with this activity	☐	☐	☐	☐	☐
No MUSIC played					
The silence was disturbing	☐	☐	☐	☐	☐
I would prefer music with this activity	☐	☐	☐	☐	☐

APPENDIX E Structured Randomization (Latin Square)

		activity	music
1	A	GAME	none
2	B	MOVIE	High
3	C	GAME	Low
4	D	MOVIE	none
5	E	GAME	High
6	F	MOVIE	Low

	1	2	3	4	5	6
1	A	B	C	D	E	F
2	B	A	E	F	D	C
3	C	D	E	F	A	B
4	D	C	A	B	F	E
5	E	F	A	B	C	D
6	F	E	C	D	B	A
7	B	A	C	D	E	F
8	A	B	E	F	D	C
9	C	D	E	F	B	A
10	D	C	B	A	F	E
11	E	F	B	A	C	D
12	E	F	C	D	A	B
13	F	E	D	C	B	A
14	C	D	F	E	A	B
15	B	A	F	E	D	C
16	E	F	B	A	C	D
17	D	C	B	A	F	E
18	A	B	D	C	E	F
19	F	E	D	C	A	B
20	C	D	F	E	B	A
21	A	B	F	E	D	C
22	E	F	A	B	C	D
23	D	C	A	B	F	E
24	B	A	D	C	F	E