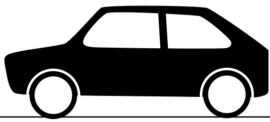
COMFORTABLE CAR INTERIORS

Experiments as a basis for car interior design contributing to the pleasure of the driver and passengers



Irene Kamp

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Rector Magnificus,	*Voorzitter*
Professor dr. P. Vink,	Technische Universiteit Delft, *promotor*
Professor dr. M.S. Hallbeck,	University of Nebraska-Lincoln
Professor dr. M. Hassenzahl,	Folkwang University Essen
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Professor dr. M.P. de Looze,	Vrije Universiteit, Amsterdam
Professor dr. H. de Ridder,	Technische Universiteit Delft

Dit project is uitgevoerd in opdracht van BMW AG.

In the past, nothing is irretrievably lost, but rather, on the contrary, everything is irrevocably stored and treasured.

Viktor E. Frankl - Man’s search for meaning

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INTRODUCTION

i. Framework

June 29, 2007, the Apple iPhone went on sale. From the moment Steve Jobs unveiled the new phone in January 2007, the technology was referred to by bloggers as revolutionary. In the online media the iPhone was called a technological saviour; the Jesus phone (Campbell & La Pastina, 2010). Analysts expect the iPhone 5 in 2012. This means that in approximately 5 years 6 models (iPhone 1, 2, 3, 4, 4s, 5) have been introduced. Every new model causes excitement among the Apple-community and it seems that people stand in line for pre-orders. With over 183.000.000 items sold from its release in 2007 until early 2012, the iPhone can be called a success. Despite some imperfections, iPhone owners seem to love their phone (McCracken, 2008). They are more satisfied with their purchase than other smartphone users (Kraapa, 2011). Many explanations are given online for this satisfaction and love. The exceptional and intuitive user interface (Benjamin, 2008), the fact that it has become a status symbol for many people (Malik, 2010) and the many useful and fun applications (according to Parr, 2011, especially the application Siri make people fall in love with iPhone) are just a few reasons.

The iPhone is a very successful product that is sold world-wide. It illustrates that when people love a product they forgive (small) imperfections and show brand loyalty. It also illustrates that a growing group of people can afford luxurious products. The downside of this "iPhone love" is that with the annual introduction of updated models, the lifespan decreases. Some even argue that the phones are made to last only one year (Siegler, 2009). The decreasing lifespan and increasing group of people who can afford luxurious products implicates a negative effect on the environment and natural resources.

Cars illustrate this growing availability and affordability of luxurious products worldwide as well. Predictions are made that the total vehicle stock will increase from about 800 million in 2002 to over two billion in

2030 (Dargay, 2007). In 2009 the average length of car ownership in the US was 46.3 months (Polk, 2009). Compared to 2002 this is an increase of 9.1 months. This is a promising trend from a sustainable point of view. However, according to the research of Polk (2009), the main reason for this increase was the uncertain economic times. This implies that as soon as consumers have gained confidence in their economic situation again, the length of their car ownership will decrease. Therefore it is not without reason that environmental regulations for cars and car manufacturers are increasingly stringent.

If we want cars with a longer lifespan we need to create cars people love to have, use and keep; cars that people are attached to. According to Mugge (2008) this can be achieved by products conveying a special meaning over and above its utilitarian meaning. A strategy to create this special meaning is the development of cars that contribute to the pleasure of driver and passengers. The advantages for car manufacturers of consumer-product attachment, besides the obvious disadvantage of selling fewer cars when the length of ownership increases and the consumers' car replacement is postponed, are consumer loyalty to the brand, the longer use of services provided and car owners that are more vocal in recommending their car brand to others (Mugge, 2008, pp. 118). On the highly competitive car market, these advantages are valuable and vital.

Therefore a car manufacturer should innovate to keep up with competitors, create cars that provide pleasure to convey special meaning and gain customer loyalty and meet the increasingly stringent emission regulations. These seemingly contradictory requirements were the reasons for BMW to initiate this project. The vision of BMW is that safety, comfort and (driving) pleasure should not be compromised by increasing sustainability regulations. Safety is extensively studied in other BMW projects, this PhD focuses on comfort and pleasure.

ii. Research questions

The goal of BMW for this project was to develop and assess car interior innovations that increase the comfort and pleasure of driver and passengers while remaining or reducing the costs, weight and other negative environmental effects of a car. To achieve this goal there are three central questions in this thesis:

1. What elements are relevant for designing products that contribute to the well-being of people?
2. How can this knowledge be used for making a descriptive model and for developing comfortable and pleasurable car interiors?
3. Is it possible to develop car interiors that show an improved comfort and pleasure experience for car drivers and passengers while remaining or reducing the costs, weight and other negative environmental effects of cars?

iii. Outline

In this PhD thesis five experiments are presented. These five experiments are partly chosen because of the need and interest of BMW and of course because it fits within the topic of this thesis: experiments as a basis for theory and development of car interior designs contributing to the pleasure of the driver and passengers.

This thesis is divided into three parts which is presented in Figure i.1. Part A focuses on the concepts comfort, pleasure and well-being. It describes the elements relevant to the well-being of people (Chapter one). Based on the pleasure, comfort and well-being literature a model for describing, developing and understanding products contributing to the well-being of humans is created (Chapter two).

The other two parts (B and C) focus on experiments with innovations a premium car manufacturer could introduce to increase comfort and pleasure of the driver and passengers within the framework of decreasing or remaining costs, weight and negative environmental effects. Part B starts with a study where the model created in Part one is illustrated by the development process of a new car seat concept (Chapter three) followed by an experiment on the influence of seat design on its character experience (Chapter four).

Part C describes three experiments improving the passengers' pleasure. It starts with a study on activities and postures of people during transport to give direction to car interior design (Chapter five). Chapter six describes the development and effects of a replacement and extension of the car's onboard entertainment system. The last study investigates the effects of an extension of the massage system (Chapter seven).

Finally, in the general discussion (Chapter eight) the research questions are answered and the relationship between the model developed in Part A and the studies described in Part B and C are discussed. In addition implications for car interior development are discussed and recommendations for further research are given. In Table i.1 an overview of the journal papers and patents of this thesis is given.

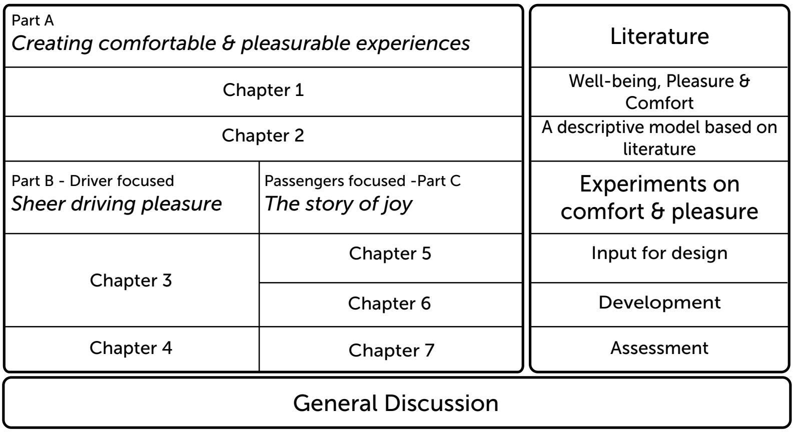

Figure i.1 *Graphical outline of this thesis.*

Table i.1 *Overview of related articles and patents related to this thesis.*

Part B	**Sheer driving pleasure** *Experiments for the comfort and pleasure experience of the driver*		
Chapter	Article title	Journal	Patent Nr.
3	A light weight car-seat shaped by human body contour	Published, International Journal of the Human Factors Modelling and Simulation (2nd author), 2011	PA 2009016051 DE
4	The influence of car-seat design on its character experience	Published, Applied Ergonomics, 2012	

Part C	**The story of joy** *Experiments for the comfort and pleasure experience of passengers*		
Chapter	Article title	Journal	Patent Nr.
5	Chosen postures during specific sitting activities	Published, Ergonomics, 2011	
6	A beamer in a Beamer - Improving the car interior perception through road projection	Submitted, International Journal of Design	PA 2011080556 DE
7	The influence of active seating during car travel on comfort experience	Submitted, International Journal of Industrial Ergonomics	PA 2009036278 DE

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PART A

CREATING COMFORTABLE & PLEASURABLE EXPERIENCES

A literature based descriptive model for developing products contributing to the well-being of people

In design education, research and industry, the attention for the human being interacting with a product has increased. Information on only physical and cognitive abilities is no longer sufficient. Knowledge about the users' expectations, goals, standards, values and so on is needed in order to create pleasurable product experiences that contribute to the well-being of people.

The goal of Part A is to create a descriptive model for creating such products. Chapter one in Part A discusses a Capita Selecta of the literature from social science and design research on well-being, pleasure and comfort. Chapter two combines this literature into a descriptive model. The result is an overview of the human-product interaction process and the relevant aspects for creating products contributing to the well-being of users.

1
WELL-BEING, PLEASURE & COMFORT

Introduction

"Any customer can have a car painted any colour that he wants so long as it is black" (Ford, 1922, p. 72). If you buy a BMW car today, e.g. a 1-series, you have a choice of six different variants (3-door, 5-door, coupé, M coupé, convertible and ActiveE). The catalogue of one of the versions offers 12 different standard exterior colours, nine rim variants, seven different types of engines, four steering wheel variants, two different front seats, eight different interior trims and 12 upholstery colours. This is offered to enable a configuration to the buyer's personal taste. And BMW cars are not an exception for that matter. Instead of designing products with a specific function or technology as a starting point, nowadays the human demands and wishes are more often the centre of the design process.

An inventory of mission statements published on the websites of different design schools shows that also design education focuses on the user. The Delft University of Technology for example uses the motto "Creating successful products people love to use" (1). The Eindhoven University of Technology describe their motto as "Creating intelligent systems, products and related services" (2) and elaborating in their mission "[these products and services are] characterized by adaptive behaviour based on the situation, context of use and users' needs and desires…".

Just like design education, design research shows, from the 1980's onward, a trend towards user centred design (UCD). In literature different definitions of UCD appear. In "The psychology of everyday things", Norman (1988, p.188) calls it "…a philosophy based on the needs and interests of the user, with an emphasis on making products usable and understandable". Mao et al. (2005) define UCD as "…a multidisciplinary design approach based on the active involvement of users to improve the understanding of user and task requirements, and the iteration of design and evaluation…". A debate is possible if the user always has an active involvement in UCD. A case where users are actively involved is participatory design (see Vink et al. 2005a), however, if the studied object is familiar to the designer, detailed data can also be gathered from observation (Jääskö & Mattelmäki, 2003). Abras et al. (2004) define UCD as "….a broad term to describe design processes in which end-users influence how a design takes shape…" Although there are various definitions in the literature that differ slightly from each other, they agree that the influence of the user is needed to develop usable and understandable products.

Despite the available information in literature, UCD was not taken seriously for decades. Gould et al. (1991) as well as Nielsen (1994) claimed that the UCD approach in software development was not used in industry. The main reasons being: resource constraints, resistance to user-centred design or usability, and/or lack of knowledge (Rosenbaum et al. 2000). Fortunately a growing number of products are well designed by firms who implement the scientific findings of UCD research into their corporate culture (Vredenburg et al. 2002; Van Kuijk, 2010).

Whereas making products understandable and usable was the focus of UCD in the late 1980's early 1990's, recently more attention is given to product hedonics. Norman for example received critique after his book "The psychology of everyday things". Some argued that designers following Norman's prescription would create usable but ugly products. Norman (2005) responds to this critique and explains that aesthetics and emotion was missing in his 1980's model. Not only Norman recognizes the importance of emotions in product design. Concepts like comfort (e.g. Vink et al., 2005b), product experience (e.g. Schifferstein & Hekkert, 2008), happiness and well-being (e.g. Desmet, 2011) are topics that gain interest. Based on commercials and other marketing activities, it seems industry has picked up on these concepts as well e.g. "Enjoyment Matters" by Benq computers, "A state of Happiness" by Center Parks tourism, "The Story of Joy" by BMW cars, "The Power of Dreams" by Honda motors, "The Perfect Experience" by JVC electronics, and "Sense and Simplicity" by Philips. Unfortunately, there are still many badly designed products (see e.g. http://www.baddesigns.com/examples.html and Van Kuijk, 2010).

Although the interest in products eliciting positive emotions seems relatively new, it is not entirely true. Carroll & Thomas already pleaded for fun in products in 1988 as did Malone in 1984 for designing enjoyable interfaces. This is not without reason. There are many benefits to comfortable and fun products. Igbaria et al. (1994) found that there are indications that perceived fun correlates with actual usage of software systems. Tourists at the Venetian market square buy coffee that cost 15 times more than at home because of the positive experience (Pine & Gilmore, 1999). Furthermore, positive emotions contribute to the subjective feeling of well-being (Keyes et al., 2002) and happier people have more energy, are more creative and have a better immune system (Lyubomirsky et al., 2005).

Creating pleasurable products contributing to the well-being of individuals has many advantages and scientific information in this relatively new area of product research is increasing. The focus of this thesis is how to develop products contributing to well-being in general and comfortable car interiors in specific. Chapter one discusses the well-being, pleasure and comfort literature. Based on this literature a model is presented which discusses the different elements relevant to the development of products contributing to the well-being of users (Chapter two). The central question in Part A is: what elements are relevant for designing products that contribute to the well-being of humans?

1.1 Well-being

1.1.1 Interest in well-being

Not only has the interest of design researchers shifted towards a positive approach. In Table 1.1 journal article results are presented for different keywords using "Science Direct". When searching for journal articles including the term well-being 133.658 articles are returned. The history indicates a growing interest in this concept; in 1993 2.005 articles on well-being were published, in 2002 4.162 and in 2011 11.996 (!). Despite the increase of the published articles on well-being, there are not yet many articles on product design and well-being (see Table 1.1). Most articles report of studies done in the field of social sciences. These studies form a solid starting point for discovering well-being in the field of product design research.

The many benefits of happy people might explain the interest in well-being. A higher level of well-being is associated with lower levels of daily salivary cortisol and pro-inflammatory cytokines, cardiovascular risk, and longer duration REM sleep (Ryff, 2004). Individuals experiencing positive affect had reduced neuroendocrine, inflammatory and cardiovascular activity according to a study of Steptoe et al. (2005). Furthermore Lyubomirsky et al. (2005) reported that becoming happy will boost your energy, creativity and immune system and happy people foster better relationships, fuel higher productivity at work and even lead a longer life.

Table 1.1 *Overview of journal articles found per key word.*

Keyword	Total articles	1993	2002	2011
Well-being	133.658	2.005	4.162	11.996
Well-being & product design	514	8	15	57
Pleasure (59935 before 1993)	106.745	2.015	1.950	4.017
Positive emotions	7.176	50	167	1291

1.1.2 Two views on well-being

Obviously there are numerous (health) benefits related to happiness. Happiness and well-being are often used interchangeably, but is happiness the same as well-being? Deci & Ryan (2008) describe that the research on well-being falls into two traditions; the hedonic view, focusing on seeking pleasure and comfort, and the eudemonic tradition, focusing on seeking to use and develop the best in oneself (Huta & Ryan, 2010).

Work in the hedonic tradition is often referred to as Subjective Well-Being (SWB), because people's own evaluation of their happiness is studied. SWB can be seen as (episodic) happiness and includes concepts like enjoyment, pleasure, comfort and 'the good life'. Whereas the eudemonic view on well-being is described as: "to live in a manner consistent with one's best potentials" (Waterman et al., 2008). Here related concepts are; acts of gratitude, develop the best in oneself, practicing kindness. This view is referred to as Psychological Well-Being (PWB) because researchers in this field suggest that when people themselves report a feeling of happiness (SWB) they are not always psychologically well.

1.1.3 Determinants of well-being

Even though well-being is personal, in the literature several general determinants for well-being are described. The main characteristics related to SWB are absence of negative affect, presence of positive affect and high life satisfaction (e.g. Diener, 2009; Vitterso, 2001). For PWB Ryff (1989) defined six different indicators: self acceptance, personal growth, relatedness, autonomy, positive relationships, environmental mastery and purpose in life.

The validity of SWB (e.g. Raibley, 2011) and PWB indicators (e.g. Springer & Hauser, 2005, Ryff & Burton, 2006) on well-being is debated. Recent studies report that the division between SWB and PWB is not so stringent; the concepts seem to overlap and complement each other. Keyes et al. (2002) found in a study among U.S. adults that SWB and PWB are related but distinct conceptions of well-being. Figure 1.1 shows the correlations of PWB and SWB characteristics found by Keyes et al. (2002).

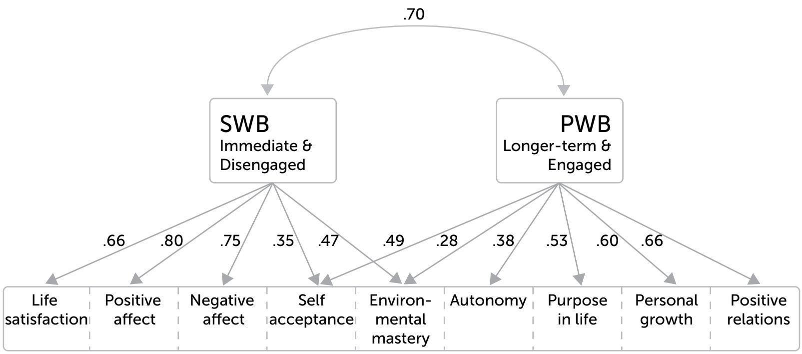

Figure 1.1 *Overlap and complementation of SWB (related to immediate outcomes and becoming disengaged from concerns) and PWB (related to longer term outcomes and feelings of engagement) according to Keyes et al. (2002).*

Huta & Ryan (2010) studied the different pursuits (hedonic and eudemonic) and found as well some distinct and some overlapping sets of well-being outcomes. Their study showed that hedonia is related to purely affective outcomes, immediate outcomes and becoming disengaged from concerns. Whereas eudemonic pursuits relate to cognitive-affective feelings of significance and appreciation, longer-term and person level outcomes suggesting that these pursuits may fulfil well-being at different time scales, becoming more engaged and feeling connected with a broader whole.

It seems that both concepts contribute to an overall feeling of well-being and that optimal well-being consists of a high level of SWB and PWB. Which was also hypothesized by Seligman (2002) as "the full life" (being high in both eudemonia and hedonia) and proof for this was found by others (e.g. Huta & Ryan, 2010, Peterson et al., 2005).

1.1.4 Strategies for improving well-being

Now the determinants of well-being have been defined, the next interesting question is: can someone increase his well-being and if so, how? Seligman (2002) introduces a straightforward equation for enduring happiness (H):

$$H = S + C + V$$

In this equation S indicates one's inborn happiness level, or set-point, C represents one's life circumstances and V are factors under one's voluntary control. Lyubomirsky (2010, pp. 20) found that the contribution to one's enduring level of happiness of one's set point is 50%, factors under one's voluntary control is 40% and one's life circumstances is only 10%. Strategies to increase (enduring) happiness are described by e.g. Seligman (2002) and Lyubomirsky (2005).

Seligman (2002) identified six virtues based on an analysis of religious and philosophical traditions (see Table 1.2). The virtues possessed by an individual are his signature strengths. When the signature strengths are cultivated enduring happiness can be achieved.

Lyubomirsky (2005) is more specific in her approach. She defined 12 tangible activities; expressing gratitude, cultivating optimism, avoiding over-thinking and social comparison, practicing acts of kindness, nurturing social relationships, developing strategies for coping, learning to forgive, increasing flow experiences, savouring life's joys, committing to your goals, practicing religion and spirituality and taking care of your body. These activities will benefit a person's happiness when the following conditions are present: positive emotion, optimal timing and variety, social support, motivation, effort and commitment and habit. She also emphasizes that not all activities are suited for all individuals and that everyone should therefore find the activities that fits him.

Intervention studies where participants had to do eudemonic activities like expressing gratitude, using signature strengths in a new way everyday show that these interventions can raise well-being (Seligman et al., 2005; Huta & Ryan, 2010; Emmons & McCullough, 2003; Lyubomirsky et al. 2005).

Table 1.2 *An overview of virtues identified by Seligman (2002).*

Virtue	**Example**
Wisdom	Curiosity, love of learning, judgement, ingenuity, emotional intelligence, perspective
Courage	Valour, perseverance, integrity
Humanity	Kindness, loving
Justice	Citizenship, fairness, leadership
Temperance	Self-control, prudence, humility
Transcendence	Appreciation of beauty and excellence, gratitude, hope, spirituality, forgiveness, humour, zest

1.1.5 Products contributing to well-being

People can thus improve their level of well-being through certain activities under ones voluntary control which contributes for 40% to the overall experienced well-being. Whether products can contribute to a person's happiness is an interesting question. Most people would argue that it is people that count, not objects and that the current materialistic world is not increasing happiness. Research findings seem to support this view; although Oswald (1997) demonstrates that in industrial countries well-being grows when national income increases the effects are small and sometimes undetectable. Happiness derived from material objects depends on other's people wealth; it is not the absolute but the relative value that counts (e.g. Easterlin, 1995; Frey & Stutzer, 2000). This means that not owning a luxurious car in itself does not make a person happy, but the fact that the neighbour does not, does.

Still there are recent examples of products that try to improve a person's happiness. An interesting example of a product targeting to change behaviour is described in the master thesis of Ruitenberg (2010). He designed key chains containing specific assignments based on the SWB strategies of Lyubomirsky which subscribers to his website receive. The users can confirm assignments at their profile page and reflect on their experiences. Products can not only evoke or stimulate meaningful activities, but products themselves can also have a special meaning e.g. a souvenir might remind you of a wonderful vacation. A study of Csikszentmihalyi & Rochberg-Halton (1981) showed that it is not only people that count, but objects with a special meaning attached to it are important as well. They found that people who have strong ties to other people tend to represent them in concrete objects whereas people who denied meaning to objects also lacked any close network of human relationships; one of the determinants of well-being.

Based on the literature discussed above, the implications for products contributing to the well-being of users are twofold:

1. Firstly, interacting with these products should improve the life satisfaction and/or increase positive affect while decreasing negative affect. They should cause a pleasurable experience; the hedonic way.
2. Secondly, these products should stimulate meaningful behaviour of individuals in a eudemonic and/or hedonic way like described by the happiness strategies to improve sustainable happiness.

Although both aspects are important for products contributing to well-being, the focus in this chapter and thesis is on developing products that cause a pleasurable experience. This decision has been made because of the long-term character of the meaningful behaviour aspect and the current inability to assess whether products increase happiness. The assumption is made that pleasure is a worthy goal in itself and that it is a necessary part for products contributing to well-being, whereas meaningful behaviour alone is probably not successful when it is not pleasurable to some degree; you will probably not succeed in losing weight if you do not enjoy working out in the gym, however if you engage in something you do enjoy (e.g. playing tennis) chances are that you reach your goal. Furthermore, whether every product in general, and car interiors in specific, should stimulate or evoke meaningful behaviour (or if it already does) is questionable.

1.2 Pleasure

1.2.1 Product experience

To know what qualities a product should have in order to evoke a positive experience, a definition of product experience is needed. Hekkert's (2006) definition of product experience includes three important aspects of affect elicitation; (1) aesthetic experience (the degree to which all our senses are gratified), (2) experience of meaning (the meanings we attach to the product) and (3) emotional experience (the feelings and emotions that are elicited). The aesthetic experience depends on the product characteristics and the emotional experience is the result of the evaluation by the user of the human-product interaction. Besides the product expectations the meaning we attach to a product should be considered as well in the process of creating pleasurable products. Schifferstein & Hekkert (2008) define a subjective product experience as "the awareness of the psychological effects elicited by the interaction with a product, including the degree to which all our senses are stimulated, the meanings and values we attach to the product, and the feelings and emotions that are elicited." Hassenzahl & Tractinsky (2006) say "UX [User eXperience] is a consequence of a user's internal state (expectations, needs, motivation, mood, etc.), the characteristics of the designed system (e.g. complexity, purpose, etc.) and the context (or the environment) within which the interaction occurs (e.g. organizational/social setting, voluntariness of use, etc.).

Based on these definitions, a pleasurable product experience is defined as an awareness of pleasurable emotions and feelings elicited by the interaction with a product and is a consequence of the user, the characteristics of the designed product and the context.

1.2.2 Two process models

Two models are used to describe the process of emotion elicitation by products. The first model is the model of product emotions by Desmet (2002). Following the appraisal theory, he describes the process of human-product interaction and emotion elicitation. A basic model (see Figure 1.2) shows the relation between human concerns, the product and the elicited emotion. The model indicates that human concerns (e.g. goals, motives) influence the product interaction and should be understood in order to understand the emotional responses to a product.

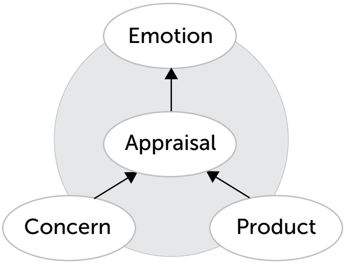

Figure 1.2 *Basic model of product emotions (adapted from Desmet, 2002).*

The second model is the research model of Hassenzahl et al. (2000) and Hassenzahl (2001) (see Figure 1.3). They used this model to investigate the intended and perceived ergonomic (EQ) and hedonic (HQ) qualities and if there was a difference between perceived EQ and HQ. The model starts with the intended qualities of the product (created by the designer). In the cognitive appraisal phase, users interpret the product qualities and evaluate product interaction. The consequences are behavioural and/or emotional.

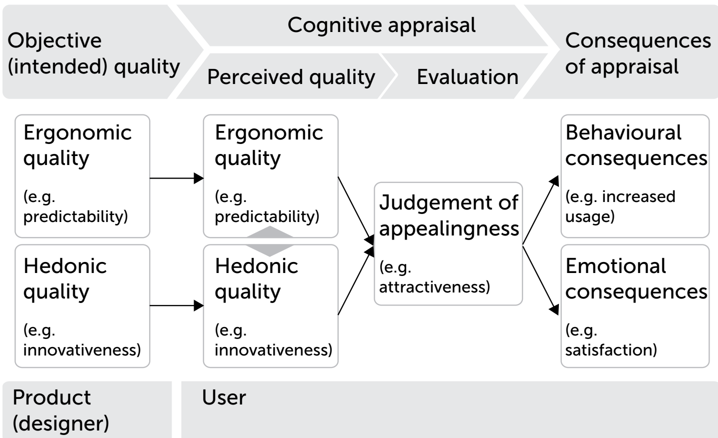

Figure 1.3 *Research model by Hassenzahl et al. (2000).*

Both models are useful for understanding the general process of emotion elicitation and the relevant product qualities. The model of Hassenzahl et al. is a more detailed with an emphasis on the product qualities, this model is useful when investigating the differences between the product's ergonomic qualities and hedonic qualities. Whereas Desmet created a basic model for understanding the general process of emotion elicitation by products.

Appraisal & consequences

The central part of both models is the (cognitive) appraisal phase. During this phase users perceive the qualities of and interact with the product. The user evaluates whether this interaction has positive or negative consequences for him. The output is an emotion and/or feeling and in the model of Hassenzahl et al. behavioural and emotional consequences are possible. If the evaluation based on appealingness, motive compliance, legitimacy and novelty (Desmet, 2002) is positive, a positive affect will be the result.

Norman (2005) describes three levels of processing during the appraisal process: visceral, behavioural and reflective. Visceral design processing is at the most basic level; based on perception it makes rapid judgments about a product. It is mainly concerned with product appearance. The second level is related to most of our behaviour and can be influenced by the third, reflective, level. It is based on expectations and appeals to our desire for usability, functionality and pleasure. The reflective level is the highest. It controls and reflects on why we prefer one product over another. It is concerned with self-image, prestige and so on.

To illustrate these levels imagine you are buying a car. You see the car in Figure 1.4 and immediately desire owning this car because of its predator-like look (visceral level). When you make a test drive you feel the joy of driving this car (behavioural level). The sales person tells you that this is a car for sophisticated and sportive people. You decide to buy the car because it fits your personality (reflective level).

Figure 1.4 *BMW Z4 (photo credits: www.netcarshow.com)* .

Context

In the appraisal phase a user perceives the product qualities and evaluates, based on the interaction, if the product has positive or negative consequences for him. This process of evaluation can take place at three different levels as described by Norman (2005). This evaluation does not take place in a vacuum. As presented in the basic model of Desmet (2002) an appraisal takes place in a certain context. Hassenzahl (2003) emphasizes the importance of the context as well. Because the situation a product appraisal takes place in can be quite diverse he proposes to focus on the mental state of the user. The evaluation of your car bought in the previous example can be very positive on a sunny day when you are cruising together with a friend on a traffic free motorway. However, the evaluation will probably be less positive when you are stuck in a traffic jam on a rainy day with the prospect of a stressful meeting for which you are already late.

Product qualities

The input in the appraisal phase is concerns or the user and the product or the intended product qualities. Hassenzahl et al. (2000) and Hassenzahl (2001) (see Figure 1.3) describe two different product qualities: ergonomic qualities, EQ, "the usability of the product, which addresses the underlying human need for security and control" and hedonic qualities, HQ, "the quality dimensions with no obvious relation to task-related goals. It addresses the human needs for novelty or change and social power induced: for example by visual design, novel interaction techniques and so on." Hassenzahl (2001) concludes that there is a difference between ergonomic quality and hedonic quality and he stresses the importance to define hedonic requirements in the design process.

Hancock et al. (2005) also recognize that products can have hedonic qualities and define "hedonomics" as "that branch of science which facilitates the pleasant or enjoyable aspects of human-technology interaction". They describe a model (see Figure 1.5) similar to Maslow's (1968) pyramid of needs. The pyramid of needs reflects how needs are prioritized; at the bottom we find physiological needs (health, food), followed by safety/security (shelter, removal from danger) and social belonging (love, affection), ego/esteem (self-esteem, prestige) and at the top self-actualization (achieving individual potential).

The pyramid of Hancock et al. (2005) reflects how the product characteristics are prioritized. The lower three levels are ergonomic needs:

- Safety; mostly described in norms and standards,
- Functionality; the things a product can do,
- Usability; "quality of use" in other words, "that the product can be used for its intended purpose in the real world" (Bevan, 1995).

The two higher levels are called hedonomics and consist of pleasurable experiences and individuation. According to Hancock et al. individuation is the highest level of product quality and is described as "...each and every single individual can customize his or her own tools to optimize the pleasure and efficiency of his or her own personal interaction...". The division between ergonomics and hedonomics is made within the usability area. Hancock et al. use for the division the three goals of usability defined by Preece et al. (2002): effectiveness, efficiency and user satisfaction. User satisfaction is considered a hedonic aspect whereas the other two are ergonomic aspects.

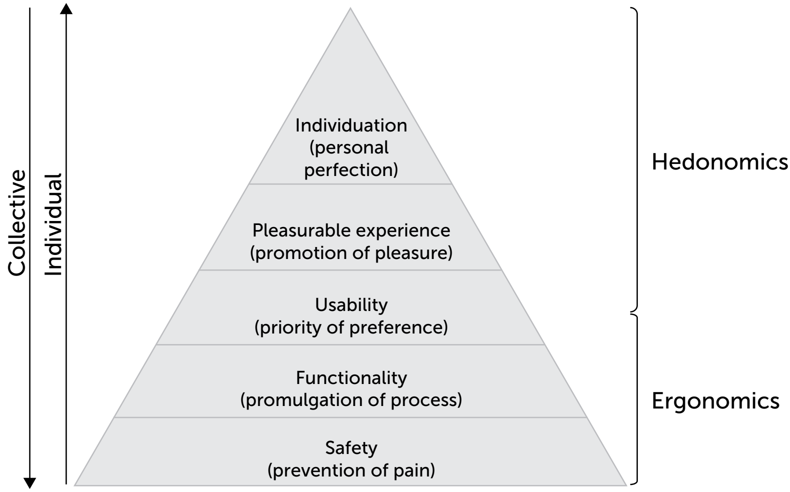

Figure 1.5 *Model of Hancock et al. (2005).*

User concerns

The second input into the appraisal phase is the user or his concerns. Desmet (2002) describes that an appraisal of a product is based on concerns; positive emotions are experienced if a person believes the consequences of a (product) interaction are beneficial to his concerns (Frijda, 1986). These concerns can be universal, cultural or contextual and three types are identified (Desmet, 2007):

1. Attitudes; relatively enduring, affectively coloured beliefs, preferences and predispositions toward objects, persons or events,
2. Goals; things one wants to get done and the things one wants to see happen,
3. Standards; our beliefs, social norms, conventions of how we think things should be. Standards are heavily influenced by a person's culture.

Knowing the attitudes, goals and standards of the user is relevant in creating hedonic product qualities.

For a holistic approach on the user Jordan (2000) suggests clusters of peoples characteristics based on his four-pleasure framework (see paragraph 1.2.4). In Table 1.3 the categories and related elements are shown. Jordan's categorization is meant as a possibility to view the user holistically and it is not necessary to address all single elements for every design process.

Table 1.3 *Clusters of people characteristics by Jordan (2000).*

Category	Elements
Physio	special advantages (skills)/disadvantages, musculo-skeletal characteristics, external body characteristics, body personalization, physical environment, physical dependencies, reaction to the physical environment
Socio	sociological characteristics, status, social self-image, social relations, social labels, social personality traits, social lifestyles
Psycho	special talents and difficulties, psychological arousal, self confidence, personality traits, learned skills and knowledge
Ideo	personal ideologies, religious beliefs, social ideology, aesthetic values, aspirations

1.2.3 Pleasant product emotions

The outcome of the appraisal phase is an emotion and/or feeling as discussed above. Based on the circumplex of emotions by Russell (1980), Desmet (2002) defined 41 relevant product emotions mainly for the appearance of a product. This circumplex distinguishes between in negative, neutral and positive emotions (see Figure 1.6). For the negative and positive emotions Russell defined three levels of arousal: high, average and low. For neutral emotions he defined only high and low arousal levels.

Twelve of the 41 emotions defined by Desmet are relevant for pleasurable experiences; three for high arousal (inspired, desiring, loving), eight for average arousal (fascinated, amused, admiring, sociable, yearning, joyful, pleasantly, surprised) and two for low arousal (satisfied, softened).

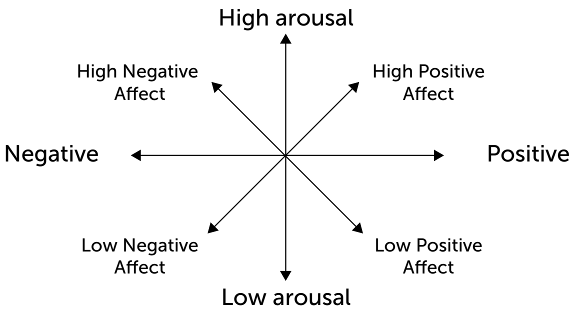

Figure 1.6 *Circumplex of emotions after Russell (1980).*

1.2.4 Four types of pleasures

Besides the different pleasant emotions, there are also different kinds of pleasures. To understand the pleasure concept in relation to products the model of Jordan (2000) is useful. He discusses a framework created by Lionel Tiger (1992). This framework defines four distinct types of pleasure: physical, social, psychological and ideological. Physio-pleasures are pleasures that come from the body and the senses. Socio-pleasure is defined as enjoyment brought about through interaction with others. Psycho-pleasure encompasses people's cognitive and emotional reactions. Ideo-pleasures are the enjoyment one gets from one's values.

The implications for products are best explained with an example. Imagine sitting in your new car (see Figure 1.7). Do you feel the softness and smoothness of the leather? Do you smell the new-car-smell? This pleasure you experiencing is on the physical level (Physio-pleasure). Now you are chauffeured to the golf course and at the course you enjoy the feeling of arriving in style like most others (Socio-pleasure). After a long day of golf you want to relax and sleep a bit while being chauffeured home; you are surprised how easy you can adjust your seat into sleep modus; the cognitive demand of adjusting your seat and the surprised feeling are aspects of psycho-pleasure. Finally, you arrive home and walking past your car you love the exterior; the sophisticated, stylish, classical appearance fits your personality, Ideo-pleasure.

Figure 1.7 *Rolls Royce (photo credits: www.carwalls.com).*

The softened feelings by the leather, the joy of driving in your car, the fun of the admiring looks of passersby are all positive emotions. In Figure 1.8 the relevant product emotions and the four types of pleasure are combined. This figure gives an overview of the categories pleasurable products can fall into and is for example useful to map observed product experiences during user research (see Figure 1.8).

Physio pleasure	Psycho pleasure	Ideo pleasure	Socio pleasure	
		The satisfied feeling of the sophisticated appearance of the car		**Pleasant excited** Inspired Desiring Loving
	Surprise of ease of adjusting the seat into sleep modus		The joy of fitting in at the golf club	**Pleasant excited** Fascinated, Yearning Amused, Joyful Admiring, Pleasantly Sociable, Surprised
Softness of leather in new car				**Pleasant calm** Satisfied Softenend

Figure 1.8 *The pleasure-emotion matrix with an example of different emotions a car can elicit.*

In summary, a pleasurable product experience is an awareness of pleasurable emotions and/or feelings elicited by the interaction with a product and is a consequence of the user (attitudes, goals and standards), the characteristics of the designed product (ergonomic and hedonic qualities) and the context. The relevant pleasant product emotions (Desmet, 2002) and the different pleasures a product can give (Jordan, 2000) are summarized in the pleasure-emotion matrix in Figure 1.8.

1.3 Comfort

A concept related to pleasurable product experiences is comfort. Research of Zhang et al. (1996) and Helander & Zhang (1997) showed that comfort is more related to experience, emotion, unexpected features, and luxury; to notice comfort something more should be experienced (Vink et al., 2005b). According to Zhang et al. (1996) comfort is associated with a feeling of well-being, luxury and refreshment (see Table 1.4). The comfort definition of Vink & Hallbeck (2012) describes this as well: "comfort is seen as a pleasant state or relaxed feeling of a human being in reaction to its environment".

Table 1.4 *Factors influencing comfort or discomfort during sitting (Zhang et al., 1996).*

Discomfort	Comfort
Fatigue, pain, posture, stiffness	Luxury, safety, refreshment, well-being

Discomfort on the other hands is more related to physical characteristics of the environment, like posture, stiffness and fatigue (see Table 1.4). Important to notice is that the absence of discomfort does not automatically result in comfort (Zhang et al., 1996; Helander & Zhang, 1997; Vink et al., 2005b). There is an 'in between' state, where neither comfort nor discomfort is experienced.

1.3.1 A comfort model

In a literature review De Looze et al. (2003) conclude all literature agrees that comfort is a subjective experience. This means that a product in itself is not comfortable, but the user decides whether it is (or not). Even though comfort is a subjective experience, there are common factors. Based on recent research and inspired by the model of De Looze et al. (2003) and the model of Moes (2005), Vink & Hallbeck (2012) propose a new comfort model (see Figure 1.9).

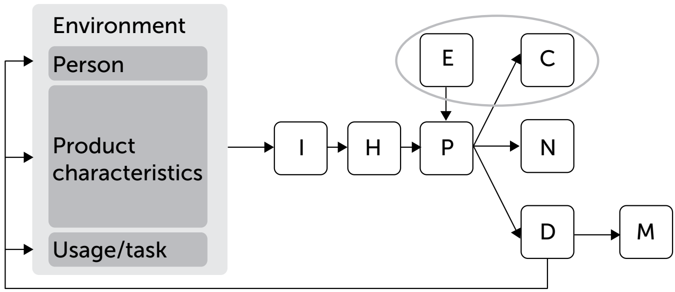

Figure 1.9 *The comfort model of Vink & Hallbeck (2012), I = interaction, H = human body effects, P = perceived effects, E = expectations, C = comfort, N = nothing, D = discomfort, M = musculoskeletal complaints.*

Input of the model

Just like in the model of Desmet (2002) and Hassenzahl et al. (2000), the input in this model is the person and product characteristics. In this model the usage/task is mentioned separate and the environment is not placed around the interaction phase, but around the input elements. In a previous comfort model described by Vink et al. (2005b) the person's input are not, like in de model of Desmet, the concerns but the sensors, history and state of a person. When discussing the important elements in aircraft interior comfort and design, Vink & Brauer (2011) emphasize the importance of the history (or expectations) and the mental state; just like Hassenzahl (2003). Besides the difference in state of one user (like in the example of driving relaxed in your convertible on a sunny road versus a stressful rainy day), the state of different users in the same situation can be different as well. When someone arrived on time at the airport his comfort experience of the aircraft seat is different than that of someone who had to run with his hand luggage to the gate; the last person will probably perceive the aircraft seat as more comfortable.

The environment is described in terms of the physical environment and exists of elements like temperature/humidity, visual input, smell, noise, pressure/touch and posture/movement. Bubb & Estermann (2000) created a pyramid of forces influencing the comfort feeling in vehicles (see Figure 1.10). According to Bubb & Estermann smell is the most influential aspect of experiencing discomfort; if a vehicle smells bad, the majority of people will have difficulty experiencing comfort.

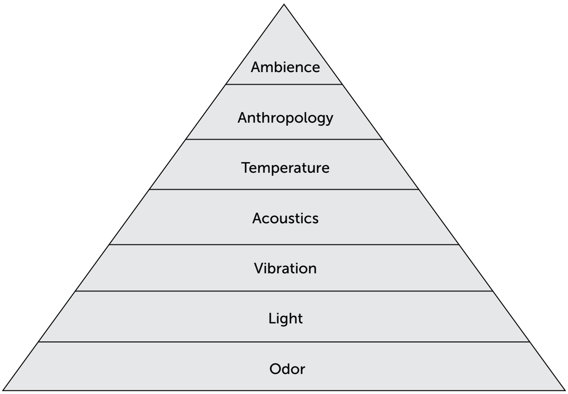

Figure 1.10 *Forces influencing the comfort feeling in vehicles (Bubb & Estermann, 2000).*

Interaction phase

The appraisal phase can also be identified in the comfort model, only described in three different phases: the interaction with the product (I) resulting in internal human body effects (H) and the perceived effects (P). The expectations (E) are listed separately and circled together with the output 'comfort' because Vink & Hallbeck believe that expectations are often linked to comfort. Expectations are pre-trial beliefs about a product or service (Olson & Dover, 1979). In marketing literature, expectation is considered an important element in product satisfaction (e.g. Cardozo,

1965) and exists of past experiences, word of mouth, expert opinion, publicity, communication controlled by the company and exposure to comparable products (Boulding et al. 1993).

Outcome of the model

There are three possible outcomes: comfort (C), "nothing" (N) or discomfort (D). Discomfort can result in musculoskeletal complaints (M). There is a feedback loop from discomfort to the person; when the discomfort is too high people will change their state (shift in their seat, adapt the product and so on).

Summarizing, comfort is defined as a pleasant state or relaxed feeling of a human being in reaction to its environment (Vink & Hallbeck, 2012). Whether comfort is perceived depends on the expectations one has, and the internal human body effects caused by the interaction with the product. The interaction is influenced by the environment, the person, the product characteristics and the usage/task.

1.4 Conclusion

This chapter discussed the literature on well-being, pleasure and comfort. The key points are summarized in this paragraph. Based on the well-being literature, it was concluded that the implications for products contributing to the well-being of users are twofold:

1. Firstly, interacting with these products should improve life satisfaction and/or increase positive affect while decrease negative affect. They should cause a pleasurable experience; the hedonic way.
2. These products should stimulate meaningful behaviour of individuals in a eudemonic and/or hedonic way like described by the happiness strategies to improve sustainable happiness.

A pleasurable product experience is an awareness of pleasurable emotions and/or feelings elicited by the interaction with a product and is a consequence of the user (attitudes, goals and standards), the characteristics of the designed product (ergonomic and hedonic qualities) and the context. The relevant pleasant product emotions (Desmet, 2002) and the different pleasures a product can give (Jordan, 2000) are summarized in the pleasure-emotion matrix in Figure 1.8.

Finally comfort is identified as a closely related concept to pleasurable experiences. It was defined as a pleasant state or relaxed feeling of a human being in reaction to its environment (Vink & Hallbeck, 2012). Whether comfort is perceived depends on the expectations one has, and the internal human body effects caused by the interaction with the product. The interaction is influenced by the environment, the person, the product characteristics and the usage/task.

In the next chapter a model for developing products contributing to the well-being of people based on the literature discussed in this chapter is created.

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2
A MODEL FOR DEVELOPING PRODUCTS CONTRIBUTING TO THE WELL-BEING OF PEOPLE

Introduction

Literature on fun products provides some insights for designing pleasurable experiences. Challenge, fantasy and curiosity (Malone, 1980), user control and participation with appropriate challenges, variation and multiple opportunities, social opportunities in terms of co-activity and social cohesion (Brandtzaeg et al., 2004) are all aspects contributing to the fun factor of a product. Carroll (2004) states that "Things are fun when they attract, capture, and hold our attention by provoking new or unusual perceptions, arousing [positive] emotions in contexts that typically arouse none, or arousing emotions not typically aroused in a given context."

These examples describe what a product should do, not what aspects are relevant for developing fun products. Hassenzahl (2011) summarizes the entire process for technology-mediated experiences into three levels: why, what and how. As Hekkert (2011) mentions in a reaction on it, this could be applicable for designing any experience. The charm of Hassenzahl's summary is that it captures a complicated process in three relevant levels.

The information on how to develop fun products and the information on well-being, pleasure and comfort discussed in the previous chapter, is used to make a descriptive model, which is the topic of this chapter. The result is an overview of the process and the relevant aspects for creating products contributing to the well-being of users. Hassenzahl's Why, What and How model is used to describe this descriptive, literature based model. The only difference with Hassenzahl is that the order is not Why, What and How, but, following the ViP (Vision in Product design) method of Hekkert & Van Dijk (2011) Why (the goal of the model), How (the process of achieving this goal) and lastly What (the input for the process).

2.1 Why – the goal

Most design processes (should) start with a "Why?" question. The answer to this question is the goal of the product. In this case the answer to the question is developing a product contributing to the user's well-being. The relevant affect and behaviour that products contributing to the user's well-being should elicit and evoke are described in Chapter one. That is the output of the model described in this chapter. In Figure 2.1 a detailed representation including the well-being determinants of the model is presented.

Because the differences between SWB (subjective well-being) and PWB (psychological well-being) remain vague and controversial they have been replaced with Pl (Pleasure) and M (Meaning). Another reason for replacing SWB and PWB is that pleasure and meaning describes the implications for products clearly; products contributing to well-being should (1) elicit pleasant emotions & feelings and (2) stimulate or evoke meaningful behaviour; a pleasure attribute and a meaning attribute.

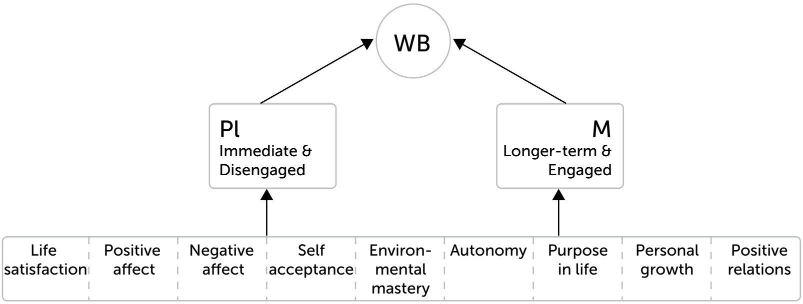

Figure 2.1 *Detailed representation of the "Why" part of the well-being model (WB = Well-Being, Pl = Pleasure, M = Meaning) adapted from Keyes et al. (2002).*

2.2 How – the process

The "How?" question gives an answer on how to reach the product goal (the "Why?" question). How should the interaction look like to achieve the product goal? The answer for this model is "a product contributing to well-being is reached with an interaction that elicits a pleasant emotion and/or stimulates or evokes meaningful behaviour". The relevant elements are described by combining the research model of Hassenzahl et al. (2000, Chapter one, paragraph 1.2.2), the model of emotion elicitation of Desmet (2002, Chapter one, paragraph 1.2.2) and the comfort model of Vink & Hallbeck (2012, Chapter one, paragraph 1.3.1).

2.2.1 Differences

The goals of all models differ; the model of Vink & Hallbeck (2012) aimed at presenting the relevant aspects resulting in comfort, nothing or discomfort. Hassenzahl et al. (2000) used their model as a research model to investigate the intended and perceived ergonomic (EQ) and hedonic (HQ) qualities and if there was a difference between perceived EQ and HQ. Desmet displayed the process of human-product interaction and emotion elicitation.

Although all models include a person (Vink & Hallbeck, 2012), user (Hassenzahl et al., 2000), human concerns (Desmet, 2002) as input for the appraisal (or evaluation) process, the characteristics differ. Desmet describes the person in terms of concerns, whereas Vink & Hallbeck look more at the physical, sensory part of the human being.

In the model of Desmet the behavioural consequences as presented by Hassenzahl and Vink & Hallbeck (the feedback loop from D, discomfort, to input and "M") are not shown. Vink & Hallbeck describe only negative behavioural consequences (only when discomfort is experienced) whereas in the model of Hassenzahl et al. a clear distinction is made between behavioural consequences and emotional consequences.

Only Hassenzahl et al. emphasize the difference between the EQ and HQ intended by the designer and perceived by the user. In the research model the environment/usage/task is not explicitly included (as in the model of Vink & Hallbeck) or the context (as Desmet calls it), however in the updated model of product experiences (Hassenzahl, 2003) the situation is added. Whereas Desmet and Hassenzahl (2003) show the context mainly during the appraisal phase, in the comfort model of Vink & Hallbeck, the environment is placed around the input (person, product characteristics and usage/task).

The comfort model of Vink & Hallbeck emphasizes the importance of the expectations (or history) and mental state on the comfort experience. Hassenzahl (2003) also recognizes the importance of the mental state of the user and the expectations can be found in the difference between the designers intended product qualities and the users' perceived product qualities.

2.2.2 Similarities

Though all three models have a different goal, they show several similarities. Of course in all models the product is present either more in detail like in the model of Hassenzahl et al. (ergonomic quality and hedonic quality) or general like in the comfort model (product characteristics) and in de model of Desmet (just product).

The appraisal phase is the central point in Desmet's model, but also visible in the other two models, though divided into three (Vink & Hallbeck) or two (Hassenzahl et al.) steps. Interaction and human body effects result in the perceived effects in the model of Vink & Hallbeck. Hassenzahl et al. identify two major phases in the cognitive appraisal phase; perceived qualities and judgment of appealingness. In Figure 2.2 an overview of the different models combined is given. This model clearly shows that all three models overlap and complement each other.

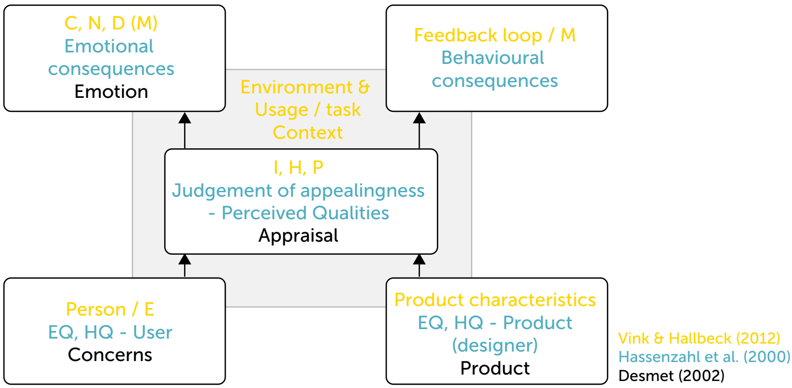

Figure 2.2 *Theoretic models combined.*

2.2.3 Process

In Figure 2.3 the details of the "How" part of the model is presented. The input into the evaluation phase (E) exists of a human (H) and a product (P) just like in the theoretical models. The task/usage present in the comfort model is not included. This is taken into account either as one of the goals of the user or as an aspect of the context. The context (or environment) is placed around the appraisal phase and the in- and output elements are partly included. It is not only placed around the input elements, like in the model of Vink & Hallbeck because physical aspects of the environment (like temperature, humidity, noise and so on) have a direct influence on the interaction with the product. The context is everything but the product attributes; it is the unintentional, non-designed aspects. For example smell is an important aspect in car interiors, this is not the smell of the developed interior itself (this was intentionally done), but it are the smells of e.g. the passengers or factories you pass by. Factors relevant for the context are listed in Table 2.1.

The output of the model exists of affect (A) and behaviour (B). The relevant pleasant product emotions are defined by Desmet (2002) and the kind of pleasures a product can elicit by Jordan (2000). In Chapter one, paragraph 1.2.3 and 1.2.4 these are discussed in detail. Examples of relevant behaviours have been discussed in Chapter one as well; the virtues of Seligman (2002) and activities of Lyubomirsky (2005) in paragraph 1.1.4.

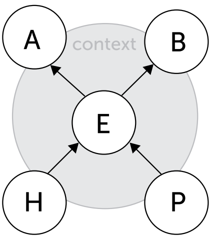

Figure 2.3 *A representation of the "how" part of the model (A = affect, B = behaviour, E= Evaluation, H = Human, P = Product).*

Table 2.1 *Factors relevant for the context.*

Aspect	**Examples**
Mental state of the user	Stressed, relaxed, angry, bored
Situation a product is encountered	Public, private, business, commercial, internet, physical
Sensory input	Smell, touch and pressure, temperature and humidity, noise

2.3.1 Product aspects

In Figure 2.4 the product aspects for the well-being model is presented. In this paragraph the different aspects are discussed.

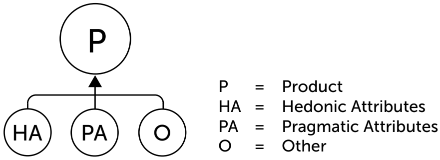

Figure 2.4 *Product aspects.*

Attributes

In Chapter one, paragraph 1.2.2 the ergonomic and hedonic product qualities as defined by Hassenzahl (2001) were discussed. Hassenzahl (2003) elaborated his research model and changed the ergonomic and hedonic quality of a product into the pragmatic and hedonic attributes of a product. In this well-being model a division is made following Hassenzahl (2003) between hedonic and pragmatic attributes. The reason for using pragmatic instead of ergonomic qualities is because of the definition of ergonomics given by the International Ergonomics Association: "Ergonomics (or human factors) is the scientific discipline concerned with the understanding of the interactions among humans and other elements of a system, and the profession that applies theoretical principles, data and methods to design in order to optimize human well-being and overall system performance." In this definition optimizing human well-being is presented as a goal of ergonomics. Therefore the term pragmatic seemed more suitable.

The pragmatic attributes are, as in the model of Hancock et al. (2005), safety, functionality and usability. Following Hancock et al. the boundary between hedonic and pragmatic attributes is placed within the usability field (indicated with a dotted line in Figure 2.5). The hedonic attributes in this model are "pleasurability" and "meaningfulness". A decision was made to use meaningfulness instead of individuation at the top of the product attributes because, as was concluded in Chapter one, products contributing to the well-being of people should elicit a pleasurable experience and evoke or stimulate meaningful behaviour, which is not necessary reached by customization of products. In Figure 2.5 all product attributes are presented.

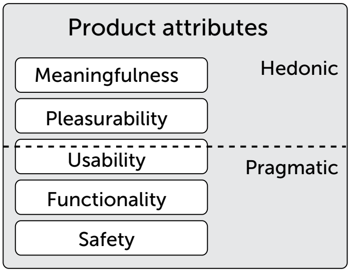

Figure 2.5 *Product attributes.*

"O" Costs, benchmark, regulations and brand image

Besides hedonic and pragmatic product attributes other aspects play a role as well in designing products:

1. Economics gives answers to the user questions like "can I afford this product and is the prize right?" For users the primary costs (direct costs when buying a product) and secondary costs (costs related to the use of a product; e.g. gasoline for a car) are of importance.
2. Laws and regulations have influence on the product. In the car industry for example the emission regulations are the primary cause of interest in lightweight interior features and bodywork.
3. Benchmark this "involves investigating industry's best practices, analyzing and evaluating one's own operation for opportunities, and implementing an action plan that includes the structure of goals, objective, and operating targets" Boxwell (1994).
4. Brand image and values are important for buying decisions; however this depends not only on the products a company sells but on the marketing strategies and company policies.

These aspects all influence the product but do not play a primary role in the development of pleasurable product experiences. In the overall model these factors are represented by O (other, see Figure 2.6).

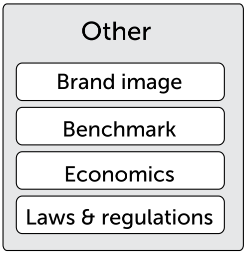

Figure 2.6 *Relevant aspects influencing the product in a design process.*

2.3.2 Human aspects

In Figure 2.7 the human aspects for the well-being model is presented. In this paragraph the different aspects are discussed.

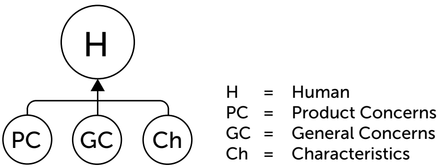

Figure 2.7 *Human aspects.*

Product concerns

In Figure 2.8 the product concerns are presented. Product concerns are not found in any discussed model. This part describes the importance of user's concerns about the product in designing pleasurable products.

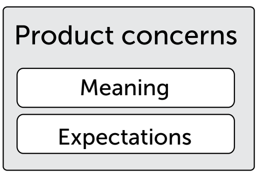

Figure 2.8 *Product concerns.*

Expectations

Even though neither Desmet nor Hassenzahl include explicitly expectations in their model, Vink & Hallbeck believe that expectations (E) are strongly linked to comfort. In paragraph 2.3.1 it was discussed that expectations are an important element in product satisfaction which is according to Preece et al. (2002) a usability aspect. In the product attributes section, this aspect of usability belonged to the hedonic attributes of a product. Therefore expectations are important for the design process of pleasurable products.

Meaning

None of the models discussed in Chapter one included meaning as a separate element. Although, product meaning is closely related to the person's concerns and is therefore an important aspect for pleasurable products. A new BMW sports car can evoke very different emotions and feelings based on the observers' concerns and meaning; people who see a car as a status symbol and identifies with BMW's image (sporty, fast, luxurious,...) can feel admiration. However, someone who attaches pure functional meaning to a car and considers BMW's as aggressive will say sports cars are impractical (negative attitude) and might be disgusted by the design of the car.

Product meaning also explains why some products that fail to complete safety, functional or usability goals are still loved and considered pleasurable. Hancock et al. presented their model (see Figure 1.5) as a pyramid to communicate a hierarchy. This means that as long as a product is for example not safe, it will fail to be considered functional. Russo (2010) gives an example that illustrates the relevance of product meaning in relation to the hierarchy presented by Hancock et al.. She describes a case of a nail cutter that sometimes cuts into the flesh of a user instead of the nail, but the owner does not want to part from this nail cutter because of other qualities it possesses. It seems that in this example, the safety level is not completed (cutting into the flesh cannot be considered safe for a nail cutter). Still the user loved this product. Another example is the citrus squeezer of Alessi. This is not the perfect juicer (some models cannot even be used for squeezing oranges because the acid ruins the coating), still Norman (2005) says he does not want to part from it and displays it in his home. Again, the functional level is not completed, but it still gives a pleasurable feeling.

This seemingly illogical product attitude of forgiving a product his failure to fulfil his pragmatic functions has to do with the meaning of the product for the person and depends on the hedonic attributes. The nail cutter in Russo's example is not just a functional object; it is an object of personal identity and the failing functional and safety quality is forgiven. Several social and psychological studies focus on the meaning of products. Csikszentmihalyi & Rochberg-Halton (1981) interviewed eighty families on their favourite household objects. They identified different kinds of meaning classes for products: past (memories, recollection, heirloom, souvenir, had it for a long time), associations (ethnic, religious, collections, gifts), present-future (experience, intrinsic qualities of object, style, utilitarian, personal values), and person codes (self, immediate family, kin, nonfamily). Instead of four product meaning classes Dittmar (1992) describes two different types of product values: instrumental (the functionality of the product) and symbolic (this value refers to a person's identity).

In consumer product literature studies are available on the meaning of products. Richins (1994) looked at the private and public meaning of products. Based on literature she created categories for meaning that create value: utilitarian value, enjoyment, representations of interpersonal ties, identity and self-expression. She concludes that the public and private meanings of possessions are based partially on public meanings and partially on the owner's personal experiences with the object. Hirschman (1980) examined three sets of stimulus attributes (affective distortion, evaluative vs. factual content and functionality vs. aesthetic appeal) and proposes to categorize stimulus attributes into two groups: tangible features and intangible associations.

Fournier (1991) created a meaning-based framework for consumer-object relations based on a theoretical foundation. She used three underlying dimensions of psychological meaning: objective versus symbolic (tangibility), shared versus personalized (commonality) and high versus low emotional response (emotionality). Tangibility is concerned with whether the value of the object is tangible and verifiable through the senses or subjective, interpreted through experience and dependent upon associations. If an object is primarily objective the meaning is resident in the product itself, if subjective, the meaning is in the mind of the user. Commonality indicates whether the meaning is shared by others or if the meaning is individual; your car can evoke pleasant memories of a special road trip and vacations, but for the neighbour it is just a way of transport. Emotionality deals with the level of arousal a product elicits. In Figure 2.9 the model is presented. She stresses that the model is consumer-dependent. The given product examples in Figure 2.9 are only included for heuristic purposes because "...individual variant in terms of cultural background, experience, the polysemic character of the meaning of objects and the context dependency if interpretation preclude the absolute assignment of individual objects to categories.".

This model can be useful in the product design process to identify the arena of different types of meaning a product can have for a person.

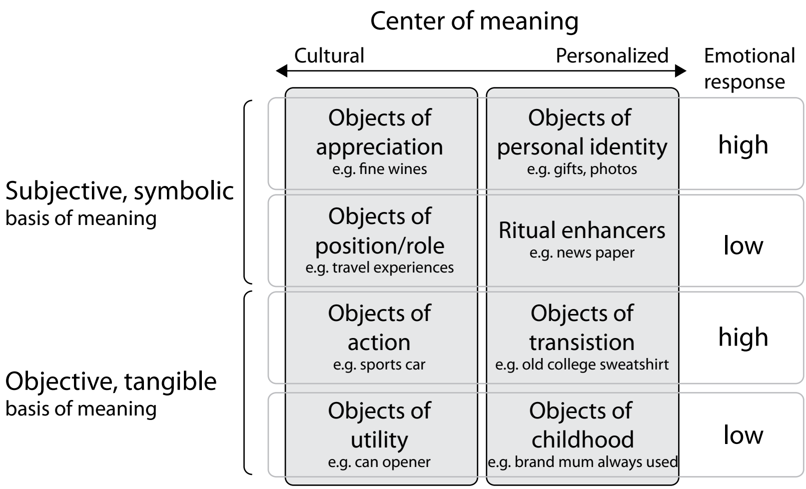

Figure 2.9 *Meaning-based framework of consumer-object relation adapted from Fournier (1991).*

General concerns & characteristics

Desmet (2002) describes that an appraisal of a product is based on concerns and identifies three types (see Chapter one, paragraph 1.2.2): attitudes, goals and standards. In that same paragraph the categorization of Jordan (2000) was discussed. He emphasises the importance of a holistic view on the user when designing pleasurable products. Vink & Hallbeck (2012) focus more on the physical and sensory characteristics of humans. In Figure 2.10 the aspects used in the descriptive model are presented.

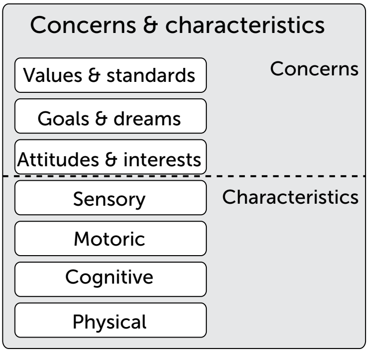

Figure 2.10 *An overview of human aspects: General Concerns & Characteristics.*

There has been made a distinction between concerns and characteristics. The characteristics involve physical characteristics (like; height, weight), cognitive abilities (can the user understand the product), motor skills (can the user operate the product) and sensory characteristics (can the user sense sensory product features; e.g. is the sound of an alarm clock loud enough to awaken a person). They are comparable to the Physio characteristics of Jordan (2000). These characteristics are observable and have to do with the ability to use a product. When the product does not fit the person's characteristics at all and is unable to operate the product as expected (e.g. if someone cannot figure out how to make a telephone call with his telephone, or if a car seat is too far away from the steering wheel so driving is impossible), than the product will evaluated negatively or if not, the user attached a special meaning to the product based on his concerns.

If the user can operate the product as expected, it depends on the concerns whether the product is experienced positive or negative. Concerns are not directly observable and can be universal, cultural or contextual. They are related to wanting and desiring a product and, following Desmet & Hekkert (2002), are divided into three categories:

1. Attitudes & interests. This concern is about the appealingness of a product to a person. It is based on the products size, shape, form and so on. Not only personal taste but also personality, social image, interests and talents influence the appealingness. The thermos in Figure 2.11-a can appeal to someone because of its bright colour and elegant shape.
2. Goals & dreams. This concern is about the desirability of a product to a person based on his goals and dreams. In this case the product acts as an event; through the product a goal is established (or not). A person can desire the car in Figure 2.11-b because of the fun it will bring him.
3. Values & standards. This concern is about the praiseworthiness of a product to a person. It is heavily influenced by culture and answers the question what a person values, beliefs, considers normal, and how he thinks things should be. The product acts as an agent; it causes or contributes to an event. A person can feel disgusted by the gun in Figure 2.11-c because he considers it inappropriate to give such a condemnable product an innocent Hello Kitty-look.

Photo credits:
http://www.varbak.com/photo/cabiro-photos-pink-mini

Photo credits:
http://www.nytimes.com/interactive/2011/03/20/magazine/purse-pistols.html?ref=magazine

Figure 2.11 *a. Thermos, b. BMW-car, c. Gun.*

Concerns are subjective and a product can elicit mixed emotions based on the subjective concerns and objective characteristics. If you would pick up the gun in Figure 2.11-C for example it might be a bit small for the size of your hands (physical characteristic), when you try to shoot you easily understand how to fire it (cognitive characteristic) and you hit a target in your very first attempt (motor skills). The grip feels soft and luxurious in your hands (sensory), besides you are a big fan of Hello Kitty (attitude), however, you never wanted to shoot anyone or anything (goal) and you think guns should not be publically allowed because it causes too much harm to society.

Although the product experience is subjective and the elicited emotions can be mixed, information on the concerns and characteristics of your target group is important for designing (potential) pleasurable products. The next paragraph describes the relationship between human and product aspects.

2.3.3 Relationship between PA and HA

The categorization of the product aspects and human aspects are made from a designer's point of view. It tries to approach the product and the user in a holistic way. In this paragraph the connection between the product aspects and human aspects is established. In Figure 2.12 the relationship is presented graphically. The dotted line indicates the division; the items above and below the dotted line are related. This is not a strict division it's made for the sake of understanding the design process for pleasurable products holistically.

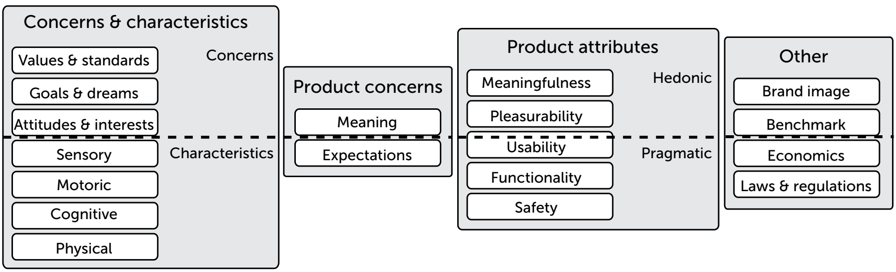

Figure 2.12 *The relationship between product aspects and human aspects.*

To develop safe, functional and usable products that meet the expectations pragmatic attributes are needed. Designers should know what the user expect (expectations) and what he is able to do (in terms of physical, cognitive, motor and sensory abilities). If a car is designed for elderly people, information on their cognitive, motor and sensory abilities is needed to develop displays they can easily read, seats that can be adjusted intuitively and/or rotate for getting comfortably in and out of the car, create buttons that are big enough to see and control and so on.

To develop pleasurable products that exceed the expectation and therefore gain a special meaning for the user hedonic attributes are needed. Designers should know what a product means for a user and what is appealing, desirable and pleasing to him (attitudes, goals and values; his concerns). When designing a car for the Indian market, designers should know that the cow is a sacred animal (value); therefore cow leather in the interior should not be used.

Knowing what people are able to do and expect is necessary in order to create satisfying products. For designing pleasurable products "more" is needed, to discover this "more" attention to attitudes, goals and interest of the user should be paid.

2.4 Descriptive model for products contributing to well-being

2.4.1 Final model

In Figure 2.13 a schematic overview of the model discussed in this chapter is presented. The Why, How, What phases are projected over the descriptive model and the different phases are connected with arrows. It starts at the bottom with the different human concerns and characteristics as well as the product attributes and other relevant factors. The human aspects and product aspects are input for the appraisal phase which takes place in a certain context. The outcome of the product interaction and evaluation are affect and behaviour. In this model the outcomes are pleasurable emotions and feelings and meaningful behaviours contributing to the well-being of the user.

On page 65 (Figure 2.14) the model is presented graphically. Here the role of the designer in the process is clearly presented. This model is useful to explain the important aspects of designing products that contribute to the well-being of people in a more intuitive way. It starts with the designer who needs to gather information and define the product attributes. There is also an arrow from the designer to "other" because designers need to take into account the other factors (as described in paragraph 2.2.2) as well. In the evaluation phase the user and product are presented in a context and the output are affect and/or behaviour. The elicited affect should be pleasurable (partying people represent the hedonic aspect) and the behaviour should be meaningful (a meditating person represents the meaningfullness). Because both aspects are contributing to the overall well-being of individuals, they are presented on a scale.

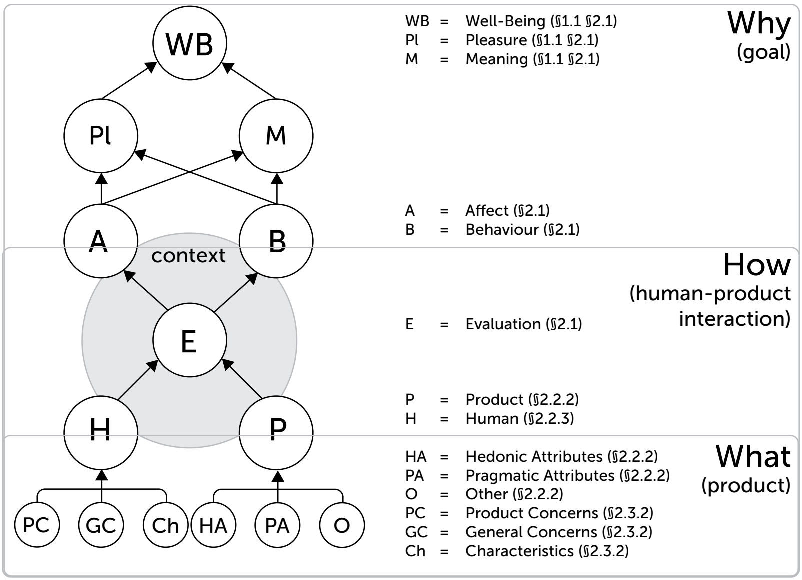

Figure 2.13 *Schematic overview of the pleasure model with Hassenzahl's (2012) three levels layered over it.*

2.4.2 Implications of the model

Product experiences and emotions contributing to well-being are subjective. It is not possible to design a pleasurable product experience; it depends on the user if he evaluates it as such. This model is not a navigation system where designers enter a destination and it guides them automatically step by step to that destination; this would be impossible. The goal of this model is to provide a holistic overview of the human-product interaction process; the relevant input (human & product aspects) and desired output (pleasurable emotions and feelings & meaningful behaviour) for products that contribute to the well-being of the user.

The product aspects can be used to structure the product requirements. The human aspects can be used to structure the information that is needed for the requirements. The appraisal phase shows that the context influences the evaluation as well as the human and product aspects. Although the pragmatic product attributes and objective human characteristics are relevant in designing pleasurable products, the focus in such design processess should be on the human concerns and hedonic product attributes. The human concerns focus on what a user considers meaningful and pleasurable and is input for developing hedonic requirements resulting in hedonic product attributes. To gain a rich insight into the users' concerns several methods of which a few listed below can be used:

- Personas; a detailed profile of fictional characters representing the lifestyle, behaviour, goals, desires and so on of the target group (e.g. Cooper et al., 2007).
- Storyboards; creating a story and presenting a scenario in which a product is used, e.g. a day out of the life of the product. It provides rich information on the context and user of the product (e.g. Cooper et al., 2007).
- Context mapping; Cultural probes/diary studies; subject experts are filling out a booklet during a period of time writing down their experiences with a specific product, interaction with this product or routine. It provides rich information on tacit knowledge of the (potential) users and their environment.
- Brainstorming; a creative technique to generate ideas/solutions for a product/problem together with designers and/or users. Mind mapping; it is a creative technique to quickly structure information. The mind map can be created by designers, develop-

ers or together with (potential) users.

- Mood boards; Creation of boards reflecting the future style, environment etc. for the product either based on gathered information or defined by users. (Sleeswijk-Visser, 2009; Sanders, 2002)
- The values one has can be tested with several methods like the list of values (Beatty et al., 1985) or the Rokeach value survey (Rokeach, 1973, Reynolds & Jolly, 1980). Hofstede (1991) defined different cultural dimensions which can be helpful for products on a global market.
- Field studies; observing (potential) users in their day to day live in order to gain a rich context (like needs, wishes, unexpressed problems) of a product (Kamp et al., 2011).
- User interviews, surveys/questionnaires, focus groups, self reports (e.g. Vredenburg et al., 2002, Calder, 1977).

Testing products in an early phase to receive feedback on usability can be done with:

- Heuristic evaluation; a holistic evaluation examining the product and rating it, based on usability principles (see Nielsen & Molich, 1990)
- Prototype including user tests (Wizard of Oz); a (simplified) model of the product or service is build and tested with (potential) users. The goal is among others to; find flaws in the design, explore the design itself and communicate with all the stakeholders in the design process. (see e.g. Buxton, 2007, Poggenpohl, 2002).

Assessment-tools on what kind of pleasure the product elicits or if the product contributes to well-being are scarce. If a product elicits the 'right' (pleasant) emotions can be assessed with the Emocard-method (Desmet, 2002) and Facereader application (http://www.noldus.com/human-behavior-research/products/facereader). Social science studies report of several questionnaires assessing well-being of individuals like the Oxford Happiness Scale (e.g. Hills & Argyle, 2002) or Seligman's authentic happiness inventory (Seligman, 2002); whether these scales are also appropriate for testing if products contribute to well-being or if (and if, how) they need adjustments are interesting subjects of future research.

2.4.3 Final remarks

In this part the literature on well-being, comfort and pleasure is discussed (Chapter one). Based on this information a descriptive model for designing products contributing for the users' well-being is created (Chapter two). In the following two parts examples of experiments on car interiors contributing to the driver's (Part B) and passengers' (Part C) pleasure are presented. This decision to only focus on the pleasurable experience and not on evoking meaningful behaviour has been made because of the long-term character of the meaningful behaviour aspect and the current inability to assess whether products can increase happiness. The assumption is made that pleasure is a worthy goal on itself and that it is a necessary part for products contributing to well-being, whereas meaningful behaviour alone is probably not successful when it is not pleasurable. Furthermore, whether every product in general and car interiors in specific should stimulate or evoke meaningful behaviour (or if it already does) is questionable.

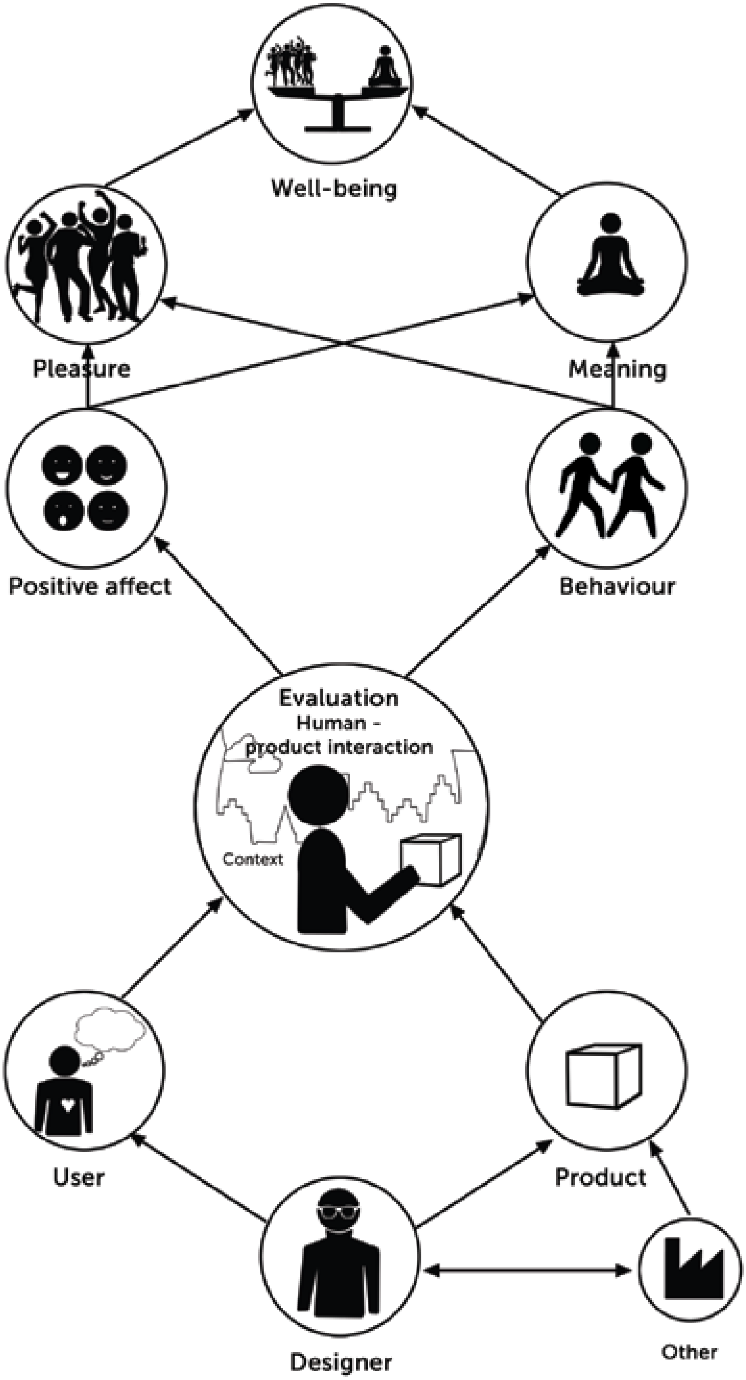

Figure 2.14 *Graphical representation of the developed descriptive model.*

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PART B
SHEER DRIVING PLEASURE

Experiments on the comfort and pleasure experience of the driver

One of the main challenges for car manufacturers is the stringent environmental regulations without compromising driving pleasure for drivers globally. In order to comply with the stringent regulations a new car seat was developed. This seat had to be lightweight but not comprising comfort and preferably enhance driving pleasure. To gain insight in the possibilities for enhancing driving pleasure, the values and meaning of a car for people were researched.

Part B presents two studies. The first chapter describes the development of a new lightweight seat concept. The second part discusses the emotional experience of this developed concept and what seat design characteristics influence this experience and how.

3

A LIGHT WEIGHT CAR-SEAT SHAPED BY HUMAN BODY CONTOUR

The following chapter is a published article in the International Journal of Human Factors Modeling and Simulation.

Reference: Franz, M., Kamp, I., Durt, A., Kilincsoy, Ü., Bubb, H. and Vink, P. (2011). A light weight car-seat shaped by human body contour, *International Journal of Human Factors Modelling and Simulation*, Vol. 2 (4), 314–326.

Abstract

The aim of this study is to develop a light-weight, comfortable seat. The idea is to shape a seat with a minimum of material by using the contour of the seated human. Twenty-five participants were asked to sit in a vacuum mattress placed on a wooden seat frame with similar angles as the car seat construction angles. They were instructed to sit in a comfortable position and perform driving movements. The mattress was then fixed, the contour scanned and digitised. All scans were superimposed giving input for a seat shell design made out of glass fibre laminate. The comfort experience of the shell was tested by 25 participants and compared with a standard BMW seat. The study shows that it is possible to create a rather comfortable seat using the human surface anatomy. However, more research on defining the specific form for the ideal shell is needed.

Keywords: seat requirements; sitting comfort; car seat; seat shell; light weight; seat development; seat design; comfort experience; body contour; digital contour.

3.1 Introduction

More stringent emission regulation forces car manufactures to build environmental friendlier cars. To achieve a more responsible image and meet the regulations, higher efficiency cars with less and lighter materials are needed. As for the car interior, seats contribute for a major part to the weight. Future car seats should therefore be lightweight and provide a maximum of comfort, which could be contradictory.

In car manufacturing mostly data are used for the construction of car seats based on experience of engineers and 3D digital models (e.g., Jack and Ramses). Additionally, several studies are available providing information for designing and constructing comfortable car and office seats (Vink, 2005). Based on the study of Helander & Zhang (1997) general aspects of sitting can be defined that play a role in comfort and discomfort. Based on questionnaires, they found that discomfort is more related to physical characteristics of the environment such as posture, stiffness and fatigue. Comfort is more related to subjective factors such as luxury, relaxation, etc.

Information on the seating position and pressure distribution can be found as well in literature. For example the optimal seat angle was found by Harrisson et al. (2000). Wilke et al. (1999) proposes that a reduced pressure in the intervertebral discs is achieved through a backward leaning position. Also, Zenk (2008) found in his research that a relaxed, well supported position results in a low pressure in the spinal discs. Mergl (2006) defined the ideal pressure distribution for car seats and showed that the comfort is rated high when there is an ideal pressure distribution under the legs and buttock. De Looze et al. (2003) showed in his literature review that there are several studies indicating that a good pressure distribution in the seat cushion is related to the comfort experience. Dieën et al. (2001) found that a seat should not enable one ideal sitting position but stimulate variation in posture. Lueder (2004) also mentions the importance of chairs that enable users to shift dynamically between ranges of stable and healthy postures, in a review on the ergonomics of seating. For office chairs the effects of systems that give active movement have been described (Van Deursen et al., 2001) and studied (Ellegast et al., 2011) and show that variation in the task is important to stimulate variation in posture. Andreoni et al. (2002) analysed pressure and comfort in a larger number of seats with different shapes and foam stiffness, and defined correlations with the shape of the human body at the interface measured by the imprinted surface. Using this method it was possible to find an optimum for the foam.

There are indications that a better fit to the contour of the body leads to more comfort (Friehmelt, 2009). A shell following the body contour and using a minimum of upholstery material could also be a solution for creating a light weight and comfortable car seat. However, data on the anatomical human contour of a group of people in a position described in literature and facilitating some change in posture are not available yet.

The purpose of this study is therefore to define a contour of the back of the human body in the driving position described by Zenk (2008), Mergl (2006) and Harrison (2000) in order to design a seat shell which follows closely this body contour. This shell should be light weight and experienced comfortable as well. Therefore, the research question of this study is:

Does a lightweight seat with a form based on the human body contour in a driving position create comfort and is it appreciated?

3.2 Methodology

To answer the research question several steps were taken. Firstly, a laboratory research was done to find the optimal contour of the back, buttocks and thighs contacting the seat while the participants performed driving tasks. Secondly, these data were scanned and transferred to a computer aided design (CAD) software (CATIA V5, R15). A seat was designed and manufactured based on these results. Thirdly, a re-test was performed to analyse and compare the results from part one with the new body contoured light weight seat. Lastly, the new seat was compared with a standard BMW seat in a user test.

3.2.1 Laboratory test

In total 25 participants took part in this research: 15 men and ten women aged between 20 and 40 years (mean age: 30 years) from 5th percentile women to 95th percentile men (mean height: 176.6 cm, mean weight: 77 kg). All participants had driver experience and were instructed to sit in a research mock up with a vacuum mattress (see Figure 3.1).

Figure 3.1 *Frame with vacuum mattress after imprinting in the lab.*

The subjects were instructed to perform some driving tasks such as moving a steering wheel, using the gear, look in the mirror and pressing the pedals (clutch, brake, and accelerator). The objective was to push the body into the rescue mattress as to create a contour specifically optimal for these driving tasks. After performing the driving tasks and finding their own optimal position, the test subjects had to rate their sitting position and comfort feeling via a questionnaire. Additionally, the Emocards method developed by Desmet et al. (2001) was used. The Emocards used in this research consisted of 2 × 8 different faces (male as well as female) expressing different emotions. The first step was to rate the first emotional impression about the tactile experience of their own sitting position by choosing the Emocard that comes closest to their emotional experience.

The second step was to rate their sitting position using prescribed words. With the assistance of a semantic differential, a clear connection between a linguistic answer and a psychological correspondence to the Emocard was established (see Table 3.1 for the semantic differential). Positive and negative attributes were not automatically listed in this way on the semantic differential, they were deliberately mixed. The main purpose of this element was to evaluate how the subjects felt in the seat and their first impressions.

Table 3.1 *Semantic differential used to rate the sitting position.*

Restricted	O	O	O	O	O	O	O	Unrestrained
Cosy	O	O	O	O	O	O	O	Unpleasant
Enfolding	O	O	O	O	O	O	O	Off putting
Insecure	O	O	O	O	O	O	O	Secure
Inviting	O	O	O	O	O	O	O	Unwelcoming
Protected	O	O	O	O	O	O	O	Unprotected
Heavy	O	O	O	O	O	O	O	Exhilarating

The third step was to complete a questionnaire in which the ability to find a comfortable sitting position and the ability to do a long drive in that position were questioned. The goal of the questionnaire was to find out what body postures were important for a comfortable sitting experience in a car seat and what aspects could cause discomfort according to the participants. In the questionnaire, space was available for comments to discover what people said and thought (tacit knowledge), and also what they knew, felt and experienced.

After performing the driving tasks, rating the emotions and completing the questionnaire, the air was removed out of the mattress. The test subject had to leave the now vacuumised, research seat and a picture was taken with a digital camera and each individual imprint of the subject was scanned with a 3D laser scanner (Steinbichler Optoscan T-scan 2).

3.2.2 Seat development process

In order to combine the shapes derived from all the individual scanned contours, a three-step process was carried out: At first all the scanning data were arranged in a certain position, approaching the scatter plots of the scans as close as possible to each other, using a best-fit algorithm. This was realized with 3D modeling software, which can handle scanned scatter plots and perform shape design. Because of the major divergence of each individual shape, based on the body height and the proportions, it was necessary to prioritize particular scanned areas. Based on seating comfort literature (e.g., Mergl, 2006; De Looze et al., 2003) the buttocks and lower back area were in this case prioritized for the best-fit algorithm. As a result bigger variations in the shoulder and the front thighs were allowed (however the aim was to have as less variation as possible). Next, an arithmetic averaging of the resulting scatter plot was performed, by creating one new shape which fits best to all the initial scanned body contours. The disadvantage of this averaged contour is that it does not suit tall people any more. In order to overcome this obstacle, finally a last step is necessary. For this reason the contour was enlarged by defining a uniformly continuous offset of the surface in the positive direction. Finally, a new shape was created, which fits closely each individual person regardless of height or proportion.

Based on these contour data a seat shell prototype was built of glass fibre laminate, fitting the extreme (largest) subjects. Inflatable cushions were put in the shell, which could be adapted in such a way that all 25 scanned subjects would fit by relating it to the CATIA data. On top of the inflatable cushions a 30 mm light weight 3 mesh spacer fabric (http://www.muellertextil.de/) was used to enable airflow between the human body and seat and then the upholstery fabric was placed on the surface. The seat shell was built on a standard car seat frame. The backrest was adjustable, as was the angle of the seat cushion.

3.2.3 Comparison new seat with mattress

With this new seat, the same evaluation was done as with the rescue mattress. The same participants as in the laboratory test participated (three participants could not take part in this second test). They had to sit in the new seat, performing driving tasks, rate their emotional experience and finally answer the questions on the experienced comfort in the questionnaire. The tasks and questions were identical with the ones during the laboratory research described in paragraph 3.2.1. To compare both situations, a paired t-test was done.

3.2.4 Comparison new seat with a current BMW seat

In order to get a feeling on the comfort experience and the light weight aspect of the newly developed seat, a comparison to a current BMW seat was made. Both seats were weighed on a scale. The comfort rating of the 7 series seat was done in a past experiment (with 40 participants). The same test conditions were applied in this study: the same questionnaires, frames and seat positions were used.

3.3 Results

3.3.1 Laboratory test

Most participants (44%) rated the tactile input of their own sitting position in the vacuum mattress with a neutral arousal, positive emotion (see Figure 3.2).

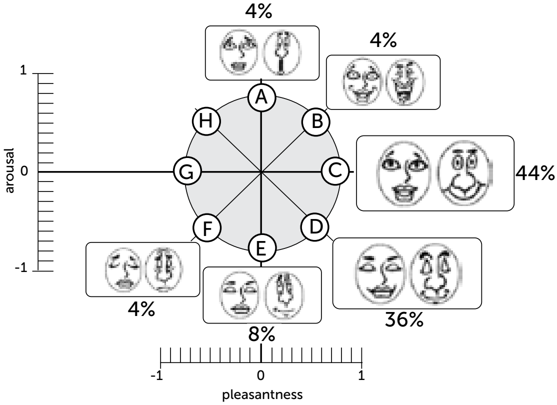

Figure 3.2 *Emocard rating of the imprinted mat.*

The results of the semantic differential showed this neutral feeling as well; participants rated all semantic differentials neutral or slightly more positive, except for 'restricted' (see Figure 3.3). All subjects confirmed that they could find a comfortable sitting position in the mattress. Of all participants 88% believed that they could drive for a long time in this position. Three subjects (12%) disagreed because they expected to need rest breaks in this position.

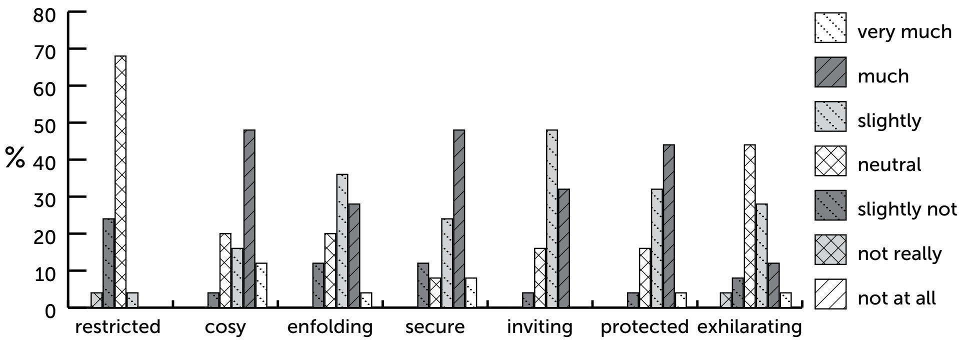

Figure 3.3 *Semantic differential rating of the imprinted mat (N=25).*

3.3.2 Seat development process

After all mattress imprints were photographed and scanned, the data was converted to the CAD software CATIA v5. The general seat shell was created by using the 'best fit' of all superimposed scans to find the final, ideal seat shape (see also Section 3.2.2). Using Polyworks software, the discrepancies between the superimposed scans appeared to be less than 3 mm. Three millimetres was the maximum difference in the outer areas. The outer form was taken (see Figure 3.4) as the bases for the shell as for the smaller subjects the inner form could be filled by pumping up the aircushions.

A new glass-fibre seat shell was built following the CATIA design. Initially inflatable cushions which could be inflated up to 3 mm were put in the shell, to make sure the seat could be adjusted to the 5th percentile women as well as the 95th percentile man. After a pre-test with seat experts, a decision was made to have the cushions more inflatable, because the seat felt too hard. Based on the experts experience an arbitrary decision was made to increase it to 15 mm also to enable variation in posture needed for the various driving tasks. This seat shell was built on a metal car seat frame and the backrest and seat position could be adjusted (see Figure 3.4).

Figure 3.4 *Seat shell in CAD software (left), inflatable cushions in the prototype of the light weight body contoured seat (middle), prototype of the light weight body contoured seat (right).*

3.3.3 Comparison new seat with mattress

In the re-test the tactile input of the sitting position in the body contoured seat shell was rated slightly positive, to neutral (Figure 3.5). When compared with the semantic differential questionnaire, the results of the laboratory test shown in Figure 3.6 shows a similarity to the semantic differential of the retest with the seat shell. The overall results look similar when the mean scores of the new seat concept are compared to the mattress (see Figure 3.7 and Table 3.2). In Table 3.2 the mean, standard deviation and P values for the paired t-test can be found. No significant relationships were discovered. Both seats are a bit less rated on the restricted aspect and all the other descriptive words are rated neutral or slightly more applicable. A closer look at this graph shows minor differences between both set-ups; the mattress was experienced a bit more cosy, inviting and protected. Whereas the seat shell concept was rated on average more enfolding, secure and exhilarating. However, as the differences were not significant no conclusions can be drawn.

All test subjects confirmed that they could find a comfortable sitting position in the body contoured light weight seat shell and mentioned that they could drive for a long time in this position, which was better than for the mattress (there 12% doubted that they could drive for a longer period of time).

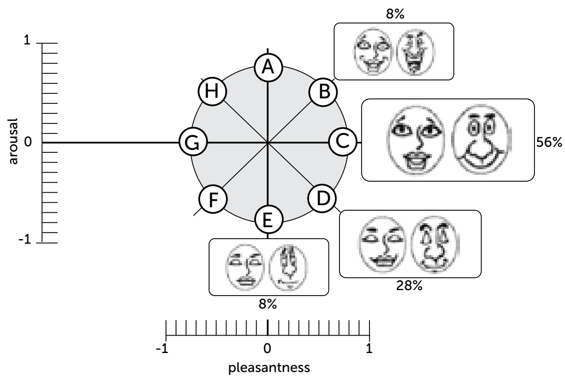

Figure 3.5 *Emocard rating of new seat concept.*

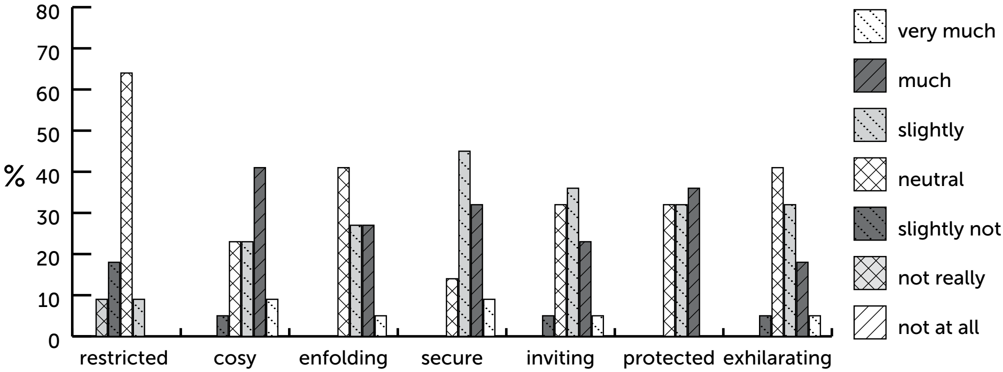

Figure 3.6 *Semantic differential rating of the new seat concept.*

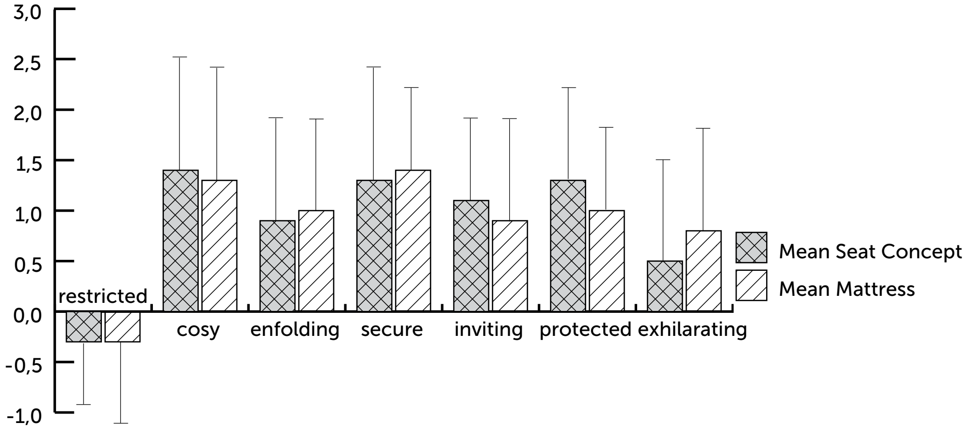

Figure 3.7. *Average values and standard deviation for the new seat concept vs. the rescue mattress.*

Note: On the vertical axis the scale is shown: −3, −2, −1, 0, 1, 2, 3 where 3 is very much and −3 not at all. Zero is neutral and the negative scores mean that the descriptive words are less applicable to the test seat.

Table 3.2 *Overview of mean and standard deviation for the mattress research and the new seat concept.*

Descriptive words	Mean mattress	St dev mattress	Mean seat concept	St dev seat concept	Mattress vs. seat concept (P)
Restricted	−0.3	0.6	−0.3	0.8	0.833
Enfolding	1.4	1.1	1.3	1.1	0.642
Secure	0.9	1.1	1.0	1.0	0.589
Inviting	1.3	1.1	1.4	0.8	0.874
Protected	1.1	0.8	0.9	1.0	0.424
Exhilarating	1.3	0.9	1.0	0.8	0.315
Cosy	0.5	1.1	0.8	1.0	0.365

3.3.4 Comparison the mattress, the new seat concept and a current BMW seat

Figure 3.8 shows the comparison between the mattress, body contoured seat and a BMW standard seat. The body contoured seat and also the mattress, is in all categories better than the BMW standard seat, except for the category restricted-unrestraint. The standard seat does not fit all body regions to the anatomical curves. The most frequently mentioned area, where the new seat follows the body better was the lumbar/lower back region. When the weight of the standard BMW seat is compared to the new body contoured seat shell, it turns out that the new concept is almost 50% lighter.

Secondly, this study indicates that a seat based on the body contour of 25 subjects is comparable to a standard BMW seat. The contour felt better in the lumbar region in the contour seat and many descriptive words given to the seat come close to the standard seat. However, the category restricted-unrestraint might need some attention.

Thirdly, the body contoured seat weighs almost 50% less than a conventional BMW seat. However, this was only the prototype compared to a fully functional BMW seat. When the seat is further developed, extra weight can be expected due to safety measurements and crash regulations.

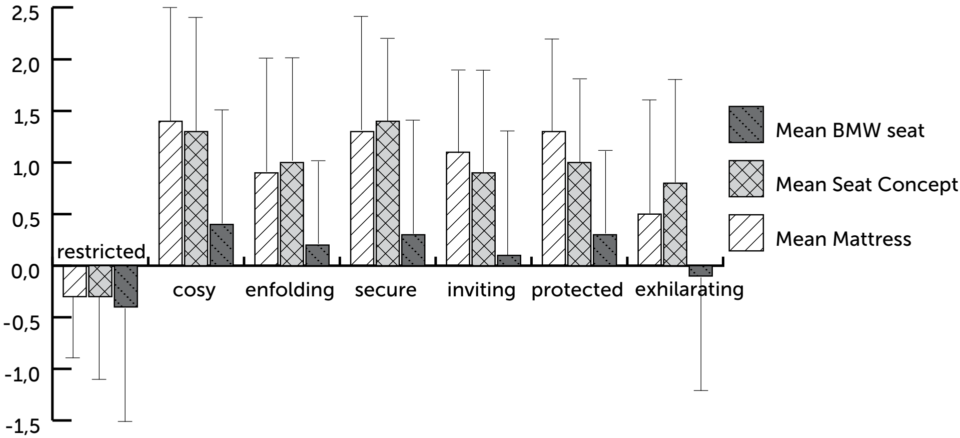

Figure 3.8 *Comparison between the mattress, body contoured seat and a BMW standard seat (mean and standard deviation).*

3.4.2 Reflection of the methods

In the process of designing a comfortable body contoured car seat it appeared that the questionnaires and Emocards were useful. It gave insight into the experiences of the user when they were able to verbalize and visualize their (tacit) needs and wishes. These needs and wishes were stated directly by the participants, minimizing interpretation by the researcher. In this way the subjects were able to choose their most preferred position more consciously and this position was scanned. Using tacit knowledge in seat design is not new for instance Van Rosmalen et al. (2009) used this in designing a lounge seat. The seat experiment is an example of research that provides more information that can be incorporated in the design of a comfortable car seat. It is acknowledged, that the testing time in the lab test and also the retest were based on a short term evaluation. It would also be interesting to do a retest under real driving conditions for a longer time. More research is needed to specify the long term comfort of the seat concept. Another issue which could disturb the outcomes is the fact that the method is not sensible enough to measure differences. The methods have been used before in various studies. De Looze et al. (2003) did find significant differences between office seats with Emocards and this method and Franz (2010) also found differences using the method with car seats. However, these were all short term tests, which support the need for a long term test as well.

In conclusion, the research methods used provided useful information for the design of a comfortable seat giving a good seating experience. The studies complement each other and are valuable for the creation of a new seat and provide the opportunity to understand the anatomy and the user's needs. For more detailed design requirements additional research is needed, e.g. comparison to other car seats, different contours and their emotional perception and long term tests.

3.4.3 Surface material for the body contoured seat

The new body contoured seat shell combines all of the imprinted contours of the subjects. Each individual contour can be found in this (digital) seat shell. This means however, that for some individuals, the body contour shape is not an exact fit. For this reason a specific surface material is needed to cover these contour differences. Pre tests have shown that regular foam material works very well to eliminate these differences. However, the more light weight solution of inflatable cushions (air does not increase the weight) also seems promising. This inflatable cushion allowing some variation is also important to be able to have another posture. It is important to allow these changes in the seat position as van Dieën et al. (2001) and Lueder (2004) have also shown that being able to vary the posture, reduces local perceived discomfort.

The contour and the development process of the body contoured light weight seat is patented PA2009016051 DE.

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4
THE INFLUENCE OF CAR-SEAT DESIGN ON ITS CHARACTER EXPERIENCE

The following chapter is a published article in the journal Applied Ergonomics.

Reference: Kamp, I., 2012. The influence of car-seat design on its character experience. *Applied Ergonomics,* Vol. 43 (2), 329-335.

Abstract
Producing higher efficiency cars with less and lighter materials but without compromising safety, comfort and driving pleasure might give a competitive advantage. In this light, at BMW a new light weight car-seat concept was developed based on the human body contour. A possibility to increase the comfort is using a seat which elicits positive tactile experiences. However, limited information is available on seat characteristics and tactile experiences. Therefore, this study describes the contour of three different car-seat designs, including a light weight seat, and the recorded corresponding emotion and tactile experience of 21 persons sitting in the seats. Results show that the new light weight car-seat concept rated well on experienced relaxedness, even with the lack of a side support. The most important findings are that hard seats with rather high side supports are rated sporty and seats that are softer are rated more luxurious.

4.1 Introduction
In the automotive industry innovation is vital. Not only does the industry have to keep up with competitors but also has to maintain (or expand) market share and meet the increasingly stringent emission regulations to demonstrate a committed "green" responsibility in the ongoing public environmental debate (Franz et al., 2011; Zenk et al., 2012). Car manufacturers have to produce environmentally friendly cars. Most of them are already proactively working toward reducing fuel consumption and emission levels and developing alternative technologies e.g., efficiency programs like Blue Lion of Peugeot, Efficient Dynamics of BMW and Blue efficiency of Mercedes Benz. Mercedes' Blue efficiency is a package of fuel saving technologies. Advancements include improved aerodynamics, weight reduction, lower-displacement engines and ECO start/stop to help save energy. Their ultimate goal is emission free driving. The Efficient Dynamics program of BMW also focuses on fuel saving technologies like cleaner engines, auto start stop function, brake energy regeneration, electric power steering, air vent control, gear shift indicator and tires with reduced rolling resistance. Peugeot's challenge is to reduce the

greenhouse gases to limit global warming and a reduction of atmospheric pollutant discharges to limit impact on air quality. They have taken several initiatives like: a 'zero emission' car in Europe, the development of a cleaner diesel engine, energy saving tires and so on. Besides the improvements in their technology, Peugeot also incorporates environmental friendliness in their sales network facilities by sales areas with limited glazed areas, allowing better control of energy expenditures for heating and air conditioning. These premises also give priority to the use of natural materials such as wood and are organized so that the workshops are adapted to sorting and recyclability of automotive wastes. In short, when reviewing these efficiency programs, it becomes clear that harmful emissions should be reduced and efficiency should be increased. However, the vision of BMW is that safety, comfort and driving pleasure should not be compromised by these developments.

The question is what a premium car manufacturer can do to increase comfort, besides a well-shaped backrest and seat shell contour. To answer this question, it is necessary to have a closer look at the concept 'comfort'. Vink (2005) indicates that "discomfort is more related to physical characteristics, whereas comfort is more related to experience, emotion, unexpected features, and luxury". Literature is available on physical seat characteristics: the optimal backrest width and seat cushion width based on anthropometrics as specified by Reed et al. (1994) in their literature review. De Looze et al. (2003) found in various studies that good pressure distribution increases comfort; Mergl (2006) has specified this optimal pressure distribution. Studies on the effect of extra features, like massage systems, showed positive effects on EMG measurements and comfort experience (Durkin et al., 2006; Franz et al., 2008, 2011; Frohriep & Petzel, 2006). Adding more features to a car seat will however increase the weight of the car and is, in view of the environmental discussion, not favoured. How can the experience of a car seat then be enhanced? One option could be to design a seat that fits well to the human body as well as to the emotional status of the car. In other words, adapt the seat design to the character of a car; e.g., having a truck seat in your race car will probably not enhance the driving pleasure. However, in current literature not much information is available on what aspect of seat design enhances a specific emotion like sporty or luxurious.

Therefore in this study three different car-seat designs are described objectively and tacit emotions of people sitting in these seats are measured subjectively. Two seats are existing car seats already in use in several car models on the road. The third seat is a new concept developed at BMW (see Figure 4.1). The seat is very thin and its potential weight reduction is approximately 50% in comparison with a fully equipped current seat (including electric adjustment of backrest, seat inclination, massage and so on). The backrest and seat shell closely follow the human body surface contour. The (small) discrepancies between the seat contour and the individual who sits in the seat is filled by pneumatic pads. The purpose of this study is to determine whether the new developed seat concept has not only advantages in terms of weight reduction, but also in terms of seating comfort. A second purpose is to find a relationship between the elicit emotion and seat contour of a car seat. The main questions addressed in this paper are:

- How is the new car-seat concept rated in relation to existing seats?
- What seat design is experienced appropriate for what specific car model type?

Figure 4.1 *New car-seat concept based on the human body contour developed at BMW (Franz et al., 2011).*

4.2 Method

This research is presented in two parts; an objective part to determine the contour characteristics of the seats and a subjective part in which participants were asked to rate their comfort experience in different seats with Emocards.

4.2.1 Objective research

Three car seats from different car model types with different contours where used in this experiment. The seats were chosen based on their difference in design and on the car model type the seats are in: one seat with steep wings used in sportive cars (contour 1, the lightest shade in Figure 4.2), one seat that is less contoured (contour 2, the middle shade in Figure 4.2) used in luxurious cars and a new seat concept based on the human body contour (contour 3, the darkest shade in Figure 4.2).

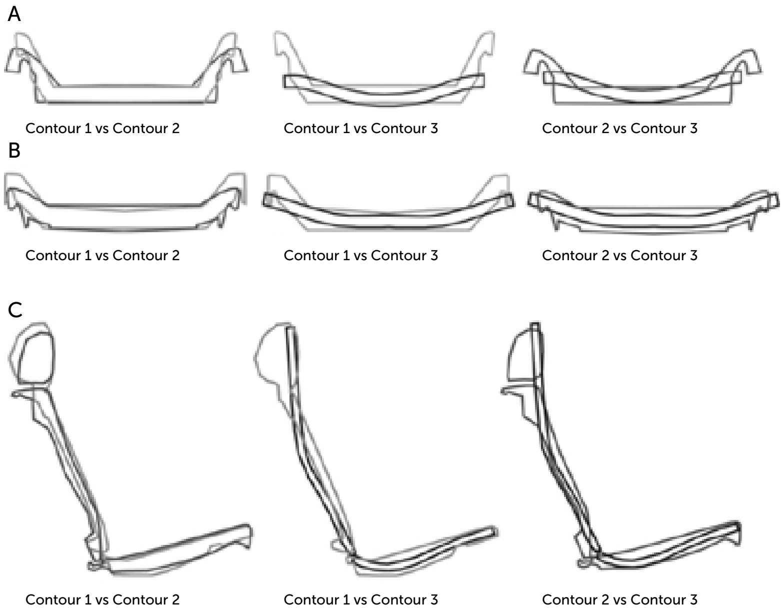

Figure 4.2 *a. Horizontal cut through the backrest to see the difference in contours. b. Horizontal cut through the seat surface to see the difference in contours. c. Vertical cut through the seat to see the difference in contours.*

To define the shape and contour of all three seats, the following aspects where measured:

- Width of seat and backrest. To determine the width of the backrest and the seat, two measurements where done; the largest external width including the wings and the width between the wings at this place (Figure 4.3a);
- Steepness of back- and seat wings. To determine the steepness, the angle of the wings is measured (tan a = height wing/width wing) (see Figure 4.3b) at the place where the wings was the highest;

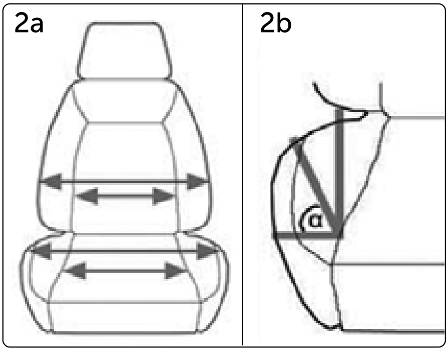

Figure 4.3 *a. Measurement of backrest and seat width. b. Measurement of steepness of wings*

- Contour of backrest. This is determined based on the amount of seams and the protrusion of the lumbar support (based on CAD data);
- The hardness of the seat cushion, based on the thickness of the foam material and hardness in kPa.

4.2.2 Subjective research

Participants

Twenty-one healthy subjects, fifteen males and six females, participated in the experiment. Their mean height was 1.78(1.63-1.92) m and their mean weight was 76 (48-107) kg.

Seats

Two seats in this set-up were existing seats from different car segments; one seat from a luxurious car and one from a sports car. The third seat was the new concept seat based on the human body contour as described in the introduction. All seats had the same backrest angle (25 degrees) and seat angle (14 degrees), which resembles the optimal seating angle found by Harrison et al. (2000).

Set-up

The subjective evaluation of the chairs by all test subjects was realized with three different instruments of survey (preliminary survey, survey of each chair while sitting on the seat and a closing comparison of all chairs). Before the actual test took place a pilot study was done to find any gaps or ambiguities in the research setup. The subjective part of the research was carried out in a laboratory environment. In the laboratory three car seats formed a circle (Figure 4.4). To avoid that the appearance of the seats influenced the comfort experience of the participants, all seats were covered with a thin blanket.

Figure 4.4 *Research set-up with covered seats. The seats are deliberately covered so participants are not influenced by the appearance of the seats and focus on the seats' sitting comfort.*

All participants received a short introduction before the actual test was done to explain what they needed to do. Before they sat down, questions related to their current emotional state and the desired emotion a perfect car seat should elicit were asked. For the rating of emotions the Emocard method was applied. This is a nonverbal self-reporting method developed by Desmet et al. (2001) based on the circumplex of emotions created by Russell (1980). This circumplex is based on two dimensions; 'pleasantness' and 'arousal'. The 16 Emocards are placed on eight distinct places on this circumplex (see Figure 4.5). Each octant of the circumplex is represented by both a male and a female face. Participants can express their emotional responses to the seats by marking the face that best indicates their response.

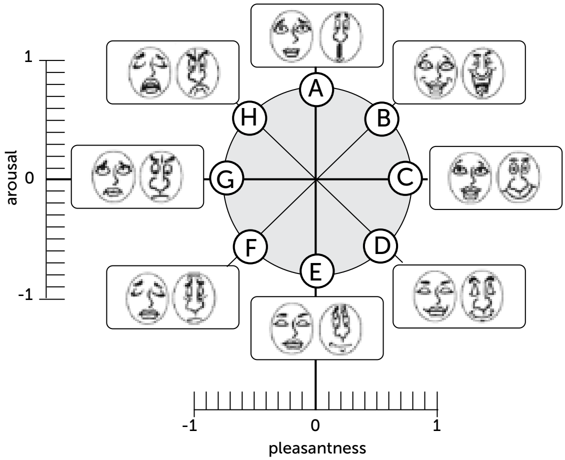

Figure 4.5 *The 16 Emocards placed on Russell's circumplex of emotions (after Desmet et al., 2001).*

After the first questions, they had to sit on every covered car seat for several minutes while obtaining a driving position. A sloping footrest to simulate this position was provided. It was not allowed for the participants to adjust the seat. They had to complete a questionnaire for each seat. They rated each seat on a 5 point scale (1 not at all, 5 very) using several keywords and choosing the car model type where they would expect to find this seat. The keywords in this experiment were a selection from the descriptive words Zenk et al. (2008) found in their research on most important aspects for car-seat users. At the end of the seat specific questionnaire they could indicate (in words as well as circling a specific area on a seat picture) whether there were negative or positive aspects to the seat.

The sequence of the three seat evaluations was systematically varied across subjects. All seats were tested for approximately 5 min. After all seats were tested, the participants had to choose the most comfortable, the most luxurious, the sportiest, the 'feeling most protected' (from here on indicated as protected) and the most relaxed seat. They also had to indicate which of the three seats they preferred and rate this seat on a 10 point scale (1 = very bad, 10 = excellent). The information obtained from the questionnaire was tested with the Wilcoxon test to find if there is a significant relation between the seat aspects (seat width, backrest width, seat wing steepness and so on) and the specific feeling the seat elicited (luxurious, comfortable, sporty and so on).

4.3 Results

4.3.1 Objective seat contour

The contours of the three car seats used in this experiment are described in more detail in Table 4.1, Figure 4.2 shows several cuts of the seats. Seat 1 is a leather roadster/sports car seat (lightest shade), seat 2 is a leather seat used in the BMW 1 and 3 series which can be described as a luxurious seat (middle shade) and seat 3 is the light weight seat concept with leather upholstery developed at BMW (black) described by Franz et al. (2011).

Table 4.1 *Contour description of the seats.*

Seat	**Width (cm)**	**Wings (°)**	**Contour (seams)**	**Foam hardness & thickness of layer**
Contour 1	50 – 31	51	2 horizontal 1 vertical	9 kPa 80 mm
Contour 2	48 – 29	35	2 horizontal	8 kPa 80 mm
Contour 3	52 – 52	No wings	Body shaped	6 kPa 25 mm
Backrest	**Width (cm)**	**Wings (°)**	**Contour (seams and lordosis)**	**Foam hardness & thickness of layer**
Contour 1	49 – 31	60	2 vertical Slight	8 kPa 35 mm
Contour 2	51 – 27	47	2 horizontal Most	6 kPa 80 mm
Contour 3	50 – 50	No wings	Body shaped (see Figure 4.2)	6 kPa 25 mm

4.3.2 Subjective - comfort experience

The desired emotion for a car seat

To experience the emotion the participants wanted to elicit in the perfect car seat, they had to indicate which of the eight Emocards they would give the perfect car seat. The majority of the participants wanted to have a pleasant and slightly arousing emotion when sitting on the perfect seat (see Figure 4.6). The Emocard chosen by 71% of the participants shows a pleasant emotion, but medium level of arousal.

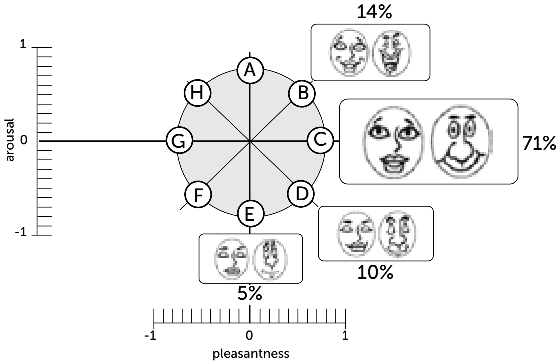

Figure 4.6 *Desired emotion for the perfect car seat.*

The overall elicited emotion per car seat

Participants rated the overall elicited emotion per seat. In Figure 4.7 the results are graphically presented for all seats, representing only the desired emotions for the perfect seat (see Figure 4.7). The intensity of the colour indicates the level of arousal (the darkest shade is the highest arousal). The most positive overall emotions are elicited by seat contour 1 (86%), followed by contour 2 (76%) and contour 3 (52%).

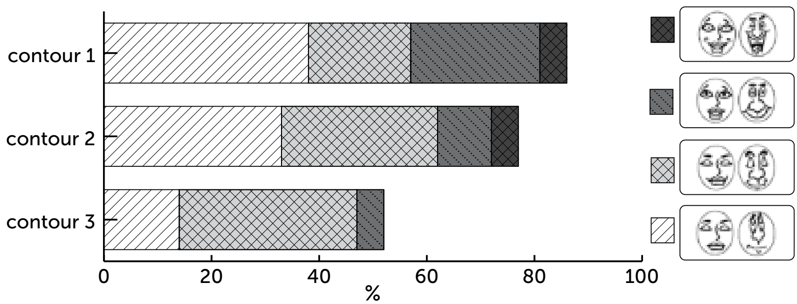

Figure 4.7 *The chosen overall emotion per seat where only the desired emotions for the perfect car seat are presented.*

Which contour is the most...?

Each seat had to be rated separately on the following feelings: comfortable, luxurious, sporty, protected, and relaxed. In Table 4.2 the results are shown of the seats that were significantly experienced as comfortable, protected, relaxed, sporty and luxurious.

Table 4.2 *Overview of significant relation between seat contour and experience keyword.*

	contour 1	**contour 2**	**contour 3**
Comfortable	No, p <= 0.159	No, p <= 0.520	No, p <= 0.348
Protected	No, p <= 0.561	No, p <= 0.980	**Yes, p <= 0.0305 No protected feeling**
Relaxed	No, p <= 1	No, p <= 0.173	No, p <= 0.298
Sporty	No, p <= 0.839	No, p <= 0.865	No, p <= 0.258
Luxurious	No, p <= 0.147	**Yes, p <= 0.0076 No luxurious feeling**	**Yes, p <= 0.00053 No luxurious feeling**

Table 4.3 *Overview of seat contour, overall rating and frequently mentioned remarks.*

	Positive remarks	**Negative remarks**
Contour 1	Lordosis is comfortable (not too much)	Headrest is too hard
	Nice, comfortable, soft foam material	Side support is too far away
Contour 2	Nice width in seat surface as well as backrest	The lordosis is too pronounced
	Comfortable side support	Too “flat”
Contour 3	Nice, big seat surface	Backrest is too hard
	Great contour	No or to little side support

Positive and negative remarks

In the questionnaire, participants could indicate the positive and negative seat aspects and optionally add comments. Table 4.3 gives an overview of the most often given remarks (positive and negative).

This seat belongs in....

Participants had to indicate, per seat, in which car (race car, sports car, convertible, luxury car, SUV, station wagon or van) they would expect to find the seat. They could choose only one car model type per seat evaluation. In Figure 4.8 the results are shown as follows: the darkest shade indicates a practical car (sport utility, station wagon and van), the middle shade the luxurious segment (convertible and luxury car) and the lightest shade the sporty segment (race and sports car). Contour 1 is expected in a luxurious car. Contour 2 has the least pronounced feeling of sports, luxury or practical car and contour 3 is mostly expected in luxurious and sportive cars (see Figure 4.8).

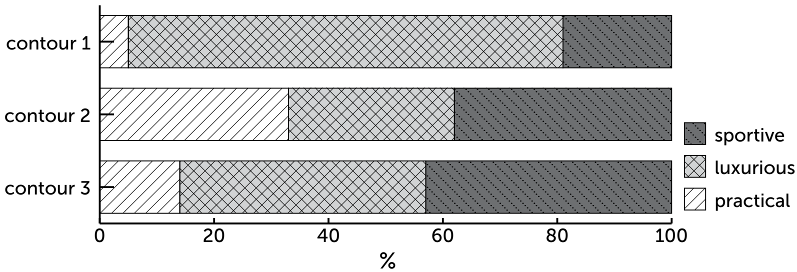

Figure 4.8 *Overview of car-seat contour per expected car segment.*

Desired seat

When the participants had to choose one of the tested seats for their own car, contour 1 (38%) was favoured followed by contour 2. Contour 3 was mentioned by 29% of the participants. Besides indicating which seat they would choose for their own car, they also had to rate this seat (1= very bad, 10 = excellent). Contour 1 received an average of 7.5, contour 2 a 6.0 and contour 3 a 6.8.

Most comfortable, luxurious sporty, protected and relaxed is seat...

After all seats were tested, participants had to indicate which of the seats they thought was most comfortable, luxurious, sporty, protected and relaxed. Figure 4.10 shows the results of a keyword representing contours of each seat. The results of this question where also tested for significance between seat aspect (seat width, backrest width and so on) and elicited feeling (comfortable, sporty and so on) (Table 4.4).

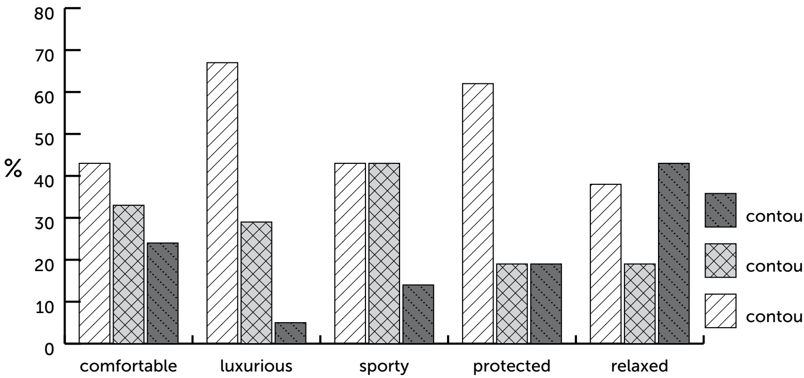

Figure 4.9 *Overview of mentioned seat contours per keyword.*

Table 4.4 *Overview of significant relation between seat aspects and elicited feeling.*

Segment	**Aspect**	**Significant (p<=0.05)**
Comfortable	Width	No, p <= 0.487
	Contour	No, p <= 0.622
	Steepness wings	No, p <= 0.487
	Hardness	No, p <= 0.358
Luxurious	Width	Yes, p <= 0.001
	Contour	No, p <= 0.109
	Steepness wings	Yes, p <= 0.001
	Hardness	Yes, p <= 0.002
Sporty	Width	Yes, p <= 0.010
	Contour	Yes, p <= 0.043
	Steepness wings	Yes, p <= 0.010
	Hardness	Yes, p <= 0.043
Protected	Width	No, p <= 0.198
	Steepness wings	No, p <= 0.198
	Contour	No, p <= 1.000
	Hardness	No, p <= 0.057
Relaxed	Width	No, p <= 0.198
	Contour	No, p <= 0.244
	Steepness wings	No, p <= 0.198
	Hardness	No, p <= 0.854

4.4 Discussion

There have been many papers in automotive magazines, the non-scientific literature, regarding studies about seat characteristics. In the scientific literature Harrison et al. (2000) defined seat and backrest angles, Reed et al. (1994) lumbar supports and Mergl (2006) and Zenk et al. (2012) defined the ideal pressure distribution. However, these scientific studies did not compare differences between classes of cars and did not focus on the tacit emotions.

4.4.1 How is the new car-seat concept contour emotionally rated in relation to existing car seats?

In comparison to the other seats tested in this research, the other two seats are rated slightly better than the new car-seat concept. Of all participants 52% had an overall positive feeling when sitting in this seat. In contrast, 29% had an overall (slightly) negative feeling mainly due to the lack of side support and because the seat was too hard. Of all participants, 19% had neither a pleasant nor a negative feeling, although the arousal level was high. This would mean that people were surprised by the actual feeling of the seat. Before they sat down, they expected to experience a different feeling. The concept seat was most often mentioned as most relaxing (43%) and second most mentioned as most protected (19%) of all seats tested. It is also important to realize that this study was conducted in a laboratory environment with German test subjects. In practice it is shown that side wings have a negative influence on the in- and egress of the vehicle. Even though this study did not focus on the in- and egress of the vehicle, it is important to realize that in a real setting the seats can be rated differently. In a comparison of drivers from different countries, Vercaygne (2008) found that Germans prefer wings more than drivers from other countries.

4.4.2 What seat design is experienced appropriate for what specific car segment?

The seat design with the softest foam and steepest wings (contour 1) is rated by most participants as luxurious and protected and is expected by most participants to appear in luxurious cars. The seat with the least prominent wings, hardest foam material, most contoured backrest and seat surface is expected in luxurious and sportive cars. The least contoured seat with the average wings, smallest width and average hardness is expected in all car segments; there is no specific car segment the participants would expect this seat in.

Overall it can be said that contour 1 elicits the preferred emotion by most participants. Of all the seats, this is the one with medium seat and backrest width and steepest seat and backrest wings.

From this research it is clear that only sporty and luxurious seats have specific design characteristics (strong side supports and rather hard foam material for sport seats and more than average width, less than average wing steepness and soft foam material for luxurious seats). More research is needed to address different aspects (position of headrest, additional features like massage) to find out what makes a car seat protected and what makes a seat suitable for more practical cars.

The only significant influence on the elicited emotion is the width, contour, steepness of wings and hardness for sporty seats, and luxurious feelings are influenced by the width, steepness of wings and hardness of the foam material. This study is clearly a first step to more detailed information on this subject. In a follow-up more participants should be tested and different aspects examined i.e., cushion stiffness.

A limitation of this research is that participants only had to sit in each seat for several minutes and that they could not adjust their seat. The importance of this limitation is described by Zenk et al. (2012) and Vink et al. (2012), who found differences in short term and long term comfort experiences. Also, effects of adjustments are shown by for instance Harrison et al. (2000). Ellegast et al. (2012) mention that many seat studies done in laboratory conditions have their limitations and that the subjects are often not familiarized with the chairs and had only a short time to become familiar with these. The focus in this paper was on the short term comfort. It could be that differences between seats increase in the long term. However, this paper reflects the situation in a showroom situation where people decide on the basis of short term feelings (and appearance). Follow-up studies should be conducted for differences in perceived emotion across the seats over a long term basis and in actual driving situations where the seats can be adjusted.

The fact that the seats were covered should not have influenced the results: all seats were leather seats and the covers were all white cotton sheets.

4.4.3 Conclusion

This study indicates that with this experimental set-up it is possible to discover differences between seats. This study shows that the new car-seat concept rated well on experienced relaxedness, even with the lack of side support. The most important findings are that hard seats with rather high side supports are rated sporty, seats that are softer are rated more luxurious.

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REFLECTION & IMPLICATIONS

The relationship between the model developed in Part A and the experiments in this part is discussed using the Why, How and What model of Hassenzahl (2011). The model of Hassenzahl is meant for designing experiences however these three questions are relevant for the studies in this thesis in the following manner:

- Why is this research carried out? The answer describes what is offered to users (drivers) and it describes the goal of the research.
- How should the research be designed to reach the goal? The answer to this question describes the relevant literature, information and decisions regarding the test set-up.
- What information was asked and what methods were used? The answer to this question describes the actual information that was gathered and what methods or tools were used.

Finally the implications for car interior development of the findings will be discussed per experiment. In Figure B.1 the studies presented in this part are placed within the developed model.

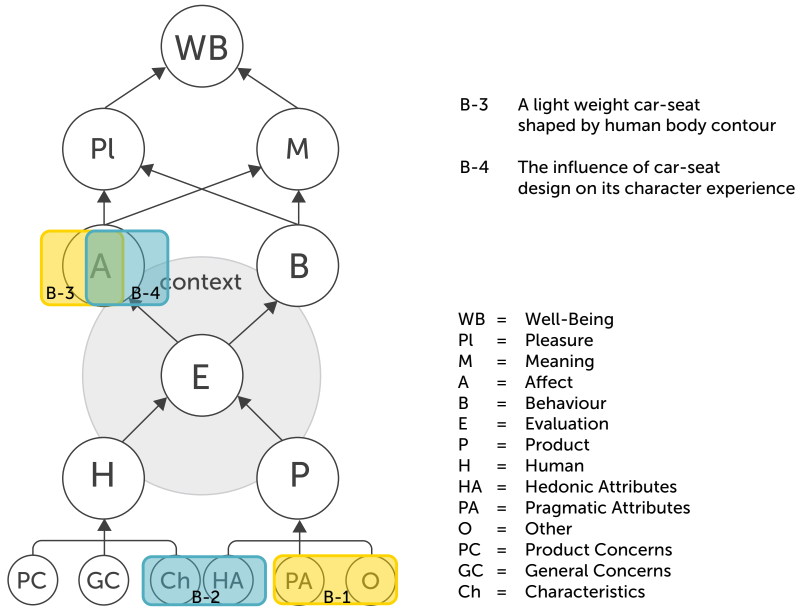

Figure B.1 *An overview of the theoretical model with the discussed studies included.*

B-3 A seat concept based on human contour

WHY – This project was initiated by the demand for weight reduction in the car interior (O in the model). Because seats contribute for a major part to the weight of the overall interior, the aim was to create a light-weight seat. An important aspect in this process was to concentrate on the improvement possibilities of the seat in terms of interaction and comfort and not only on reducing weight through different materials, or less material. The goal of the development process and the study was to offer a comfortable, light-weight seat.

HOW – This seat should be comfortable and according to Helander & Zhang (1997) and Zhang et al. (1996), this means creating a seat that elicits a feeling of luxury, safety and relaxation (the seat should have Hedonic Attributes, HA in the model). It was hypothesised that a seat contour following the human body contour closely would create such feelings and to develop a prototype the contours of people (Characteristics, Ch in the

model) was needed. To test the hypothesis feedback on the seat experience of the prototype by potential users was needed.
WHAT – Test subjects were invited in a laboratory and sat in a rescue mattress to define the seat shell contour. Objective data of the imprint (Ch in model B.1) and subjective data on the comfort experience with Emocards and semantic differentials were gathered (the output, A in model B.1). The scans made of the rescue mattress after subjects sat in it were scanned and a shell based on these contours was created digitally. A prototype based on this digital information was created and tested for comfort experience (A, in model B.1).

Implications
Firstly, this study showed that it is possible to define a body contour with the maximum variation between the subjects of only 3 mm. Secondly; this study indicates that a seat based on the body contour of 25 subjects is comparable to a standard BMW seat. Thirdly, the body contoured seat weighs almost 50% less than a conventional BMW seat. However, when the seat is further developed, extra weight can be expected due to safety measurements and crash regulations.

The implications of this study are not only interesting to the automotive industry but also other transportation industry can use this knowledge to create comfortable light weight seats. This is perhaps not directly linked to individual human concerns; however it contributes to the collective concern of a better, sustainable environment.

B-4 The influence of car seat design on its character experience

WHY – The studies described in Chapter three and four are closely related. However the aim of this research is different. The goal of this research was to find the relation between the seat contour (PA) and seat experience (A). This information was needed to enhance the driving experience. For example the seat in a sports car, like a BMW z4, should feel sporty to enhance the sportive feeling and drive style, a more luxurious and comfort focused car, like a BMW 5 series, should offer a comfortable and luxurious seat.

HOW – In order to find a relationship between different seat contours and their elicited feeling, seats with different contours (PA in model B.1) were used for comparison including the new seat concept. To discover the elicited feeling of the contours (A in model B.1) potential users had to rate the different seats.

WHAT – Subjects were invited into a laboratory where they sat in three different seats. To investigate the subjective feeling questionnaires including different keywords describing a feeling (comfortable, luxurious, relaxed, sporty etcetera) were used. The objective seat contour was measured and digitally compared to find a relation between contour and elicited feeling.

Implications

Results from this experiment show that the new light weight car-seat concept rated well on experienced relaxedness. The most important findings are that hard seats with rather high side supports are rated sporty and seats that are softer are rated more luxurious.

This information is important for several reasons. Firstly it is useful for the development of the seat concept based on human contour. It shows its weaknesses (it does not feel luxurious and sporty at all and the seat was overall rated slightly worse than the other seats in the experiment) and gives input on how to improve the seat; for a more luxurious car the concept should be made softer, if the concept is placed into a sports car it needs more side support.

Secondly, this information is used as input for another BMW project. In this project the seat adjusts itself based on drive style (based on information like; break force, speed, gear shifting). The information on how the seat should adapt is necessary e.g. if a narrow seat with side supports is experienced sporty, the concept seat could inflate itself and create more side support to react on a sportive driving style.

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PART C
THE STORY OF JOY

Experiments on the comfort and pleasure experience of passengers

This third part is about the passenger. Not much information is currently available on back seat comfort or pleasure experience. The following three chapters report of studies focused on improving the experience of the rear seat without adding extra weight to the car.

The goal of Part C is to present examples to make the rear seat more pleasurable without adversely affecting the weight of the car. The first study focuses on the users' expectations and wishes. It investigates what people want to do and how they sit during travel and leisure situations. The second chapter describes the development of a lightweight replacement for the entertainment system in the car and the development of one of the possibilities; projection of the road ahead onto the back of the front seat. The last study reports of an extension of the massage system. The current massage system in the BMW 7-series is a passive way of relaxation. The new system that is developed and subject to research is an active seat; here the passenger can control a game with his upper body. The effects of these movements are tested for muscle activity and user experience.

5
CHOSEN POSTURES DURING SPECIFIC SITTING ACTIVITIES

The following section is a published article in the journal Ergonomics.

Reference: Kamp, I., Kilincsoy, Ü., Vink, P. (2011). Chosen postures during specific sitting activities. *Ergonomics*, Vol. 54 (11), 1029-1042.

Abstract
This research study analysed the interaction between people's postures and activities while in semi-public/leisure situations and during transportation (journey by train). In addition, the use of small electronic devices received particular emphasis. Video recordings in German trains and photographs in Dutch semi-public spaces were analysed using a variation of Branton & Grayson's (An evaluation of train seats by observation of sitting behaviour. Ergonomics, 10 (1), 1967) postural targeting forms and photos. The analysis suggests a significant relationship between most activities and the position of the head, trunk and arms during transportation situations. The relationship during public situations is less straightforward. Watching, talking/discussing and reading were the most observed activities for the transportation and leisure situations combined. Surprisingly, differences in head, trunk, arm and leg postures were not significant when using small electronic devices. Important issues not considered in this study include the duration of the activities, the gender and age of observed subjects and the influence of the time of day. These are interesting issues to consider and include for future research.

Statement of Relevance: This study shows what activities people choose to carry out and their related postures when not forced to a specific task (e.g. driving). The results of this study can be used for designing comfortable seating in the transportation industry (car passenger, train, bus and aircraft seats) and semi-public/leisure spaces.

Keywords: postures; activities; seating; comfort; transport: tasks; train seats; sitting postures; small electronic devices

5.1 Introduction
In the early 1990s, advancing developments in information technology accelerated the accessibility of large amounts of information available to the general public on a high level. These developments impacted people and their activities on a high level as well. Twenty years ago, a common upgrade to laptops was a colour monitor (http://en.wikipedia.org/

wiki/Smartphone, accessed 8 August 2011), and, in 1992, the first Smartphone was introduced by IBM, 'Simon' (http://en.wikipedia.org/wiki/Laptop#History, accessed 8 August 2011).With the breakthrough of the World Wide Web, people became more mobile and accessible than ever. And the development continues, with increasing sales figures of mobile phones as well as smartphones, notebooks and other mobile devices, for example, the I-Pad (http://www.gartner.com/it/page.jsp?id¼1372013, accessed 8 August 2011). With new technological developments, the borders of previously strictly defined spaces are fading. The classical office is being redefined. The office space does not have to be in an office building, because office work can be performed at home or while travelling. The same concept applies to watching a television program or a movie; nowadays, people are not restricted to the living room or the cinema; people can choose to watch whatever they want, wherever they want. The demand is for more flexible and comfortable seating possibilities for these advanced information technologies. These new demands are also relevant for travel seats and for seats in semi-public/leisure spaces. Semi-public/leisure places may include large waiting areas at a train station, airport, inside and outside shopping areas and any space that provides some type of seating. Seating is also of importance for the automotive industry. This is especially true in combination with the introduction of different car power supplies. By adapting the interior to these changes and enabling a comfortable and flexible use of electronic devices offer a competitive advantage to the industry. The design of effective interiors requires an understanding of human behaviour. This is an opportunity to increase the experience and comfort for car passengers.

However, the long-term effects of these devices on natural behaviour is unknown, and further research is needed to define what activities people want to do, how they perform the activities and what the corresponding postures are associated with these activities. The purpose of this study is to discover what activities people want to do when travelling from A to B or in semi-public/leisure places and how they prefer to sit during these activities.

In the past, research has focused on postures and the effect of these postures during specific activities. Grandjean et al. (1983) conducted a field study to assess the preferences of visual display terminal (VDT) operators. Fujimaki & Mitsuya (2002) studied the seated posture for VDT work focusing on the advantages of a reclining, 'slumped', posture. Observations and research have been conducted on people's postures while watching television (Van Rosmalen et al. 2009) and laptop usage in non-desk settings (Gold et al. 2012a). Kolich (2003) investigated the differences between car occupant preferences and anthropometric accommodation, and Parkin et al. (1995) observed how drivers sit during driving tasks. Additionally, there are research studies on seat design for specific tasks. For example, Groenesteijn et al. (2009) focused on office chair controls and design in relation to office tasks, and Jacobs et al. (2011) investigated which notebook accessory (ergonomic chair, desktop monitor and notebook riser) combined with participatory ergonomics training would have the greatest impact on reducing self-reported discomfort in university students using notebooks. Bronkhorst & Krause (2005) observed the posture and activities of 1700 passengers in a commuter train when redesigning a new train seat. In the late 1960s, Branton & Grayson (1967) evaluated train seats and investigated whether people would sit differently due to the variation in seat design. Harrisson et al. (2000) reviewed the literature to determine an optimal automobile seat and spinal model of a driver; several seat characteristics like the vertical position of the lumbar support and its prominence are summarised in the literature review of Reed et al. (1994).

Unfortunately, these research studies were conducted prior the introduction of personal small electronic devices in the 1990s, or the studies were conducted in a private and rather unlimited space, like the research of Van Rosmalen et al. (2009). These studies are not realistic for a study in semi-public/leisure spaces, because there is little to no privacy in these spaces, for (public) transport situations as there is not an unlimited amount of space to move in. There is limited research focusing on the relationship between posture and activity; in most research, one of the two is taken as a given fact. Many researchers investigate the sitting postures and comfort experience of someone with a specific task like in the automotive industry where comfort research is done for driver seats and postures (e.g. Parkin et al. 1995). The driver of a car has a dedicated task (driving the car) and his posture is therefore derived from this activity. Because passengers do not have this dedicated task, their posture is different and this should be reflected in the seat design (Rebiffe 1980). Unfortunately, the car passengers have not been the primary subjects of research and their postures and activities are mostly dictated by their seats and limited space.

This research focuses on the postures of people during activities they choose themselves. This means the people were observed (by using video recordings and photographs) during situations while having some freedom of choosing their activities: during train travel, waiting for public transport, having a drink on a terrace and so on. They had some freedom in how to sit within the limitations of the available seating options in the surrounding environment. The situations in semi-public spaces have some resemblance to a passenger sitting in a car. The differences are important as well (the height of the seats, the available space, the dynamic character of a car travel), but, in both situations, people are visible to others and people have to be a bit flexible and creative in what they do and how they sit while doing it because they are not at home or in an office where they have the option for more movement and accessibility to more devices and power sources for the devices at their disposal.

Research questions:

1. What are the primary activities of people on train journeys and in semi-public places/leisure situations and what is the chosen posture during these primary activities?
2. Is there a difference between activities and postures in dynamic versus static situations?
3. When people use mobile devices, what is the most frequently observed posture?
4. How can the results of this study contribute to the design of future car interiors?

5.2 Methods

5.2.1 Definitions

Postures

Before the actual observations took place for this study, postures were defined and classified in order to record them quickly and easily during the observational research. For this purpose, the rapid coding technique was used based on the coding technique of Branton & Grayson (1967) in their study, 'Evaluation of train seats by observation of sitting behaviour'. Each posture was represented by a set of four figures. The first figure refers to the position of the head, the second to the trunk, the third to the arms and the fourth to the legs. The denotation of the positions listed in Table 5.1 is slightly different from the Branton & Grayson model due to the differences in seat design regarding available support and shape of seat cushion, back and headrest.

Table 5.1 *Denotation of postural positions.*

	Description	**Nr.**
Head	Free of support	1
	Against headrest	2
	Supported by hands	3
Trunk	Free from backrest	1
	Against backrest	2
	Lounging (slumped back)	3
Arms	Free from armrest	1
	Upon armrest	2
	Only elbow	3
Legs	Free, both feet on floor	1
	Crossed	2
	Other	3

Activities

First, a pilot study was conducted to define the activities. The researchers walked through train carriages writing down the observed activities and the frequency of these activities. The results of the pilot study determined the activities for the study. During actual testing, the most observed activities (see Table 5.2)were listed on a tally sheet. In order to analyse the data, the activities were grouped into low-level, medium-level and high-level activities. Low-level activities included sleeping, relaxing and watching/observing. Medium-level activities included reading, talking/discussing and eating/drinking. The use of small electronic devices and working/using larger electronic devices were defined as high-level activities.

Table 5.2 *Activity and number of observed individuals during train journeys and semi-public/leisure situations.*

Level	Activity	Train	Leisure
LOW	Sleeping	78	0
	Relaxing	133	39
	Watching / observing	49	36
MEDIUM	Reading	112	10
	Talking / discussing	134	35
	Eating / drinking	18	32
HIGH	Using small electronic devices (e.g. Smart phones)	22	11
	Working / Using larger electronic devices (e.g. Laptop)	22	12
	Total	568	175

Samples and recording

The sitting behaviour of 743 different people (adults and children) was recorded by two techniques to estimate the characteristics of the human sitting postures in relation to their activities. The first technique involved video recording 568 seated individuals on a train ride in Germany. The second technique was conducted in the Netherlands and used photographs of 175 individuals in different sitting situations by a student of the graphic academy who had the assignment to photograph people in waiting and leisure areas. The only requirement for selecting the sitting situations was that the sitting situation could not be at home or in a private atmosphere. Both the video recordings and photographs were made unobtrusively as not to influence the observed individuals.

These two techniques of observation were chosen with the assumption that humans tend to assume postures that minimize the associated amount of muscle effort, i.e. people prefer to be in a relaxed and comfortable position. People will make themselves as comfortable as possible in a given situation, depending on the environment, available seating and desired activity. A pilot run during a train journey was done prior to the observations to define the activities and to confirm if the method proposed would work well. Table 5.2 lists the activities and number of subjects.

Data analysis

Postural data derived from video recordings and images were subsequently recorded on tally sheets. The postures per body part were printed on the left side of the tally sheet and, on the top of the sheet, the list of activities are defined (see Figure 5.1). The observers had to observe every individual and mark the corresponding cell. For every individual, four checks under the observed activity were needed (e.g., a person reading a book while leaning with his head against the headrest, his back against the backrest, using the armrests and his feet crossed would receive checks in the column 'reading' and in the cells 2222). It was possible to compare the results of the two techniques, because the photographs were analysed using the same tally sheet.

After analysing the recordings with the tally sheet, the data were entered into SPSS (version 17.0.0, 2008). The chi-squared test was used to find significant relationships between the activities and postures ($p < 5$ 0.05), because the level of measurement consists of categorical and nominal variables (individuals are divided into distinct categories and there are more than two categories).

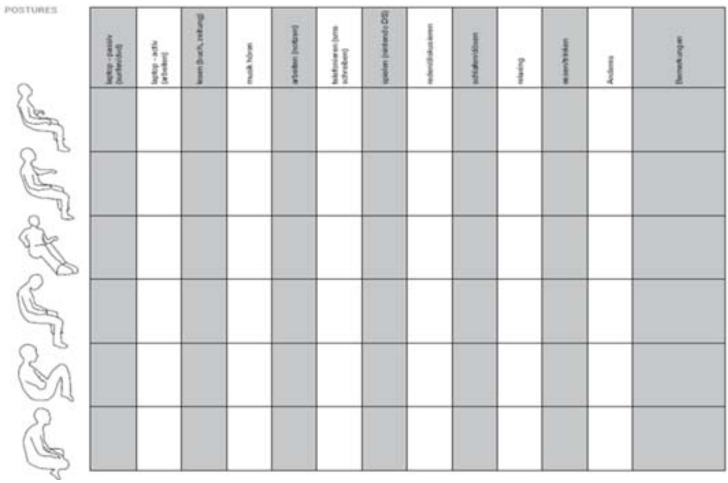

Figure 5.1 *Example of the tally sheet used to analyse train recordings.*

5.3 Results

5.3.1 Activities

Most observed activities during train journeys

Table 5.3 is an overview of the observed activities during the train journeys. Talking and discussing was primary and most often observed (23.6%), closely followed by relaxing (23.4%) and reading (19.7%).

Table 5.3 *The most observed activities during the train journey.*

	Talking / discussing	Relaxing	Reading	Sleeping	Watching	Using small elec. Dev.	Working – using larger elec. dev.	Eating / drinking
%	23.6	23.4	19.7	13.7	8.6	3.9	3.9	3.2

Most observed activities during leisure situations

Table 5.4 is an overview of the observed activities during semi-public/leisure situations. Relaxing was the most often observed activity (22.3%), followed by watching (20.6%) and talking/discussing (20.0%). Sleeping was not observed.

Table 5.4 *The most observed activities during semi-public/leisure situations.*

	Relaxing	Watching	Talking / discuss-ing	Eating / drinking	Working – using larger elec. dev.	Using small elec. Dev.	Reading	Sleeping
%	22.3	20.6	20.0	18.3	6.9	6.3	5.7	0.0

Comparison of activities during train journeys and leisure situations

The most striking difference between the train journeys and semi-public/leisure spaces is that sleeping was not observed during semi-public/leisure situations. Talking/discussing activities were commonly observed during both train journeys and semi-public/leisure situations. This activity was primary (23.6%) for train journeys, yet third in frequency (20.0%) during semi-public/leisure situations. During train journeys, relaxing was second (23.4%), although it was primary (22.3%) during semi-public/leisure situations. Watching was second in semi-public/leisure situations but not one of the top three activities during train journeys. Instead of watching, reading was one of the top three activities during train journeys. However, reading did not appear in the top three for semi-public/leisure situations.

Chi-squared tests of the raw data for the observed activities showed that the differences between travelling by train and semi-public/leisure situations were significant in some cases. Sleeping, as already mentioned, was not observed during semi-public/leisure situations. During train journeys, 78 individuals were observed sleeping. The fact that no one sleeps in semi-public/leisure situations is highly significant ($p < 0.001$), and, for train journeys, the chance that someone does sleep is significant ($p < 0.05$). In semi public/leisure situations, it can be expected that people are just watching ($p < 0.001$). Watching is not to be expected by people travelling by train ($p < 0.05$). Reading is positively significant for train travellers ($p < 0.05$) however, negatively significant for semi public/leisure situations ($p < 0.001$). There is also a substantial correlation for eating and/or drinking during train journeys and in semi-public/leisure situations. However, during train journeys, a negative significant relationship was found. It is expected that individuals will not eat and/or drink on a train ($p < 0.001$), whereas, in semi-public/leisure situations, people are expected to eat and/or drink ($p < 0.001$). Relaxing, talking/discussing, working/using larger electronic devices and using small electronic devices did not have a significant relationship in either train journeys or semi public/leisure situations. There is a significant relationship between the situation (train journeys or semi-public/leisure situations) and the activity. However, there is a medium association between the situation and the performed activity (Cramer's V = 0.38).

5.3.2 Postures

Most observed postures during train journeys

Table 5.5 is an overview of the observed postures during train journeys. Posture 1211 (head free of support, trunk against the backrest, arms free from armrest and legs free with both feet on the floor, see Figure 5.2) was observed most with 40%, followed by 2321, head against the headrest, back in a slumped position, arms upon the armrest and legs free with both feet on the floor (15.1%), and 1212, head free of support, trunk against the backrest, arms free from armrest and legs crossed (12.5%).

Table 5.5 *An overview of the 10 observed postures during the train journeys in percentages.*

	1211	2321	1212	2221	2231	3333	1111	1112	2313	1233
%	40.0	15.1	12.5	10.9	8.3	6.5	5.1	0.5	0.7	0.4

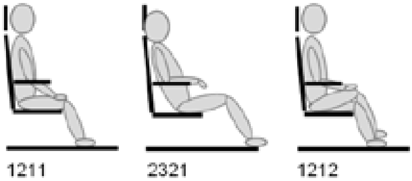

Figure 5.2 *The three most observed postures during train journeys.*

Most observed postures during leisure situations

Table 5.6 shows the postures observed in semi-public/leisure situations. The first remarkable fact is that there are more postures observed; during train journeys of all theoretical possible postures (64), only 10 were observed; however, during semi-public leisure situations, 16 different postures were observed. The most frequently observed postures were 1111, head free of support, trunk free from backrest, arms free from armrest and legs free with both feet on the floor (32.0%), followed by 1211, head free of support, trunk against the backrest, arms free from armrest and legs free with both feet on the floor (19.4%), and 1212, head free of support, trunk against the backrest, arms free from armrest and legs crossed (15.4%, see Figure 5.3).

Table 5.6 *An overview of the observed postures during semi-public/leisure situations in percentages.*

	1111	1211	1212	1222	1232	1332	1121	1221	1233	3333	2332	1322	1323	1331	1333	3332
%	32.0	19.4	15.4	9.1	8.0	6.3	1.7	1.7	1.1	1.1	1.1	0.6	0.6	0.6	0.6	0.6

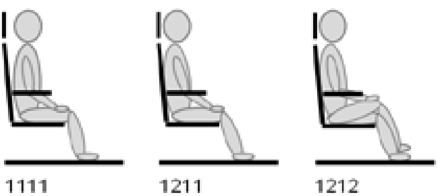

Figure 5.3 *The three most observed postures during semi public/leisure situations.*

Comparison of postures during train journeys and leisure situations

Table 5.7 is an overview (in percentages) of the observed posture of head, trunk, arms and legs for both the train journey and the semi-public/leisure situations. Included in this overview is the level of significance.

Table 5.7 *An overview of head, trunk, arm and leg postures during train journeys and semi-public/leisure situations.*

		Train (%)	Leisure (%)	Total (%)
Head	1	58.5-**	97.1***	67.6
	2	35.0***	1.1-***	27.1
	3	6.5	1.7-*	5.4
Trunk	1	5.6-***	35.4***	12.7
	2	72.0	53.1-*	67.6
	3	22.4	11.4-*	19.8
Arms	1	58.8	65.1	60.3
	2	26.1	15.4-*	23.6
	3	15.1	19.4	16.2
Legs	1	79.4	54.9-**	73.6
	2	13.0-***	41.7***	19.8
	3	7.6	3.4	6.6

During train journeys, the head is most likely supported ($p < 0.01$), against the headrest ($p < 0.001$), the trunk is against the backrest ($p < 0.001$) and the legs are most likely not crossed ($p < 0.001$). During leisure situations, the head is free from support ($p < 0.001$) and not leaning against a headrest ($p < 0.001$) or is supported by the hands ($p < 0.05$). The trunk is free from support during leisure situations ($p < 0.001$), and it is not expected that the trunk is leaning against a backrest or is slumped. In this study, in the leisure situations, there was no backrest available most of the time; therefore, people were bent forward or sitting with the back straight and upright ($p < 0.05$). The arms are not supported by armrests ($p < 0.05$), the legs are most likely to be crossed ($p < 0.001$), and both feet are not on the floor ($p < 0.01$). Overall, the position of the head in relation to the situation is significant; however, there is a moderate association between the situation and the position of the head (Cramer's V = 0.352). The trunk position and the leg position both depend significantly on the situation; again there is a medium association, Cramer's V = 0.383 and 0.307, respectively.

5.3.3 Postures in relation to activities

Train journeys

The relationship between postures and activities for the train observations are represented in Figure 5.4. The light shading indicates a low activity level (activities, e.g. sleeping, relaxing and watching), the darker shading represents medium activity levels (activities, e.g. talking/discussing and eating/drinking) and the darkest shade presents high activity levels (activities, e.g. using small and larger electronic devices).

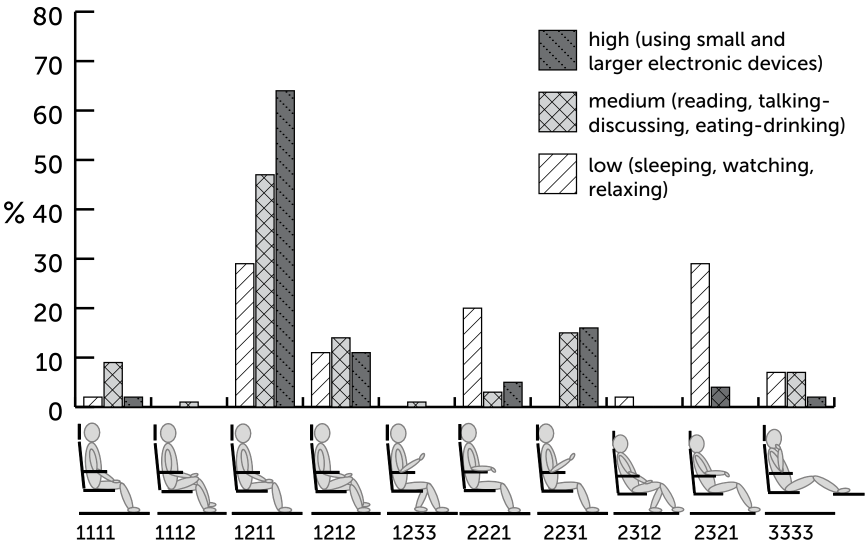

Figure 5.4 *A graph representing postures and activities during train journeys.*

Figure 5.4 shows that postures 2321 (29.2% of all individuals who were doing a low-level activity), 1211 (28.8% of all individuals who were doing a low-level activity) and 2221 (20.0% of all individuals who were doing a low-level activity) were observed when people did activities at a low level. For medium-level activities, the most observed posture was 1211 (47.0% of all individuals who were doing a medium-level activity), followed by 2231 (14.8% of all individuals who were doing a medium-level activity) and 1212 (14.0% of all individuals who were doing a medium-level activity). The high-level activities were mostly carried out in posture 1211 (63.6% of all individuals who were doing a high-level activity), 2231 (15.9% of all individuals who were doing a high-level activity) and 1212 (11.4% of all individuals who were doing a high-level activity).

Leisure situations

Figure 5.5 represents the relationship between postures and activities during leisure situations. The shading in Figure 5.5 is the same as in Figure 5.4.

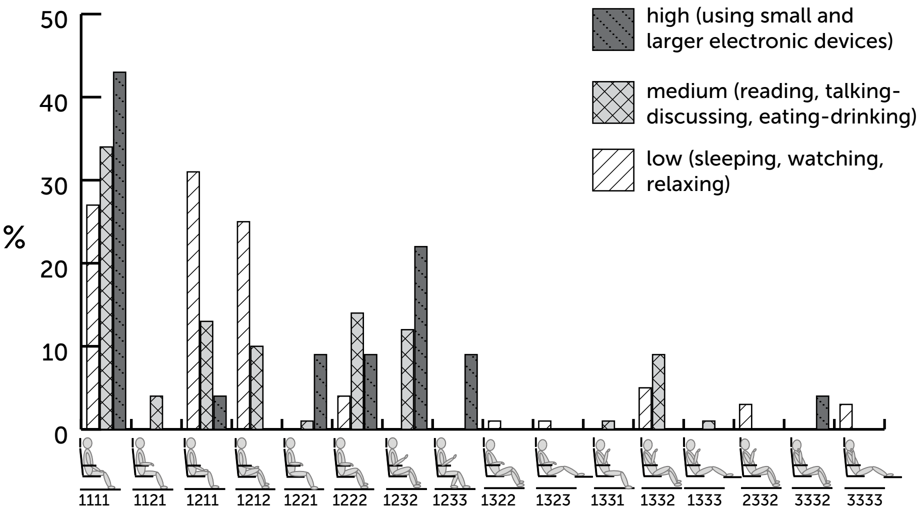

Figure 5.5 *A graph representing postures and activities during semi-public/leisure situations.*

Figure 5.5 shows that postures 1211 (30.7%), 1111 (26.7%) and 1212 (25.3%) were observed among all individuals doing a low-level activity. Among all individuals who did medium-level activities, the most observed postures were 1111 (33.8%), 1222 (14.3%) and 1211 (13.0%). The high-level activities were mostly carried out in postures 1111 (43.5% of all individuals who were doing a high-level activity), 1232 (21.7% of all individuals who were doing a high-level activity), 1221 and 1222 (both 8.7% of all individuals who were doing a high-level activity).

Travel and leisure combined

When the train journey and the semi-public/leisure situations are combined and the counts below 5 are omitted, the postures during low, medium and high activities become clearer (see Table 5.8 for the values and Figure 5.6 for the graphical representation).

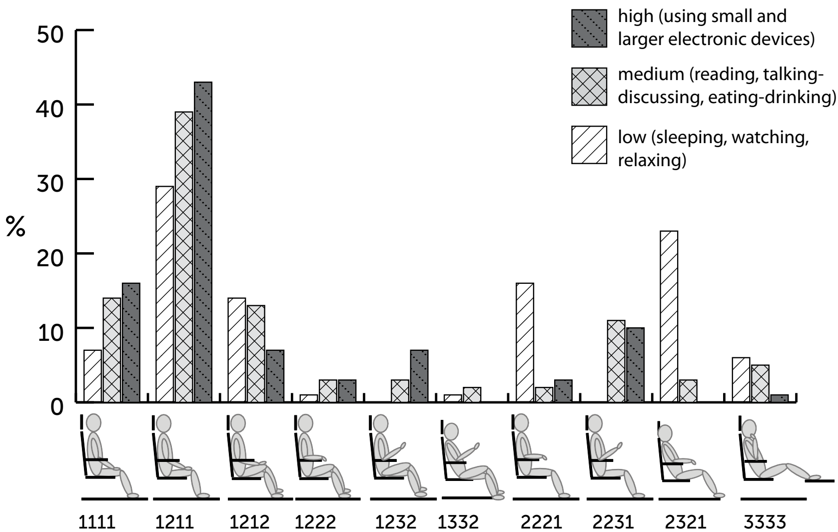

Figure 5.6 *A graph representing postures and activities during semi-public and train journey situations.*

Overall, it can be said that posture 1211 (head free of support, trunk against the backrest, arms free from armrest and legs free with both feet on the floor) is seen when people are involved in high- and medium-level activities. For low-level activities, postures 1211 (head free of support, trunk against the backrest, arms free from armrest and legs free with both feet on the floor) and 2321 (head against headrest, back in a slumped position, arms upon the armrest and legs free with both feet on the floor) are preferred.

Table 5.8 *An overview of the observed postures and low, medium and high levels of activity in percentages.*

Posture	Low (%)	Medium (%)	High (%)
1111	7.5	14.4	16.4
1211	29.3	39.3	43.3
1212	14.3	13.2	7.5
1222	0.9	3.2	3.0
1232	0.0	2.6	7.5
1332	1.2	2.1	0.0
2221	15.5	2.3	3.0
2231	0.3	11.4	10.4
2321	22.7	2.9	0.0
3333	6.0	5.3	1.5

5.3.4 Significance between postures and activities

Train journeys

With the chi-squared tests, some postures are highly significant coupled with activities (negative, e.g. the specific posture is not to be expected with the specific activity or positive, e.g. the posture is to be expected while doing the specific activity). In Table 5.9, all significant relationships are presented for the observations during the train journeys. Table 5.9 shows that the leg position varied most among the train travellers. Also, when using small electronic devices, no significance in posture was found. For sleeping, relaxing, talking/discussing and working with larger electronically devices, at least five aspects of the postures were significant.

Overall, it can be said that there is a moderate/relatively strong association between the activity performed and position of the head (Cramer's V = 0.37), the trunk (Cramer's V = 0.37) and the arm (Cramer's V = 0.49). The position of the feet does not have a significant relationship with the activity.

Table 5.9 *An overview of significant relationships between postures and activities for train journeys only.*

LEVEL		LOW			MEDIUM			HIGH	
		Sleeping	**Relaxing**	**Watching**	**Reading**	**Talking / discuss-ing**	**Eating / drinking**	**Using small elec. Dev.**	**Working – using larger elec. dev.**
Head	1	0.001*	0.001*	--	--	0.001	--	--	0.05
	2	0.001	0.001	--	--	0.001*	--	--	0.05*
	3	--	--	--	--	--	0.01	--	--
Trunk	1	0.05*	0.01*	--	--	0.001	0.01	--	--
	2	0.01*	--	--	0.05	--	--	--	--
	3	0.001	0.001	0.01*	0.001*	0.05*	--	--	0.05*
Arms	1	0.001*	0.01*	0.01	--	0.001	--	--	0.05
	2	0.001	0.001	0.01*	0.001*	0.001*	--	--	0.05*
	3	0.05*	--	0.05*	0.001	0.05*	--	--	--
Legs	1	--	--	--	--	--	--	--	--
	2	--	--	--	--	--	--	--	--
	3	--	--	--	--	--	0.05	--	--

Leisure situations

Table 5.10 shows all the significant relationships for the observations during the leisure situations. Table 5.10 shows the less significant relationships applied when looking at the train journeys. One significant relationship was found for relaxing, watching, using small electronically devices and eating/drinking.

Table 5.10 *An overview of significance postures and activities for semi-public/leisure situations only.*

LEVEL		LOW			MEDIUM			HIGH	
		Sleeping	**Relaxing**	**Watching**	**Reading**	**Talking / discuss-ing**	**Eating / drinking**	**Using small elec. Dev.**	**Working – using larger elec. dev.**
Head	1		--	--	--	--	--	--	--
	2		0.05	--	--	--	--	--	--
	3		--	--	--	--	--	--	--
Trunk	1		0.001*	0.01	--	--	0.05	--	--
	2		--	--	--	--	--	--	--
	3		0.05	--	--	--	--	--	--
Arms	1		--	--	--	--	--	--	--
	2		--	--	--	--	--	--	--
	3		--	0.01*	--	--	--	0.05	--
Legs	1		--	--	--	--	--	--	--
	2		--	--	--	--	--	--	--
	3		--	--	--	--	--	0.01	--

Travel and leisure combined

When combining the raw data of the train journeys and the leisure situations, significant relationships were found (see Table 5.11). Remarkably, the position of the legs is the least significant with different activities. Sleeping, relaxing, watching and reading have at least five significant relationships with the postures. In Figure 5.7, the postures for low-level ac-

tivities (sleeping, relaxing and watching/reading) are presented.
In this case, it can be said that there is a moderate/relatively strong association between the activity performed and position of the head (Cramer's V = 0.37), the trunk (Cramer's V = 0.40) and the arm (Cramer's V = 0.425). The position of the feet does not have a significant relationship with the activity.

Table 5.11 *An overview of significance postures and activities for train journeys and semi-public/leisure situations.*

LEVEL		LOW			MEDIUM			HIGH	
		Sleeping	**Relaxing**	**Watching**	**Reading**	**Talking / discussing**	**Eating / drinking**	**Using small elec. Dev.**	**Working – using larger elec. dev.**
Head	1	0.001*	0.01*	0.01	--	0.01	--	--	--
	2	0.001	0.001	0.001*	--	0.001*	0.01*	--	0.05*
	3	--	0.05	0.05*	--	--	--	--	--
Trunk	1	0.01*	0.001*	0.001	0.01*	--	0.001	--	--
	2	0.05*	--	--	0.01	--	0.05*	--	--
	3	0.001	0.001	0.001*	0.001*	--	--	0.05*	0.05*
Arms	1	0.001*	0.05*	0.001	--	0.001	--	--	--
	2	0.001	0.001	0.01*	0.001*	0.001*	--	0.05*	--
	3	0.05*	--	0.001*	0.001	--	--	0.05	--
Legs	1	--	--	--	--	--	--	--	--
	2	0.01*	--	--	--	--	--	--	--
	3	--	0.05	--	--	--	--	--	--

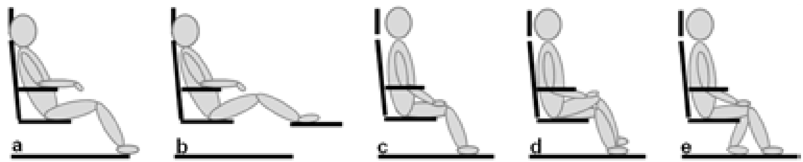

Figure 5.7 *Significant postures for sleeping (a and b) and watching (c/d/e).*

5.4 Discussion

5.4.1 Research questions

What are the primary activities of people on train journeys and in semi-public places/leisure situations and what is the chosen posture during these primary activities?

This research study was conducted to provide input for car interior design. For this purpose, the first question to be answered is what activities do people want to carry out when they are travelling by train and in semi-public/leisure spaces? As described in the introduction, car interior seating is comparable to semi-public/leisure space seating in terms of visibility to other people (inside, as well as outside the car), flexibility and improvisation that is asked of people in both sitting situations. For this study, the most observed activities for train journeys and semi-public/leisure situations overall are watching, talking/discussing and reading (see Figure 5.8). In looking at the activities performed during train travel only, the most observed activity was talking and discussing, closely followed by relaxing and reading. In their research, Khan & Sundström (2007) asked train passengers what kind of activities they preferred and how long did it take to do those preferred activities. The results showed the average journey took 72 minutes and 42 passengers spent an average of 44 minutes on sleeping/napping.

Additionally, 263 passengers spent 40 minutes reading and 79 passengers spent 35 minutes of their time chatting with other passengers. Although this article had a different research approach, both studies found similar results: talking/discussing, reading and relaxing were the most observed activities during train journeys. The research of Krishna

Kant (2007) showed that the top three activities on trains in India were talking to fellow passengers, no particular activity (interpreted as relaxing) and reading. Remarkably, sleeping/napping was not one of the three most observed activities in their study, surprising with the average train journey taking 107.6 minutes.

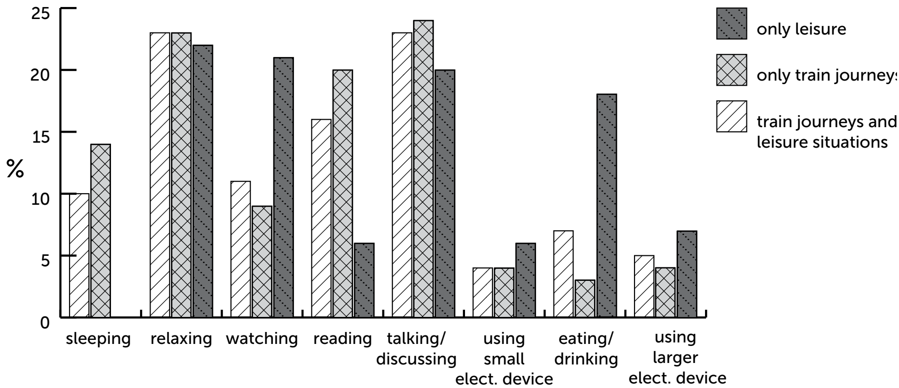

Figure 5.8 *An overview of the most observed activities during train journeys and semi-public/leisure situations, only train journeys and only semi-public/leisure situations.*

For this study, the most observed corresponding postures while watching are (see Figure 5.9) 1211, 2321 and 2221. For talking/discussing, the top three is 1211, 1111 and 1211. Finally, for reading, the results are 1211, 2231 and 1212. There are few studies on the relationship between postures and activities, although Van Rosmalen et al. (2009) researched and tested a new lounge chair concept. The activities during the research are comparable to the low activity level activities in this article. In the Van Rosmalen study, the concept seat supported head, back, arms and feet. This compares with the results on the postures in this article that the most observed postures during low-level activities are 1211, 2321 and 2221. Apart from 1211 (where only the back is supported), the other two postures indicate that the observant preferred as much support as possible (headrest, back support and armrests). Bronkhorst & Krause (2005) observed the postures of passengers riding on commuter trains but did not link postures with activities. When the results of this article are compared with the most observed postures of Bronkhorst & Krause (2005), it is clear that train passengers prefer to be supported by the backrest in both studies. Branton & Grayson (1967) observed the postures as well (again, not in relationship with the activities). The most observed postures in the Branton & Grayson study were the head was free from support, the trunk was supported, the arms supported and the legs free or crossed. The results in this article are comparable to the Branton & Grayson study, in that most of the postures existed of the head free from support, the back supported and the feet 'free'; in this study, most individuals did not support their arms with the armrests. For the design of car interiors, it is interesting to know the most observed postures, overall. Thus, independent of the activities, the most observed postures of people during train journeys and semi-public/leisure situations combined can be seen in Table 5.12 and Figures 5.2 and 5.3.

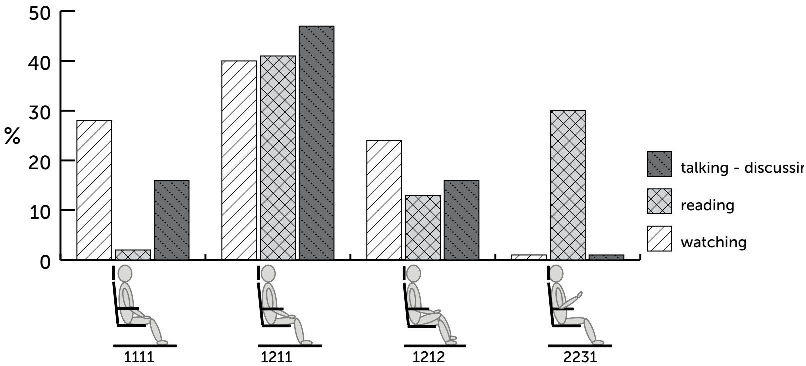

Figure 5.9 *An overview of the most observed corresponding postures for watching, reading and talking/discussing.*

Table 5.12 *An overview of most observed postures and percentages.*

Postures	Percentages
1211	35.1%
1212	13.2%
2321	11.6%

Is there a difference between activities and postures in dynamic versus static situations?

The observations for this article were conducted in two different situations. The first group of observed individuals were video recorded on regional trains in Germany, and the second group of observed people were photographed while sitting in semi-public/leisure spaces and situations in the Netherlands.

Train travel is a dynamic experience whereas semi-public/leisure situations are static. It is interesting for automotive industry to examine the difference and similarities between the dynamic and the static presented in the two observations. Car travel is similar to train travel especially for a car passenger as it is a dynamic situation; therefore, the activities and postures of train travel are interesting to the automotive industry as well. During semi-public/leisure activities, however, people choose activities where they have relatively more freedom of movement than is possible on a train journey or in a car. There are space- and movement limitations for car interior design, and people are – most of the time – in a dynamic situation. However, with the possibility of changing the car packaging options, it is interesting to look at a broader spectrum of postures and to later specify what activities and postures are possible for future car interiors. Therefore, the differences between both situations, the dynamic and the static, are summarized here.

While travelling by train, sleeping and reading were found significantly more often than during semi-public/leisure situations. Train travellers are not expected to just watch or eat and drink. The fact that people on trains are not just watching could be explained by the movement and constant rhythm of the train that often makes travellers sleepy. From this observation, the activity category sleeping was identified for the study. Additionally, the outside views may be uninteresting and/or fast changing and people are unlikely to observe the outside landscape. The category for this observation is considered relaxing for this study. It may be an unexpected finding that eating and drinking is not a likely activity for train travellers. This can be explained by the fact that the observations were done for a very brief moment in time; the observers walked through the train aisles and recorded 'on the go'. Khan & Sundström (2007) found in their study that eating and drinking was mentioned by

103 participants, but over a relatively short period of time in comparison with other mentioned activities. Therefore, people who take a sip out of a bottle or eat a candy bar are often not recorded in this study. Thus, eating and drinking over a longer period of time is not likely for commuters and train travellers on rather short trips. It is possible that people are not eating and drinking due to the dynamic character of the train travel; Corbridge & Griffin (1991) found that the chance for spilling drinks or food is higher in a dynamic situation especially the sinusoidal component with duration of 10 s, with frequencies in the range 3.15–5.0 Hz. The fact that the space is shared with strangers results in a limited amount of personal space and may also contribute to a limited amount of people eating in a train; or they may not eat and drink as not to disturb others with the smell of food or possible drink spillage. When people are in confined space, coughs and sneezes of strangers do not encourage people to eat or drink. This is partly in line with the activities (sleeping/napping, listening to music/talking/staring, reading a newspaper, reading a book or magazine and writing/typing). Bronkhorst & Krause (2005) found in their observation of activities on commuter trains. Eating and drinking was not found at all in that study.

In a static, semi-public/leisure situation, people tend not to sleep, which is sensible because sleeping is considered a private activity. Besides, most of the available seats found in the semi-public/leisure situations are not appropriate for a comfortable sleeping posture. During semi-public/leisure activities, a substantial amount of time was spent just watching. These findings are consistent, in that users would sometimes sleep on the train, but not in semi-public/leisure spaces. Users of semi-public/leisure environments are also considerably less prone to read. This could be explained by the expected duration of a train journey versus the unexpected character of a semi-public/leisure activity. When travelling by train, the duration of the journey is generally known ahead of time. However, in a static situation or semi-public/leisure activity, time cannot be as easily determined. There may be an unexpected delay, e.g. waiting for a bus or a social appointment. A cultural factor could prevent a person from reading as well, e.g. when joining a good friend sitting on a terrace, a person probably will not start reading a book. On the other hand, eating and drinking is an expected semi-public/leisure activity. In both the train journey and the semi-public/leisure situations, the observations were captured over a short period of time. Although the observation time was short, people in the semi-public/leisure situations were observed to sit down and eat a sandwich or have a drink.

When looking at the relationship between activities and postures during static semi-public/leisure situations, there is little significance for the position of head, trunk, arms and legs. This may be due to the various seating possibilities while observing the semi-public/leisure situations. The seats were all the same in the trains; each had a headrest, backrest and armrest. Also, the height of the seat and the length of the backrest were equal. For the semi-public/leisure situations, this was not the case; the seating was varied and different. People were observed sitting on benches and on other seats that did not have a headrest or armrests and so on. Not all people could sit the same way because the seats were not the same, and, therefore, their postures were varied and differed.

When people use mobile devices what is the most frequently observed posture?

When people were using mobile devices the most observed posture was 1211 (43.3%, see Figure 5.2). A remarkable observation occurred during the analysis for the train journeys. There was some significant relationship between activity and posture for most activities. However, this was not the case for the use of small electronic devices. This is an important conclusion because it was expected that the use of small to medium mobile devices would be one of the higher activities performed in these situations. The future forecasts a higher usage of these devices when looking at the increasing sales figures of smartphones, pads, notebooks and so on. Further research is needed to evaluate the relationship between sitting postures while using these devices and discomfort. The primary focus should be whether posture matter or not when using small electronic devices and if there are different activities that call for different postures. For this research instead of low-, medium- and high-level activities, the classification of McLeod & Griffin (1986) would be more useful. McLeod & Griffin (1986) distinctly classify three types of tasks as well; however, the tasks are divided as follows: Type A tasks, in which the 'subject controls the hand freely in space: examples include reaching and pointing. In some Type A tasks, the hand may hold an object which will itself be affected by motion, such as fluid in a cup'. Type B tasks, in which the 'subject's hand manipulates a control at a fixed position attached to the vibrating structure: examples include the operation of joysticks and knobs'. And, finally, Type C tasks, in which the 'subject performs a single, discrete operation, such as changing a switch setting or pressing a button'. This type of task may often be preceded by a Type A task, in which the hand moves through space in order to locate the control (e.g. Type A/low level; reading an electronic book, Type B/middle-level activity; playing a game and Type C/high-level activity; typing/working). For medium mobile devices, the trunk was in a slumped position. This corresponds with the research of Khan & Sundström (2007), stating that people put their books, writing materials and portable computers on their laps while using them due to vibrations during train transport. Bhiwapurkar et al. (2010) found that when using the laptop in a train on a table, typing was more difficult then when the laptop was placed on a person's actual lap. However, this does not automatically mean a comfortable posture; several researchers discovered that laptop computer usage (Moffet et al. 2002; Seghers et al. 2003; Asundi et al. 2010) and small mobile device usage (Gold et al. 2012b) increases downwards head tilt which increases the subjective-reported discomfort during whole body vibrations (Rahmatalla & Deshaw 2011).

Recommendations for further research

Because of practical reasons, a few important issues were not considered in this study. These issues include the influence of the duration of time, the gender and age of the observed test subjects and the influence of the time of day. The goal of this study is to give direction and guidelines for car interiors on a group level. However, the specific differences between human characteristics and conditions often influence the design. Reitenbach et al. (2009) showed, for instance, that smaller people do not like a standard office seat. The seat pan is often too deep and the large area influences the way they sit on the seat. The relationship between human characteristics, test conditions and posture is an interesting subject for further research that could lead to guidelines for adjustability features.

5.5 Conclusion

This research was a first approach to discover the interaction between desired activities and chosen postures in train transportation and semi-public/leisure spaces. Important issues that were not considered in this study include the interactions between the duration of activities, the gender and age of the observed subjects and the influence of the time of day. These specific issues call for additional research. In order to translate these activities and related postures into car interiors, some additional research has to be done. The vibrations and sometimes unexpected movements influence the possible activities in a car. As several researchers have shown (Corbridge & Griffin, 1991; Khan & Sundström, 2004, 2007, Krishna Kant, 2007; Bhiwapurkar et al. 2010), a dynamic situation often influences the chosen activities. A specific example of an activity for car travel is reading. This activity may cause nausea in some people, because linear acceleration and deceleration without the appropriate view of the road ahead cause car sickness (Probst et al. 1982). Besides vibration and movement, there is a limited amount of space available. The seating situation in a car is different than in a train. On a train, most of the seating is similar throughout the entire train, as opposed to a car; front seat versus back seats and the difference in car types, e.g. a micro car, luxurious limousine or sport utility vehicle (SUV). The most observed postures are important when considering a new car interior and are important to the design for usability and comfort. Further research is necessary to analyse car interior specific details. Additional research should be conducted on how to integrate a comfortable seat, additional storage, adapters and/or small (folding) tables in car interiors to provide for additional space to accommodate the number of possible and desired activities people want to do in a car. This research should include passenger range of motion and reach ranges so that it is possible to operate their small mobile devices and do their desired activities while travelling. Overall, it can be said that, due to the technological developments of mobile devices, it is necessary to investigate if the seating now used in cars still meets the requirements and demands of the people and their desired activities. This study is advantageous for the automotive industry but is also informative for the train, bus and aircraft industries, as well as all semi-public/leisure spaces where seating is available.

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6
A BEAMER IN A BEAMER
Improving the car interior experience through (road) projection

The following section is submitted for publication in the International Journal of Design.

Reference: Kamp, I., Vink, P., (submitted). A beamer in a Beamer: Improving the car interior experience through (road) projection.

Abstract
When sitting in the second row of any luxury car, your front view is blocked by massive seats. To improve the space perception of the rear seat passengers a new system is developed. It exists of a camera recording the road ahead, a marker attached to the front seat and a webcam recording the marker to communicate with the software the position of the seat, a mini projector projecting the live image of the road onto the back of the front seat and a laptop controlling the webcams and projection. It also opens up possibilities for movie and game projection.

This study reports on the development of the system and a first user test with respect to the drive experience and the space perception with and without the projection. The drive experience with the system is rated significantly less safe by subjects above the median age compared to the normal situation. Some people also report a feeling of nausea during cornering.

Although these first results might not be convincing for further development, there are indications that for some users, especially younger ones, the system could improve pleasure. The weight reduction achieved by this system is another aspect which makes further development lucrative. Most of the negative remarks -the hum of the projector, the non-steady image and the negative influence of sunlight on the projection- are aspects that can be improved.

Keywords: Back seat, Cars, Comfort experience, Passenger comfort, Projection, Space perception
Patent nr.: PA 2011080556 DE

6.1 Introduction
When sitting in the back seats of luxury cars like the BMW 7-series, Audi A8 or Mercedes S Class, your front view is blocked by massive seats (see Figure 6.1). Of course these seats are important; they have much functionality, are comfortable, safe (airbags, crash-active headrests) and must fulfil all regulations (1). It is debatable whether the current seat design communicates more trust and quality because of these massive dimen-

sions compared to a more slender seat.

Nevertheless, the view to the front of the rear seat passenger can be made more attractive. Partly this is already realized by integrating LCD screens into the front seats. The added extra weight (approximately two kilograms per screen), the "bulge" on the back of the front seat, the relatively small dimensions of the effective screen and the look of the screens when not in use are disadvantages. Another possibility is to make the back of the front seat functional. Foot rests, tray tables, cup holders, i-Pad holders and so on are currently on the market as add-ons or offered integrated by car manufacturers. Problems with these items are again the added extra weight and, especially with add-ons, safety in case of a crash.

Photo credits: http://www.autozeitung.de/neuheiten/der-neue-audi-a8/Der--neue-Audi-A8/n383267/42

Photo credits: http://www.speedheads.de/forum/mercedes-benz/16506-mercedes--benz-s-klasse-w-121-facelift-kommt-hybrid-antrieb.html

Photo credits: http://www.newstechnologyautomotive.com/review-2011-bmw-7--series-specs-and-photos

Figure 6.1 *Rear seat views of the Audi A8, Mercedes S Class and BMW 7 series.*

In the literature not much information can be found to make the view on the back seat in cars more attractive, comfortable or just better. When looking at other ways of transportation, there is more information available in literature. Comfort, activities and associated postures are studied in trains (e.g. Branton & Grayson, 1967; Bronkhorst & Krause, 2005; Kamp et al., 2011). In aircraft interior literature, studies on improving the comfort experience (Vink et al., 2012) and seat design (Friehmelt, 2009) are available. In most luxury cars the back seats already prevent discomfort (see Chapter 7 of this thesis). To create or improve the comfort experience more attention should be paid to feelings of well-being and relaxation (Zhang et al., 1996). At BMW this was the inspirational source for the start of a project to improve the space perception in the rear seat without adding extra weight to, or reducing the weight of the car. A prototype was build where a live image of the road in front of the car is recorded and projected on the back of the front seat.

This study reports on the development of this new light weight system as a replacement of the current entertainment system and a first user test using the prototype for road projection. The goal of this user test was to evaluate the experience of seeing a live image of the road projected onto the back of the front seat. This information serves as input for further development of the system.

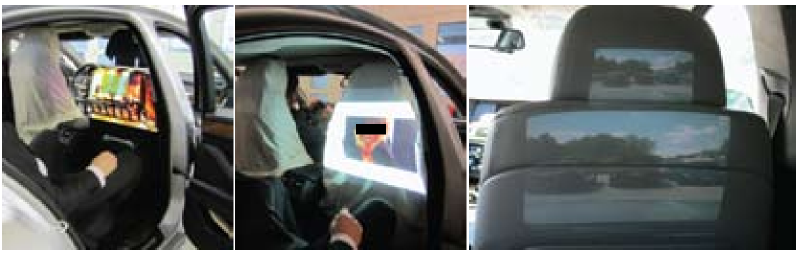
6.2 Process

6.2.1 Development of a light weight entertainment system

As in many design processes, this design process started by an orientation phase. A part of this phase was benchmarking three premium cars (Audi A8, Mercedes S class, BMW 7 series). One of the main conclusions was that while sitting in the back seat the passenger's view to the front is blocked by the front seats in these cars. The only significant measures seen to create a better rear seat experience were small screens, foot rests, tray tables, cup holders and i-Pad holders. The conclusion of this phase was that a significant better solution should be possible and needed as often the owners of these cars are sitting in the back seat.

In the next phase improvement ideas were gathered, by means of a brainstorm. Extreme ideas like projecting a fireplace (see Figure 6.2) were suggested. After a selection phase three ideas seemed interesting to explore further. During the brainstorm it was suggested to remove the front passenger seat. Literally removing the front seat is in fact unpractical as the car owner cannot do this themselves. Seats in luxury cars weigh around 50 kilograms. Another selected brainstorm idea was to make communication with the driver easier. This idea was explored in more detail as it seemed feasible. For this idea a test set-up was created. A webcam mounted to the dashboard recording the driver was connected to a laptop fixed to the backside of the front seat. The assumption was made that this set-up has two advantages: firstly, the front seat was now 'replaced' by the face of the driver and secondly, the back seat passenger did not have to bend forward to talk with the driver. In a test the system worked and communication was possible. However, disadvantages also existed: the laptop was not nicely integrated in the front seat and there was no need to see the driver all the time. A third idea from the brainstorm was using a projector and a camera which could be pointed at the driver and at the road in front of the car. This was input for our project and at this point the patent procedure started.

It was decided to test this system as well. A normal projector (see Figure 6.2) was installed on the backrest of the second row. The image was projected on the back of the front seat. Now the entire seat disappeared and was replaced by the projection. Not only was there a camera installed at the front pointing at the driver, but turning the camera offered an interesting view for the back seat passenger as well. Of course the projector can also be used as an entertainment system, laptop extension or videoconferencing screen. However, disadvantages soon became clear; the temperature in the car increased dramatically with the time the projector was turned on. The size and weight of the projector caused problems as well; in the current interiors every gram is discussed and every millimetre is battled for. Besides, the specifications of a normal projector are not needed in a car; the projection distance is maximal 60 centimetres and the image size not more than 40 centimetres wide. The light conditions in a car are difficult; however the windows can be tinted or darkened with sun shades.



Regular projector in the car, fireplace option.

Regular projector in the car, in car communication option.

Solution with custom software and micro projector, street view in front of the car option.

Figure 6.2 *Process and different possibilities.*

The next step was therefore to find the appropriate projector. The technology for pico projectors is constantly improving and our first pico projector was the 3M MPro 150 LED Pocket Projector. The image size was a bit small (203–127 millimetres) and the amount of lumen (15 lumens) not optimal for projecting in the car. However, the dimensions of the projector itself were excellent (height 2.3 millimetres, depth 130 millimetres, width 61 millimetres) and the weight phenomenal (159 grams). Another issue was that the images of the projection were deformed by the form and colour of the seat. A company was found which was able to develop a special projection solving the deformation problem. First the form and colours of the environment where the projection is shown were measured digitally and subtracted from the projected images. In this way the rear seat occupant sees a ”normal” image. A prototype that could be used for a user test was developed by the external company. The car was provided by BMW and the software, projector and laptop were installed by DeLight Solutions. The prototype exists of a camera recording the road ahead, a marker and a webcam to communicate the position of the seat to the software, a micro projector (Acer K11 LED projector; 200 ANSI Lumen, projected image: 858x600 millimetres, dimensions: 116x122x42 millimetres; weight: 608 grams) and a laptop. After the prototype was developed a second test was done.

6.2.2 User test

In this test 23 subjects participated; 7 women and 16 men. Their mean height was 178 cm (st. Dev. 9.9 centimetres) and their mean age was 33 years (std. Dev. 11 years). A BMW 5 series was used for the test. In Figure 6.3 the developed prototype is schematically presented. Behind the rear-view mirror a webcam (1) is installed. This camera records the road ahead. The live video recording is shown by the projector (3) onto the back side of the front seat. The marker (2a) is recorded by the second webcam (2b); in this way the software knows the position of the seat. The laptop (4) has the software installed that controls the webcams and projector. The software also adjusts the projected image onto the seat; without the software the image of the projector would be bigger than the seat and parts of the projected image would not be visible for the passenger.

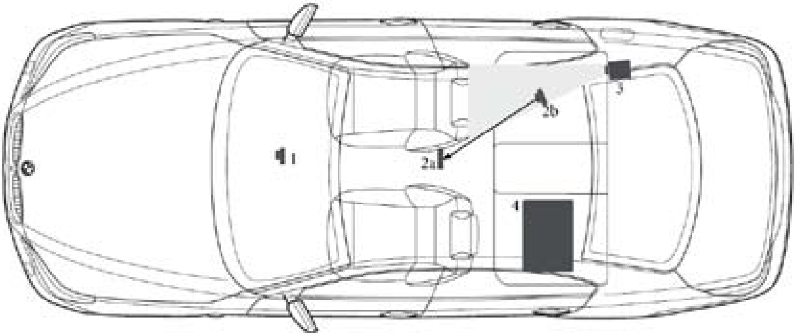


Figure 6.3 *Overview of test-set up (1 = webcam, 2a = marker, 2b = webcam, 3 = projector, 4 = laptop).*

All passengers started with filling out general information (age, height, current mood, emotion for the perfect car seat). The questions about emotions were answered with Emocards (Desmet, 2002, Desmet and Overbeeke, 2001). These cards show eight different emotions representing pleasant, neutral and unpleasant emotions with low, medium or high arousal levels. In Figure 6.4 these cards are shown on the emotion circumplex of Russell (1980).

After filling out the general questions 47.8% (11 subjects) were first chauffeured with the projection turned on. After approximately 5-10 minutes, the subject filled out a questionnaire about the drive experience. The overall space perception was rated with Emocards, keywords scores were asked on a 5-point Likert scale, the drive experience had to be described in a few words and three positive and three negative aspects of the car interior had to be indicated, there was also a possibility to add additional remarks. The projection was turned off and after driving again for 5-10 minutes a second questionnaire had to be filled out with the same questions, however now for the experience without the projection.

Twelve subjects (52.2%) started the first drive period without the projection and experienced the projection in the second drive period. The questionnaires were analyzed with SPSS 17.0. Table 6.1 gives an overview of the performed tests.

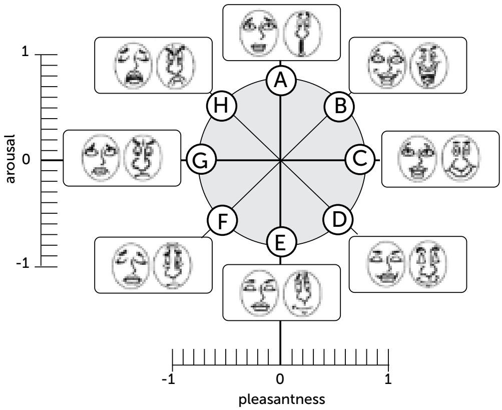


Figure 6.4 *The 16 Emocards placed on Russell's circumplex of emotions (Desmet et al., 2001).*

Table 6.1 *Overview of the tested relationship and performed tests.*

	Relationship between	**Test**
1	Projection (with/without) * Age group (below/ above median) * Order (start with/without projection)	Mixed design ANOVA
2	Projection (with/without) * Age group (below/ above median age)	Mixed design ANOVA
3	Age and keyword ratings for the situation with projection	Bi-variate correlation test (PEARSON)

6.3 Results

Before driving, subjects had to indicate with Emocards what kind of emotion they wish to experience while sitting in the perfect car seat. The majority of the subjects (82.6%) choose either a positive neutral arousal level emotion (Emocard C, 52.2%) or a positive high arousal level emotion (Emocard B, 30.4%) to express the desired emotion in the perfect seat (see Figure 6.5).

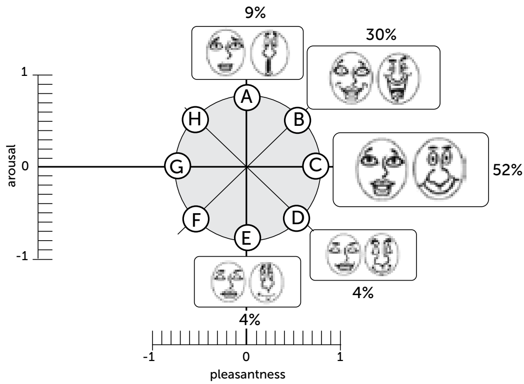


Figure 6.5 *Overview of chosen desired emotions for the perfect rear seat.*

The overall emotion during the two driving periods were asked with the Emocard method. During the drive with the projection 56.5% of the subjects choose either Emocard B or C against 43.5% for the normal driving period (see Figure 6.6).

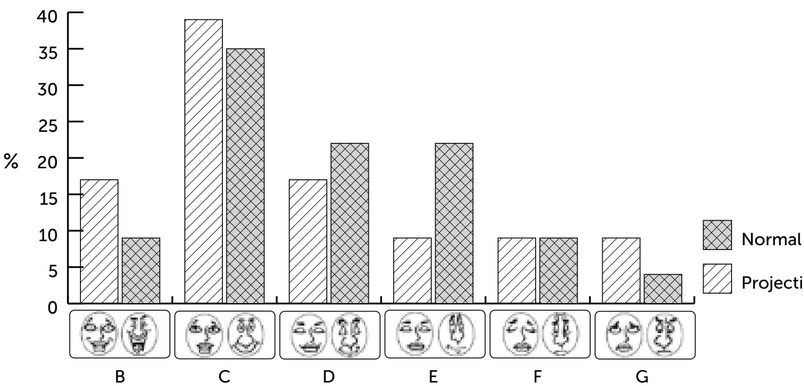


Figure 6.6 *Overall experienced emotions during the ride with and without the projection ("normal").*

Projection * Age group * order

The projection ride and the normal ride were scored on five different keywords: pleasant, safe, secure, confined and luxurious. Furthermore, the order (starting with or without the projection) varied as well; twelve subjects the first drive without the projection and experienced the projection in the second drive period, eleven started with the projection. Because we also expected a difference between older and younger people, the group was divided into two; below (N = 13) and above (N = 10) the median age (29 years). The distribution of participants is listed in Table 6.3. The mean scores of these keyword ratings in the two situations are presented in the first graphic in Figure 6.7. A mixed design ANOVA was performed and showed for none of the keywords a significant main effect of order nor an interaction effect of order (see Table 6.4).

Table 6.3 *Distribution of participants for the mixed design ANOVA Projection (with/without) * Age (above/below median) * Order (1 = starting with projection, 2 = ending with projection).*

Age	Order	Participants (N)
Below median	1	7
	2	6
Total		13
Above median	1	4
	2	6
Total		10

Table 6.4 *Results of the mixed design ANOVA test for main effects of order on the separate keywords.*

Keyword	Order – main effect	Order – interaction effect
Pleasant	$F(1,19) = .02$, ns ($p = .893$)	$F(1,19) = 1.25$, ns ($p = .277$)
Safe	$F(1,19) = .002$, ns ($p = .965$)	$F(1,19) = .39$, ns ($p = .542$)
Secure	$F(1,19) = 3.32$, ns ($p = .084$)	$F(1,19) = .20$, ns ($p = .662$)
Confined	$F(1,19) = .19$, ns ($p = .667$)	$F(1,19) = .08$, ns ($p = .781$)
Luxurious	$F(1,19) = 1.57$, ns ($p = .226$)	$F(1,19) = .68$, ns ($p = .421$)

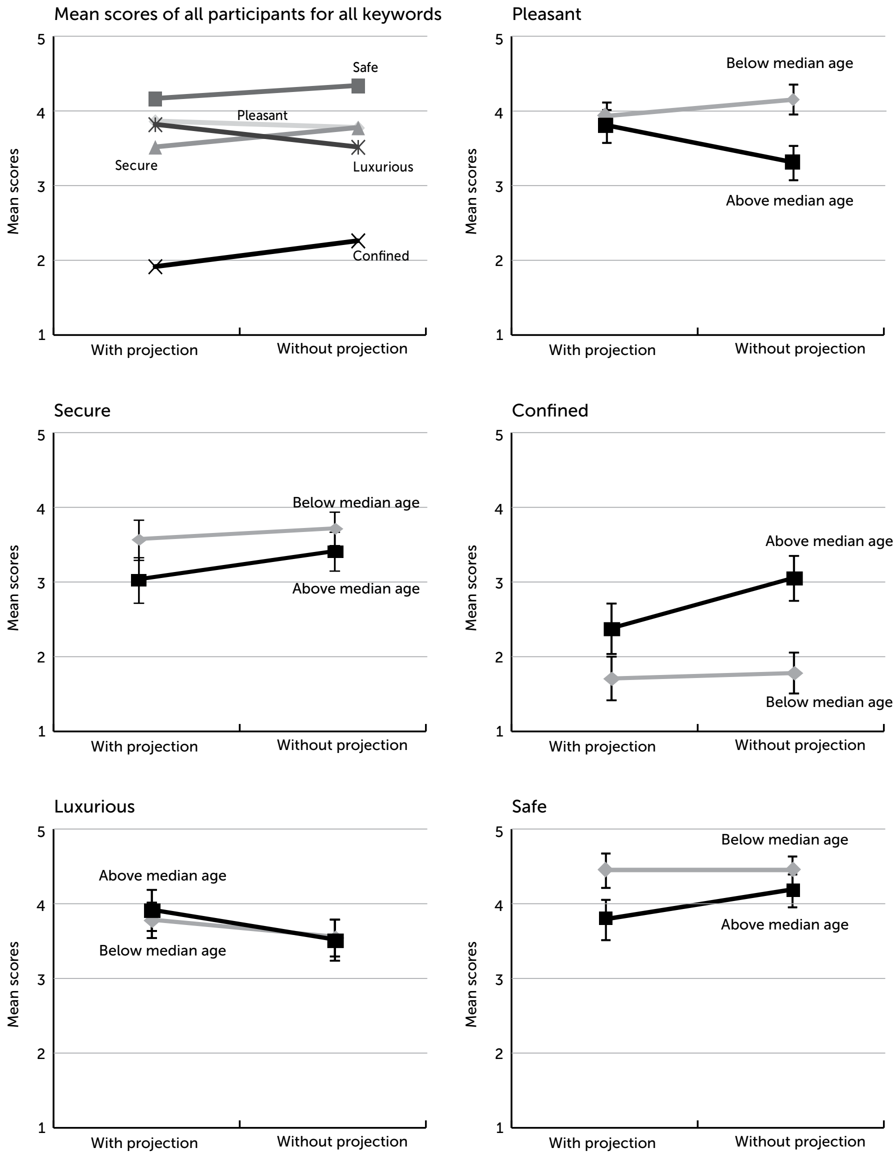


Figure 6.7 *Graphs showing the mean ratings for all keywords with and without the projection (top left) and the mean ratings of participants below and above the median age for the situation with and without projection per keyword.*

Projection * Age group

We did not expect that the order would have an influence and the analysis discussed above confirmed our expectations. Because of the low number of subjects in every group (see Table 6.3), we decided to perform another mixed ANOVA without the independent variable order. Leaving the order variable out of our analysis resulted into two groups; below the median age (N = 13) and above (N = 10). The results of this analysis is graphically presented in Figure 6.7. All effects are reported as significant at $p <= .05$. There was a significant main effect of the projection on the ratings for Safe, $F(1,21) = 4{,}32$, $p = .050$. The ride was experienced safer without the projection than with. There was also a significant main effect of age on the ratings for Pleasant, $F(1,21) = 4{,}39$, $p = .049$, and Confined, $F(1,21) = 7.74$, $p = .011$. The drive experience with the projection was experienced more pleasant and less confined by the participants below the median age than above the median age. Only for the keyword Safe there was a significant interaction effect between age and projection, $F(1,21) = 4{,}32$, $p = .050$. Participants above the median age rated the drive with the projection significantly less safe than participants below the median age. In Table 6.5 the results are presented for all keywords and the main effect of Projection, age and the interaction effect of projection and age while there was no difference without the projection.

Table 6.5 *Results of the mixed design ANOVA test for the ratings with vs. without projection * age group (below and above the median age) per keyword.*

Keyword	Main Effect Projection	Main Effect Age	Interaction Effect Projection * Age
Pleasant	F(1,21) = 0.46, ns (p=.506)	F(1,21) = 4,39, p = .049	F(1,21) = 3.37, ns (p = .081)
Safe	F(1,21) = 4,32, p = .050	F(1,21) = 2.16, ns (p = .157)	F(1,21) = 4,32, p = .050
Secure	F(1,21) = 3.61, ns (p = .071)	F(1,21) = 1.47, ns (p = .239)	F(1,21) = .71, ns (p = .408)
Confined	F(1,21) = 2.31, ns (p = .144)	F(1,21) = 7.74, p = .011	F(1,21) = 1.49, ns (p = .236)
Luxurious	F(1,21) = 3.72, ns (p = .068)	F (1,21) = .021, ns (p = .887)	F(1,21) = .27, ns (p = .610)

The correlation of age with the keyword ratings for the drive experiences with projection was tested with a Pearson correlation test. A negative correlation was found between age and the keyword 'Safe" (see Table 6.6). From Figure 6.7 it can be concluded that on average the participants below the median age rated the two situations equally safe. Participants above the median age rated the situation with the projection less safe than without. In Table 6.7 remarks and positive/negative aspects of the interior mentioned more than two times are presented.

Table 6.6 *Pearson correlation for age and keyword ratings. The asterisk indicates significance.*

	Pleasant	**Safe**	**Secure**	**Confined**	**Luxurious**
Age	-.020	-.432*	-.247	.263	.001

Table 6.7 *Remarks and Positive/Negative aspects of the Interior mentioned more two times or more.*

Normal	
Positive	*Negative*
Spacious interior	Cold leather
	Front seat rails is annoying
	Front seat is blocking the view
Projection	
Positive	*Negative*
Interesting experience	Projected image should show exactly what is missing due to the front seat
More involved in ride	Image is not sharp/steady
No need for bending forward/side-ward	Image should be larger
	Projection causes nausea, especially during cornering
	Sunlight makes the projection invisible
	Noisy "hum" of ventilator
	Seat surface should be smooth

6.4 Discussion

The goal of this study is twofold. The first goal is to test whether a projector can replace the current entertainment system to reduce the overall weight of the car. The second goal is to evaluate how the live view of the road ahead is experienced by passengers in the back seat. In the research several aspects are tested, the conclusions below are structured as such.

6.4.1 Replacement of current entertainment system

The projection is not perfect yet but offers many advantages, it has a lower weight than current entertainment systems (608 grams versus two kilograms), a bigger "screen" and when not in use the system is invisible. The negative remarks included the hum of the projector, the non-steady image and the negative influence of sunlight on the projection. These aspects can be improved.

The reason for the instable image is the marker–webcam combination. The webcam needs stable light conditions in order to recognize the marker properly. In the future there is no need for a marker and a webcam to capture the position of the seat; this information is already available in the car, however, for the prototype it was not possible to access this information.

When the projector is optimally developed for use in the car, there is a good chance the hum will be gone as well; currently in the head-up display system a similar technology is used and no hum is heard. Through integration and isolation of the projector or an optimized technology, the hum can be reduced or even removed.

The sunlight is a different problem; the projection technology is improving steadily and stronger projectors with the same size (or smaller) already exist. The fact that when sunlight is falling on the projection the image is almost invisible is hard to prevent, but this is also true for current LCD screens. Another solution is to completely blind the windows, but safety regulations forbid this in many countries.

The above mentioned optimization points need further research and development. After the prototype is improved, it should be tested again under different circumstances; different weather conditions, different roads (highways, city, country) and at different speeds.

6.4.2 Evaluation of the road projection

Emocard for perfect seat & overall experience

This research confirms the findings of a previous study by Kamp (2012) that the perfect seat/interior elicits the emotion represented by Emocard B or C (see Figure 6.4). For the normal situation Emocard B and C were chosen by 43.5% of the subjects against 56.5% for the ride with the road projection. The overall experience was therefore rated slightly better when the projection was turned on.

Keyword ratings

In this study a small significant effect of the road projection was found on a feeling of safety. It appears that with the road projection people felt less safe than without the projection. This effect was mainly caused by the participants above the median age. When testing for correlation safety was negatively related to age in the situation with the road projection. Other age related differences between the group below the median age and above were found for the pleasantness and confined feeling of the interior. Figure 6.7 shows that the interior in general was rated less pleasant and more confined by the older participants.

Csikszentmihalyi & Rochberg-Halton (1981) investigated the meaning of objects for three generations: children, parents and grandparents. They found that the objects children cherish are action orientated and this aspect is less relevant with increasing age. This could explain why the younger participants in our study felt safer than older participants in the interior with road projection: the projection engages the rear seat passenger in the driving activity which is more appreciated by younger than older subjects. Another possibility for the differences in age is explained by research of Liu & Aaker (2007) and Read & Read (2004). They found that older people, or people with significant life experiences, make decisions that favour long-term interests. It is possible that older participants do not want to be involved in the activity of driving and feel less safe, because they favour other activities like relaxing or working as to spend their time efficiently instead of watching the road ahead and thinking of what can go wrong.

Because of the limited amount of subjects, it was not possible to test the effect of mood on the interior perception. However, future research should investigate this effect. Clore & Gasper (2000) state that moods influences the subjective experience of affective feelings. They present and discuss seven principles based on prior research. One is the experience principle; "moods and emotions have cognitive consequences that are mediated by the subjective experience of affect". Hertel et al. (2000) expected and found in their study that participants in the good mood condition reported feeling more secure than participants in the sad mood condition.

Future research should also focus on the effect of the road projection on car sickness. Although two participants indicated that they thought the road projection causes car sickness, especially in cornering, an interesting hypothesis is suggested in 1955 by R.H.M. Stewart in a letter to the editor of the Lancet. He suggests the cardinal cause of car-sickness is failure of adjustment. He explains the fact that the driver does not feel car-sick is caused by his knowledge of accelerating, braking and so on. Stewart states that "...his semicircular canals therefore know in advance what is required of them...". He brings up three examples supporting his hypothesis: "...The first concerns my five children, each of whom was consistently sick in cars of various types until about the age of two, when the trouble ceased. Is not this because the child is then old enough to "fix" his surroundings and adjust himself accordingly? Secondly, the risk of sickness in cars is greater for anyone if he reads, thereby removing his perceptions from his surroundings. The third observation relates only to a single case, but I think it is significant. I have an elderly relative who has travelled in cars for many years without feeling any nausea. He has recently developed glaucoma and his fields of vision are limited to what lies straight ahead of him. If he now rides in the back of a car he can see nothing but the heads of those in front and he is horribly sick; but if he sits in the front he is free of all nausea, presumably because he can then distinguish the road well enough to anticipate the movements of the car...".

The live projection of the road ahead is potentially improving the drive experience and might be a solution for people with car-sickness if the projection adjust itself into the driving direction. Currently a system adjusting itself into the drive driving direction is already implemented for the headlights of a car; when the driver steers into a corner, the lights move with the direction of the steering wheel. This would also be a possibility for the camera recording the road projection.

6.5 Conclusive remarks

This chapter describes the design process of a lightweight replacement of the current entertainment system and an experiment of one of the possibilities (road projection). When reflecting on the design process, the most positive aspect was the testing of different setups in a very early phase. Even though these set ups were not always realistic for series (e.g. a regular size projector in a car), it provided valuable information on how the ideas would work and it was a source of inspiration for other ideas and possibilities.

Recommendations for improving the design process can also be defined. The quality of the final set-up tested with potential users should have been better; the unsteady image due to the marker-webcam combination could have been resolved by using for instance infrared technology. The feedback of users could have been gathered earlier in the design process; during the brainstorms only designers and experts on light, projection and car construction were present. At this stage input of users could have been helpful to gain insight in their wishes and dreams. Techniques to retrieve valuable insights from users are described by e.g. Sleeswijk-Visser (2009), Sanders (2002) and Vink et al. (2005).

A major disadvantage of the described experiment is the quality of the projection. Most participants still rated the system rather good; however, the influence of the unsteady image and the irritating hum is hard to measure. Though this gives valuable input for the development of the projector for car use.

Further research should focus on other possibilities; in car communication, communication with persons outside the car and use of the bigger projection screen for entertainment purposes (movies, games, internet) with special attention to the influence on motion sickness. The road projection should also be tested under different weather circumstances and at different speeds and roads to determine the influence of the car dynamics on the experience. Because this system will be globally used, experiments with different age groups and different nationalities are needed as well.

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7
THE INFLUENCE OF ACTIVE SEATING DURING CAR TRAVEL ON COMFORT EXPERIENCE

The following section is submitted for publication to International Journal of Industrial Ergonomics.

Reference: Kamp, I., Hiemstra-Van Mastrigt, S., Van Veen, S., Bosch, T., Hoogenhout, M., Vink, P. (submitted). The influence of active seating during car travel on comfort experience.

Abstract

Fully autonomous driving is not yet everyday reality, but innovations in new cars do take critical tasks out of the drivers' hands. The attention for the passenger activities is therefore growing; the future driver could perform the current passengers' activities.

Because discomfort does not appear often in luxury cars anymore, car manufacturers should focus on the comfort experience to improve car interiors for passengers. According to literature comfort experiences are more related to feelings of well-being and refreshment. Therefore at BMW a new concept is developed. It is an extension of the massage system; however, the passenger is not passive but active. With the upper body a game on a tablet pc (or in the future any other screen inside the car) can be controlled. Sensors in the back rest of the seat register the pressure exercised by the passenger and give a signal to the software.

The current study reports of three different tests; a preliminary study on average electromyographic (EMG) activity and variability in muscle activity during active seating, a preliminary study on heart rate while using the active seating system and a driving test where the discomfort is measured and the subjective opinion of potential users is asked. The EMG measurements showed a difference in muscle activity and EMG variability between active seating and other activities. Active seating is comparable to moderate intensive activity according to the heart rate study. Discomfort ratings are very low for all activities and by using the active seating system subjects feel significantly more challenged, fit and refreshed. Even though the games are not yet exciting and engaging, the majority of subjects think the movements are suitable for a car and would play the game if it was implemented in their back seats. These results are a promising starting point for further research.

Keywords: car interior, comfort, car seat, active seating, fun, gaming

7.1 Introduction

In the segment of luxury cars the back seat is often as important as the driver's seat. People in the backseat are chauffeured and want to spend their travel time effectively. Working with electronic devices, preparing the next meeting, tele- or videoconferencing are possible activities done in the rear seat. In literature much information can be found on driver (seat) comfort (e.g. Harrison et al., 2000), seat development (e.g. Franz et al., 2012), fatigue development (Hostens & Ramon, 2005) and character experience (Kamp, 2012). However studies on car passenger comfort are scarce (Kamp et al., 2011). There are a few papers describing the effect and development of comfort features which could be integrated into rear seats like massage systems (Franz et al., 2008; Frohriep & Petzel, 2006) and neck rests (Franz et al., 2012). However, the design of the rear seat is still mainly dictated by the available space and safety regulations.

Comfort studies in situations of a passive traveller can be found in the literature. Comfort, activities and associated postures are studied in trains (e.g. Branton & Grayson, 1967; Bronkhorst & Krause, 2005; Kamp et al., 2011; Groenesteijn et al., 2012). In aircraft interior literature, studies on improving the comfort experience (Vink et al., 2012) and seat design (Friehmelt, 2009) are available. General information on discomfort is abundantly available; a search by Vink & Hallbeck (2012) of "Science Direct (http://www.sciencedirect.com/)" resulted in 104.794 articles including the term discomfort. This information is helpful when improving the comfort experience for rear seat passengers, though more specific information is needed. Until today a relatively small group of people are chauffeured, however with the development of autonomous driving this group will grow. Car manufacturers are already implementing innovations assisting the driver in dangerous situations like active speed control (where the car autonomously maintains a safe distance to the vehicles in front) and self-parking systems. Google in cooperation with Stanford University developed the driverless car "Stanley" that already drove 225,000 km on public roads from its introduction until March 2011. So, in the future the driver is probably able to perform the same activities as the passenger nowadays. This is a challenging opportunity to accommodate the interior for the driver to these tasks.

Many factors play a role when improving the comfort of the rear seats. Not only the human being should be taken into account, but also safety regulations, weight as well as aesthetics are important aspects. When looking from a human factors perspective, it is important to avoid discomfort and create a situation in which comfort can exist. According to Zhang et al. (1996), discomfort is related to physical aspects and comfort is associated with feelings of relaxation and well-being. In the proposed model (Figure 7.1) by Vink & Hallbeck (2012) a feeling of comfort depends on the interaction (I) with an environment through contact between the human and the product and its usage resulting in internal human body effects (H). The perceived effects (P) are influenced by the human body effects (H) and expectations (E). This results in a comfortable feeling (C), a feeling of discomfort (D) or nothing (N). Discomfort then could cause musculoskeletal complaints (M). The circle around E-C indicates the belief of the authors that expectations (E) do often influence comfort (C).

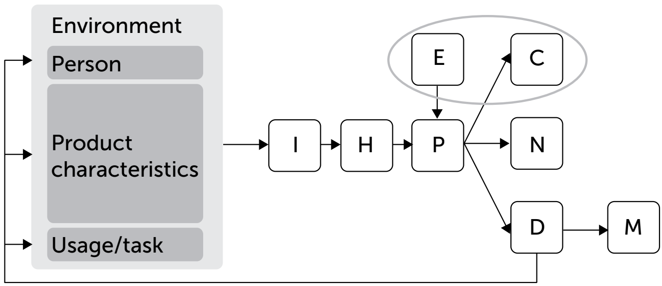

Figure 7.1 *The comfort model of Vink & Hallbeck (2012), I = interaction, H = human body effects, P = perceived effects, E = expectations, C = comfort, N = nothing, D = discomfort, M = musculoskeletal complaints.*

In summary, to improve the rear seat the feeling of well-being and/or relaxation should be enhanced without adding extra weight to the car and without failing to conform to all safety regulations (to mention a few: safety belt should still be available, airbags should function properly, view of the driver should not be blocked). At BMW a new concept is developed that takes these factors into account. It is an extension of the current massage system and consists of several sensors in the backrest capturing pressure changes exerted by the passenger. With this system it is possible to play games or do small work outs. The question is however if this system contributes to the feeling of well-being of the passenger, reduces the feeling of discomfort and promotes health. Two research questions are studied in this preliminary study:

- How is the new active seating concept experienced?
- Is there an indication for a health benefit when using this active seating concept?

7.2 Methods

To evaluate the effect on passengers the concept of a seat which can record pressure in the left and right upper back approximately at the lower point of the scapula was built into the back seat of a 7-series BMW. Several prototypes were built to finally end up in a working one. Also, a game was developed which would be appreciated by elderly as well. On a screen a ball should be balanced in the middle (see Figure 7.2).

Figure 7.2 *The backseat of the research car (left) and a screenshot of the game (right).*

The ball is rolling to either left or right and the person in the seat should press his shoulder into the seat to balance the ball. When all squares at the top are filled up blue, the game automatically proceeds to the next level. Three different studies were performed: a pilot study on EMG, a preliminary study on heart rate and a driving test. The electromyography (EMG) test was performed to discover if muscles were more active during use of the active seating compared to other activities performed on the backseat. The heart rate was recorded while at rest and while using the active seating system to have an indication of the workload level. The driving test was used to evaluate the experience of the active seating system operationalized in acceptance, comfort and fun-factor of the system with potential end-users.

7.2.1 EMG study

Subjects

To get an indication of the muscle activity four participants (three male, one female) aged between 20-21 years participated in the EMG study. Their average weight was 73.5 kg (68-78 kg) and their average height 183.5 cm (170-201 cm).

Procedure

Four subjects were measured at the same day. A short introduction at the test location was given. All subjects tested the active seating system by playing one game before the EMG electrodes where placed to make them familiar with the movements and goal of the game. Upper leg, abdominal and back EMG signals were measured by a porti 16/ASD system (TMS, Enschede, The Netherlands). Bipolar Ag/AgCl (Medicotest, Ambu A/S, Baltorpbakken 13, DK-2750 Ballerup) surface electrodes were positioned according to Hermens et al. (2000), using an inter-electrode distance (IED) of 20 mm. A reference electrode was placed on the C7 spinous process. Before the electrodes were applied, the skin was shaved, scrubbed and cleaned with alcohol. EMG signals were band-pass filtered (10-400 Hz) and continuously sampled at a sampling rate of 2000 samples/s. Skin impedance was not measured but the raw EMG signal was visually inspected to check its quality. The following muscles were included (see also Figure 7.3):

- Upper leg: m. rectus femoris
- Abdominal: m. obliquus externus abdominis
- Lower back: m. erector spinae L2 level
- Upper back: m. erector spinae T10 level
- Shoulder: m. trapezius pars transversa
- Neck/shoulder: m. trapezius pars descendens

Only the muscles on the right side of the body were measured.

When all electrodes were placed, subjects were asked to sit in the right rear seat of the test car and to perform four different tasks for approximately three minutes: reading a book, working on a laptop, playing a game on a tablet pc (e.g., Apple iPad) and playing the game with the active seating system. During every activity EMG signal was recorded twice for 10 seconds. The first recording was done when the subject started the activity and the second approximately 10 seconds after the first measurements.

Analysis of EMG signals

For each 10 s recording, the mean EMG amplitude was determined for all muscles by averaging the bandpass filtered (10–400 Hz) and rectified signal, obtained by taking the absolute value of the each sample (ARV). EMG variability was calculated for all muscles and expressed in terms of the median absolute deviation (MAD), as described by Shevlyakov & Vilchevski (2002). As indicated by its name, this estimator is the median of the absolute differences between individual sample values and their common median. This estimator of variability is more robust to outliers than the standard deviation or the coefficient of variation (Chau et al. 2005).

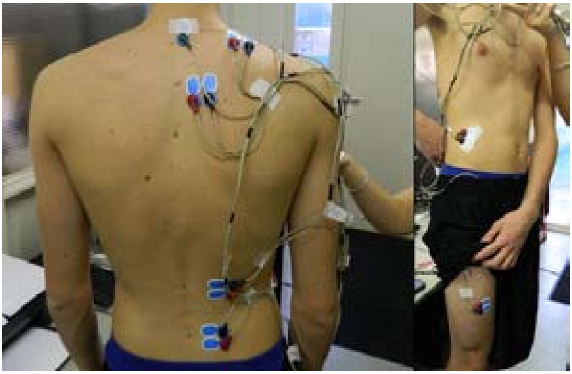

Figure 7.3 *Electrode location setup for the back, shoulder and neck muscles (left) and for the abdominal and upper leg muscle (right).*

7.2.2 Heart rate

Subjects

For the heart rate measurements we measured six subjects aged between 23-55 years old (one male, five female).

Procedure

This study was also performed in a laboratory setting. A short introduction was given and subjects were asked to wear a chest strap with electrodes and a wireless transmitter (Polar WearLink+ Bluetooth Heartrate belt LS-14). The transmitter was connected to a smartphone with a software application installed (Endomondo Sports Tracker) to read the heart rate values in beats per minute (bpm). During three minutes the heart rate was measured while sitting relaxed in the back seat of the car. The active seating system was then calibrated and the heart rate was recorded once during three minutes while the subject was playing the active seating game.

Figure 7.4 *Heart rate recording with a Polar bluetooth heart rate belt, connected to smartphone (left), with Endomondo software application installed (right).*

Analysis

The average heart rate at rest was calculated as well as the average heart rate during active seating. The maximum heart rate was calculated by means of age (Tanaka et al., 2001) in order to determine how high the heart rate is during the use of the active seating system compared to the maximum heart rate (in %).With SPSS a paired sample t-test was performed on the relative resting heart rate compared to the relative heart rate during active seating.

7.2.3 Driving test

Subjects

In the driving test 14 men and 12 women of different nationalities (European, American and Asian) participated. Their average age was 29.4 years (20-67 years), their average weight was 71.2 kg (50-105 kg) and their average height was 175.6 cm (163-193 cm). Age, weight and height was self-reported and not measured.

Procedure

The BMW 7-series with the active seating system was used for this test. Two subjects were invited in Delft at the same time and received an introduction on the study. When sitting in the car the active seating game was explained to and calibrated for the subject in the left rear seat. This was done in both previous experiments as well; calibration is needed so the system can adjust itself to the different weights of the subjects and explanation is needed so subjects know where and how they should press into the seat in order to control the game. The subject in the right rear seat was instructed to do one of the following tasks: reading a book, working on a laptop or playing a game (Angry Birds; Rovio Mobile Ltd.) on a tablet pc (e.g. Apple iPad). When someone indicated (severe) motion sickness the task least likely to cause sickness was chosen by the subject him-/herself. In total nine subjects played a game on a tablet pc, nine subjects read a book and eight subjects worked on a laptop during the ride. The subject in the left rear seat used the active seat.

After the instructions the two subjects in the rear seats were driven for approximately 30 minutes by one researcher and observed by another researcher sitting in the front row. The researcher monitored the subjects and indicated when they had to start the active seating game (left seat) and when to complete a part of the questionnaire (left as well as the right passenger). The active seating game was played for five minutes and alternated with five minutes rest. The other activity was done constantly only interrupted by completing a part of the questionnaire.

To determine if and in which body part(s) the subjects experienced discomfort the local perceived discomfort (LPD) method was used (Grinten, 1991). At the start of the driving test (t=0), after 10 minutes (t=10), after 20 minutes (t=20) and after 30 minutes (t=30) the subjects were asked to rate their discomfort on a body map divided into 22 body regions. With a Borg CR-10 scale (Borg, 1982) they could rate the intensity of the perceived discomfort.

After 30 minutes the participants changed places and their perceived experience was asked in a questionnaire with questions on whether they felt relaxed, refreshed, tired, etc. Then the same procedure as at the start of the test was followed and after approximately 30 minutes driving the final part of the questionnaire was completed.

The driving track was the same for all travels and consisted mainly of highway as this is probably the situation where the active seat will be used and the other tasks will be performed as well.

Analysis

The questionnaire consisted of questions related to discomfort and comfort (LPD, Likert-scales) for both active seating and other tasks (reading, working on laptop and gaming on tablet). A paired sample t-test in SPSS was done for active seating and other tasks combined. For this test all LPD body region scores were added.

The questionnaire also had questions on the topics like: Do you think this is a fun way of stimulation? Do you think the movements are suitable for in a car? Would you use the system if it was installed in your car? Did you think the car dynamics influenced the activity?

In the questionnaire the participants had to rate after every activity they performed how much they felt challenged, irritated and amused during the activity and how much they felt fit, relaxed, tired and refreshed using a 7-point Likert-scale. For analysis a paired samples t-test in SPSS was done.

7.3 Results

7.3.1 EMG

Analysing the EMG signal recordings resulted in an overview of the mean amplitude of the muscle activity of all subjects during the four different activities (Figure 7.5). In Figure 7.6 the average EMG variability in muscle activity of all subjects is shown.

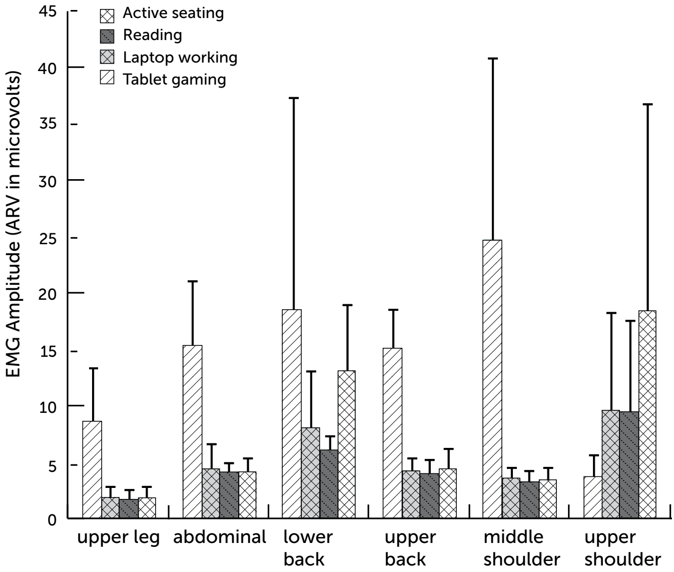

Figure 7.5 *The mean amplitude of the muscle activity expressed as the average rectified value (ARV) for all muscles averaged over all subjects. Error bars show the standard deviation between participants.*

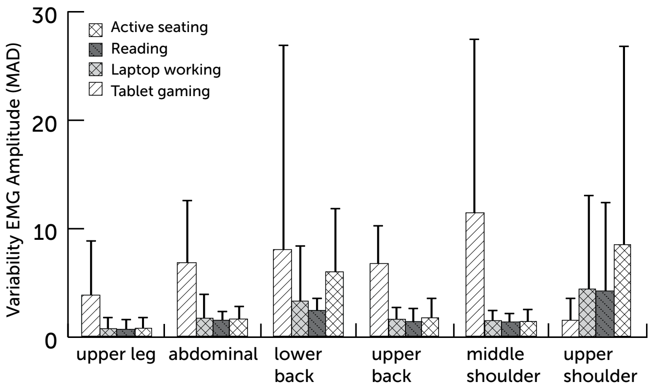

Figure 7.6 *The EMG variability in muscle activity expressed as the median absolute deviation (MAD) averaged over all subjects. Error bars show the standard deviation between participants.*

7.3.2 Heart rate

The heart rate during active seating and at rest is on average 46.4% and 41.1% of the maximum heart rate calculated by age, respectively. When comparing the average heart rate at rest of the six subjects with the average heart rate during active seating there is an average increase of 13.2% during active seating. A paired samples t-test showed a significant difference (p=0.001, t=7.048) between the relative heart rate at rest and the relative heart rate during active seating.

7.3.3 Driving test

Local perceived discomfort

The results of the averaged LPD for active seating during the test (for t=10, t=20 and t=30) is shown in Figure 7.7. The averaged LPD ratings after 30 minutes (t=30) for each of the four activities are shown in Figure 7.8. A paired samples t-test on the sum scores of the LPD showed no significant differences for none of the measurement intervals.

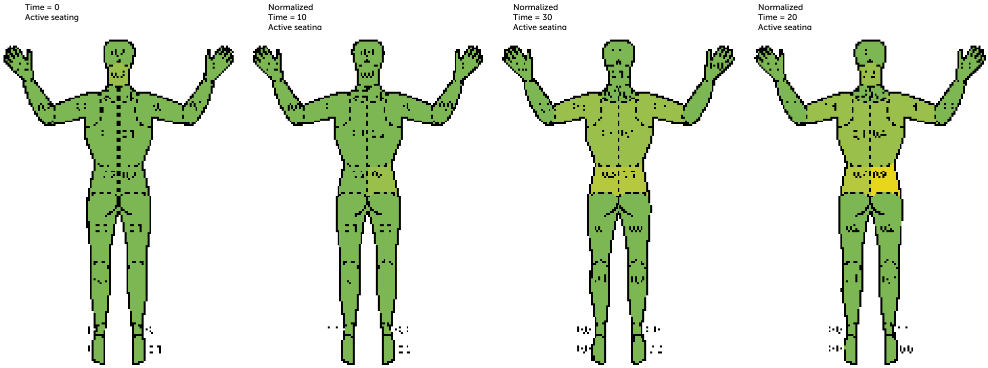

Figure 7.7 *The local perceived discomfort (LPD) ratings after 10, 20 and 30 minutes during active seating*

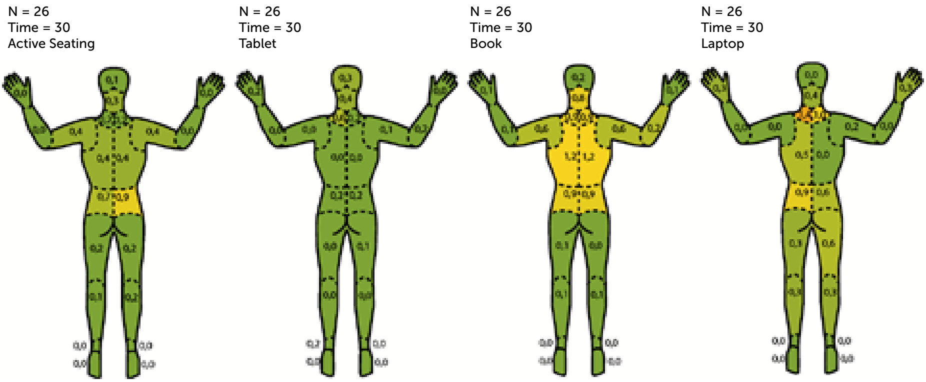

Figure 7.8 *The LPD ratings after 30 minutes for each of the four activities.*

Feelings during and after active seating versus other activities

After 30 minutes of driving and playing a game with the new active seating system for three times five minutes (alternated by five minutes rest), subjects had to rate (on a 7-point Likert-scale) how much they felt challenged, irritated and amused during the activities. They also had to indicate how fit, relaxed, tired and refreshed they felt afterwards on the same scale. The same questions were asked when the same subjects did one of the activities (reading a book, working on laptop, gaming on tablet) for the other 30 minutes. The subjects felt significantly more challenged, fit and refreshed for the active seating system compared to the other activities as shown in Figure 7.9).

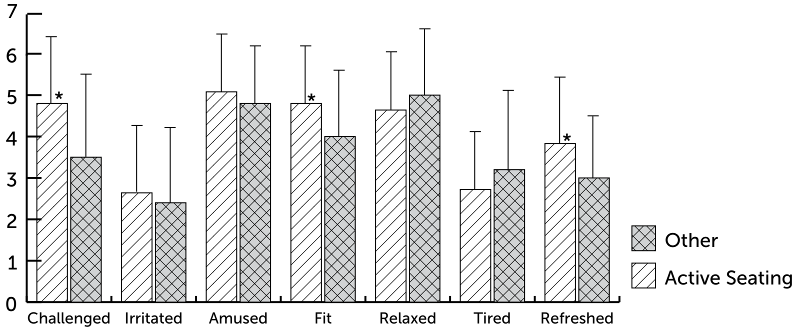

Figure 7.9 *Mean values and standard deviation (between participants) of feelings during the activity and after the activity. The asterisk indicates significant differences between active seating and other activities (p<.05).*

Subjective ratings of the active seating system

The results of the questions regarding, fun, suitability, use and dynamics influence are shown in Figure 7.10. Nine out of 26 subjects had additional remarks, six (66.7%) mentioned that the game could be more challenging. The following suggestions were given: add a competition element to the game (e.g. with the passenger next to you or with other car passengers), add more sensors; not only pressure but also sound sensors can be used, offer more levels, and create more engaging games. Additionally, three participants mentioned that the system responds a little bit slow. Influence of car dynamics is experienced mostly when cornering, where the amount of force needed to control the game is different (higher or lower depending on whether it is a left or a right turn). 81% of subjects think the active seating system is mostly suitable for highway (longer travels).

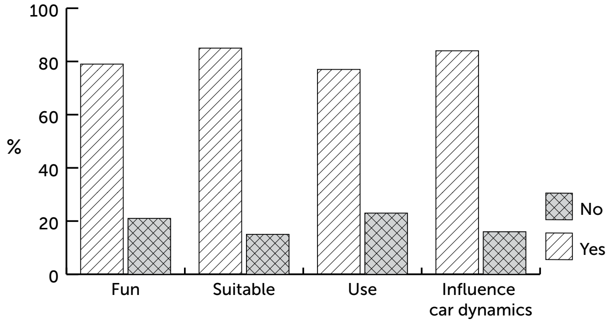

Figure 7.10 *Overview of fun factor, suitability in car, use in car and influence of car dynamics.*

7.4 Discussion

The aim of this study was to evaluate a newly developed system making travelling in the backseat more enjoyable, comfortable and health beneficial. More specifically, the study was focused on how this new active seating concept was experienced and if there is an indication for a health benefit. The results of the three studies (EMG-measurements, heart rate measurements and a driving test) related to the research question will be discussed below.

7.4.1 EMG

The EMG results showed that there is on average not only more muscle activity during active seating but also a larger variability in muscle activity. This is found for all muscles except for the upper shoulder/neck region. The higher variability during tablet work could be caused by the increased involvement of the shoulders/arms compared to active seating.

The muscle activity of the upper leg muscle (m.quadriceps femoris) during active seating was five to six times higher than during the other activities. It was surprising to see so much activity in the quadriceps, but this was needed to give enough force in pressing the back sensors. For the upper shoulder (neck) muscle, the muscle activity during active seating is two to five times lower than during the other activities. This is due to the head of the subject which is bent forward in the other activities: muscle activity in the upper shoulder (neck) muscle is needed to counteract the gravity force working on the head. As for the tablet condition, the extra increase in muscle activity and variability can be explained by the need to use the arm while playing the game. For the active seating system this means that even more muscles can be involved in playing the game if the passenger is stimulated to move his arms as well.

Based on this preliminary research active seating might lead to less muscle fatigue compared to other activities in the back seat because of temporal periodic increases in muscle loading (e.g. Falla & Farina, 2007), and more variability in muscle activity (e.g. Van Dieën et al., 2009). Due to the increase in variability in muscle activity, the active seating system also prevents a person from sitting statically which is often mentioned as unhealthy (e.g. Van Dieën et al., 2001; Leuder, 2004; Konijn et al., 2008).

7.4.2 Heart rate

The heart rate during active seating is on average 46.6% of the maximum heart rate calculated by age (Tanaka et al., 2001). According to Fox & Haskell (1970) this corresponds with light exercise (moderate activity), which is more than during the passive seating tasks and could also explain why subjects felt more fit and refreshed after using the active seat.

7.4.3 Driving test

The average local perceived discomfort (LPD) ratings of all subjects were less than 0.9 on a scale from 0-10. This means that discomfort is already limited in the current interior. Research of Zhang et al. (1996) and Helander & Zhang (1997) showed that discomfort is more related to physical characteristics of the environment, like posture, stiffness and fatigue (see Table 7.3). In case of absence of discomfort nothing is experienced. To notice comfort something more should be experienced (Vink, 2005). Important to improve in the car interior is therefore to focus on comfort aspects. According to Zhang et al. (1996) comfort is associated with a feeling of well-being, luxury and refreshment (see Table 7.3). This study shows that the majority of subjects enjoyed playing the game and felt significantly more challenged during the active seating and significantly more fit and refreshed after using the active seating system.

Table 7.3 *Factors influencing comfort or discomfort during sitting (Zhang et al., 1996).*

Discomfort	**Comfort**
Fatigue, pain, posture, stiffness	Luxury, safety, refreshment, well-being

7.4.4 General discussion – answering the research questions

How is the new active seating concept experienced?

The question whether the active seating system is a fun way of stimulation was answered positively by 79.2% of the subjects. The movements were rated by 84.6% of the subjects as suitable for in a car even though 84% did say the car dynamics (especially cornering) had a disturbing effect on performing the activities. Of all subjects, 76.8% would use the system if it was installed in their car. Based on these results it can be concluded that the system is a fun way of actively sitting in the back seat of a car.

However, it is possible that other factors influence this experience. Because the subjects were relatively young it is possible that during this test they sat for the first time in a BMW 7-series, this could have influenced their response. For all users it was the first time they used such a system in a car, which also can be influential. Already 22.2% indicated that they preferred more competition, more challenges (more different sensors) and/or better visuals. Therefore, an important aspect in the further development of the system is the quality of the interactions and visuals of the games or work outs that are offered. In our experiment only one of our subjects had to stop the test because of motion sickness. When other sensors are implemented and/or other visuals are used the effect on motion sickness is another point of attention during the development of the system.

Is there a health benefit?

The results of the EMG pilot study show that several muscles in the upper legs, abdominal region and lower back are more active compared with other activities performed in the back seat. Furthermore, the preliminary heart rate study indicates that the using the active seating system is comparable with a light exercise. It should be noted, that these results are preliminary due to the low number of test subjects. However, it is also shown that at least in this small amount of subjects the effect does exist.

Subjectively, subjects felt significantly more challenged during the active seating and significantly more refreshed and fit after using the active seating system compared to the other activities (reading a book, working on laptop, gaming on tablet pc). Based on the results of the LPD measurements discomfort hardly occurs anymore in the back seat of a BMW 7-series. Therefore focusing on pleasurable features that increase the feeling of well-being and refreshment, like the active seating system, is (according to Zhang et al., 1996) a possibility to improve the passengers' comfort experience.

7.5 Conclusion

This study existed of three parts; a pilot EMG study, a preliminary study on heart rate and a driving experiment. The results of the EMG study showed that there is an increase in muscle activity and variability. However only four participants took part in this study, therefore to make solid statistical statements on the effect of the active seating system on muscle activity and variability, further research with more participants is needed. When the active seating system is developed and extended with more sensors (e.g. if the arms or feet or involved as well), an EMG study into different muscles is interesting in the future.

The heart rate study showed as well promising results for the active seating system. However, in this study the amount of participants was not enough to make solid statistical statements. In future research, more participants with different body weights and age should be studied for a longer period of time.

Because the active seating system is a product that will be available globally, future research should also focus on different nationalities. The preference for certain games and graphics among different nationalities should be investigated as well as the influence of age on the game and graphic preference.

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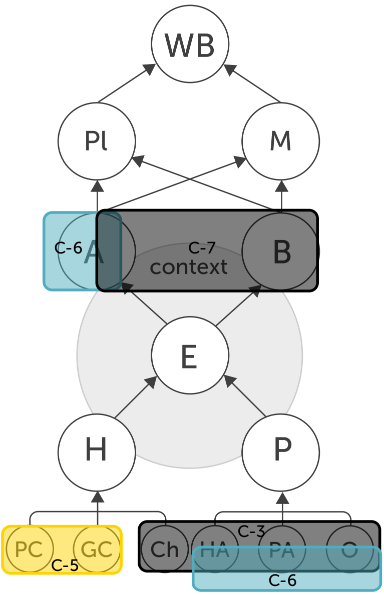
REFLECTION & IMPLICATIONS

The experiments in this part are reflected upon like the experiments in part B; with the Why, How and What model. In Figure C.1 the model developed in part A and the experiments discussed in this part are presented.



C-5 Chosen activities and postures during transport
C-6 A beamer in a Beamer
C-7 The influence of active seating during car travel on comfort experience

WB = Well-Being
Pl = Pleasure
M = Meaning
A = Affect
B = Behaviour
E = Evaluation
P = Product
H = Human
HA = Hedonic Attributes
PA = Pragmatic Attributes
O = Other
PC = Product Concerns
GC = General Concerns
Ch = Characteristics

Figure C.1 *An overview of the theoretical model with the discussed studies included.*

C-5 Activities and chosen postures during transport

WHY – A trend in the automotive industry is developing features that supports the driver and partly take over control like the automatic distance control and lane detection. These developments are the first steps towards autonomous driving. Therefore the interest in the back seat pas-

sengers is increasing, because the future driver potentially is able to do the same things as rear seat passengers are currently able to do. Not much information about the comfort experience of the rear seat passenger is available. The goal of this research is to discover how to create a comfortable rear seat experience.
HOW – Because little information is available on the rear seat passenger, it was decided to first study what people expect of and want to do in the rear seat (the Product Concerns, PC, in model C.1) as input for the development of car interiors that enable these activities (PA).
WHAT – This study observed the activities people do while they are travelling and not in control of a vehicle and in leisure situations (context in model C.1). The activities done and the associated postures were analysed in order to create basic car interior requirements (PA).

Implications

This study suggests a significant relationship between most activities and the position of the head, trunk and arms during transportation situations. The relationship during public situations is less straightforward. Watching, talking/discussing and reading were the most observed activities for the transportation and leisure situations combined. This information is needed to offer passengers and perhaps in the future when autonomous driving is a fact, also drivers, the space and support they need for their desired activities.

C-6 The development of a light weight entertainment system

WHY – The need to reduce the overall weight of the car was input, like in more studies described in this thesis, for this research. Based on a benchmark study of competitor vehicles (Mercedes and Audi) a project started to identify features that create a more comfortable and pleasurable rear seat experience without adding weight. The goal of this study was to create hedonic product attributes (HA) taking the weight reduction demands into account (O in the model).
HOW – The information that the front seats in BMW 7-series were

blocking the view more than in other benchmark cars combined with the weight reducing requirements, was a great starting point to develop a system that improves the car interior perception (A). Ideas and prototypes were needed to reach this goal.

WHAT – First a brainstorm at BMW was organized. This leaded to several creative ideas. One of the ideas, projecting the road ahead onto the back of the front seat, was developed into a prototype. After the prototype was installed into a car, users were asked to sit in the rear seat and rate the drive experience with and without the projection turned on with Emocards and descriptive words (A in the model C.1).

Implications

The idea to replace the current LCD screens with a projector seems promising. The weight reduction is per system almost 1.5 kilograms. This study identified several important necessary improvements: better integration into the car interior, removing the noise and the unsteady projection.

From this study it is also concluded that the road projection option has potential, especially for younger passengers; it scores slightly better on a pleasant feeling and the space is perceived less confined. However, on a safe feeling the system rated slightly worse compared to the normal situation. When the projector is optimised for car use, it offers numerous possibilities to increase the pleasure. Watching television/movies (as was indicated as one of the favourite activities in the car in the meaning of cars study) or communicating with passengers outside or inside the car is improved through the bigger screen. Further possibilities of this system are controlling the system with touch and creating mood atmospheres for example if the rain sensors that are already available in the car, detect rain, the projector projects a bright sunny image onto the back of the front seat.

C-7 Active seating

WHY – The activities most observed in the study discussed in Chapter six, are all passive activities like reading, observing and laptop work. This result was input for a project at BMW. The goal of this project was to change the behaviour (B) and thereby increase the pleasure (A) in the back seat with the requirements that it should not add extra weight and costs. Analyzing the current features of the back seat, the possibilities regarding the available space and trends like vitalization resulted in an extension of the massage system. The system was developed and the aim of this research was to investigate the effects of such a system on muscle activity and pleasure experience.

HOW – The active seating concept was developed and built into a car. Then verification whether the goals of the concept, change behaviour and increase pleasure, were achieved.

WHAT – Three different experiments were carried out. To test muscle activity objective EMG data was gathered of subjects using the concept in a real car in a laboratory set-up. To determine the intensity of the activity the hearth rate was measured of subjects using the concept in a real car in a laboratory set-up. The subjective experience of users was measured with the LPD method and questionnaires in a driving test on the highway.

Implications

Valuable input was gathered during this research. Measurements showed a difference in muscle activity and EMG variability between active seating and other activities. Active seating is comparable to moderate intensive activity according to the heart rate study. Not only were the results of the preliminary EMG and heart rate study promising, from the driving test it was concluded that people felt significantly challenged during the game. Discomfort ratings appeared very low for all activities and by using the active seating system subjects feel significantly more fit and refreshed afterwards. Furthermore future improvements are also identified; more engaging games, more sensors, and quicker reaction time of the system.

GENERAL DISCUSSION

This thesis started with an example of the iPhone to illustrate the availability of luxurious products to a increasing group of people worldwide and the advantages of pleasurable products people love. Of course cars in general are different from smart phones; they have a longer average lifespan, are more expensive, require different cognitive abilities and have to fulfil different regulations. But, as with the iPhone, BMW developed many new and updated models. In the period 2007 – 2012 19 facelifts or new models were introduced on the streets. Despite the uncertain economic climate sales went up with 14.6% compared to 2006 and in 2011 a record number of BMWs was sold. It also illustrates that more people in the world can afford luxurious products. The necessity to develop more sustainable and environmental friendly cars is therefore growing as well. However, this should not compromise the safety, comfort and pleasure of driving, owning and sitting in a car.

This thesis presented a descriptive model to develop comfortable and pleasurable car interiors which was illustrated by five experiments; one (Chapter five; chosen activities and postures during transport) was orientated on input for the design process, two focused on the process of developing elements for a sustainable and more pleasurable interior (Chapter three; a light weight car-seat shaped by human body contour and Chapter six; a beamer in a Beamer) and two experiments are presented that assess the effects on comfort of new sustainable innovations (Chapter four; the influence of car-seat design on its character experience and Chapter seven; the influence of active seating during car travel on comfort experience).

Each of the five studies has been discussed at the end of every chapter and the relation with the descriptive model is discussed at the end of Part B and C. This chapter presents the key findings and adds a more general discussion related to the research questions, the implications for car interior development, recommendations for further research and reflection of the process and methods.

Table 8.1 *Key findings of this thesis per Chapter.*

Findings	**Chapter**
Based on the literature of comfort, pleasure and well-being a descriptive model for developing products contributing to the well-being of people can be made.	1 & 2
It is possible to create a lightweight car seat that is experienced relaxed.	3
Regulations in the car industry are not merely restrictions, but offer an opportunity to explore the possibilities.	3
Hardness of foam influences the character experience of a seat; softer seats are experienced more luxurious whereas harder seats are more sporty.	4
The contour of side supports influences the sportiness experience.	4
Objective data from observations done in trains and leisure situations can be a suitable input for making car interior requirements (PA).	5
A projector is a promising future possibility for replacing the current LCD screens in cars when they are better integrated into the car interior, the noise is removed and the unsteady image is improved. Not only to reduce the weight of the car (O) but also for a more comfortable and pleasurable experience (HA, A).	6
Road projection is particularly suitable for younger rear seat passengers.	6
Road projection might improve the drive experience for certain types of motion sickness in cars.	6
It is possible to create a system without adding extra weight that challenges rear seat passengers and makes them feel fitter and more refreshed after car travel.	7
Testing (first) prototypes with potential users offers a rich input (PC, GC & Ch) for the development of the new car interior features.	7

Research questions

The aim of this thesis is to (1) create a descriptive model based on literature for designing products contributing to the well-being of humans (Part A) and to (2) apply this information to car interiors focusing on the driver (Part B) and the passengers (Part C). The key findings are summarized in Table 8.1.

What elements are relevant for designing products that contribute to the well-being of humans?

In Part A the literature on well-being, pleasure and comfort was discussed. It was stated that products contributing to a person's well-being should elicit pleasurable emotions and feelings and stimulate meaningful behaviour. The key elements for designing such products, compared to other design processes, are the focus on the users' concerns and hedonic attributes of a product. Information on the meaning of the product for the user and his expectations are all aspects a designer should consider during the design process. Besides the hedonic attributes, meaning of a product, users' expectations and concerns the pragmatic attributes and user characteristics (as defined in Chapter two), are relevant as well; having a comfortable and pleasurable experiences is difficult when someone cannot understand and use the product.

For understanding the different levels of pleasure and the relevant product emotions the pleasure model of Jordan (2000) and the Emocard method developed by Desmet (2002) are useful. If the product also contributes to the eudemonic well-being (in the descriptive model simply called M; meaning), more than pleasurable emotions and feelings should be the result. Such products should evoke meaningful behaviour based for example on the virtues described by Seligman (2002) or the activities defined by Lyubomirsky (2010).

In conclusion, the elements relevant for designing products contributing to the well-being of humans are the general and product concerns of the user and the hedonic product attributes. The pragmatic product attributes, other factors influencing the design process (like economics and brand image, see Chapter two) and human characteristics are relevant, but subordinate to the aforementioned elements.

How can this knowledge be used for making a descriptive model and for developing comfortable and pleasurable car interiors?

Based on three models described in literature (the comfort model of Vink & Hallbeck, 2012, the research model of Hassenzahl et al., 2000, and the model of product emotions of Desmet, 2002), a descriptive model for designing products contributing to the individual's well-being is created (Part A, Chapter two).

The input relevant for creating pleasurable car interiors are studied in the desired activities and postures (Part C, Chapter five). The development of products improving the comfort or pleasurable experience in the car has been described in: a light weight car-seat shaped by human body contour (Part B, Chapter three) and a beamer in a Beamer (Part C, Chapter six). Finally the assessment of these products are reported in the influence of car-seat design on its character experience (Part B, Chapter four) and the influence of active seating during car travel on comfort experience (Part C, Chapter seven).

The answer to the research question is that the knowledge of the relevant elements for designing products that contribute to the well-being of humans can be used for creating a descriptive model by structuring the elements into an input (human and product), interaction or appraisal and output phase; in Chapter two the development of the descriptive model is described in detail.

The second part of the research question, how can the knowledge of the relevant elements for designing products that contribute to the well-being of humans be used for developing comfortable and pleasurable car interiors, is illustrated with the different experiments described in Part B and C.

The descriptive model is used in the development of the light weight seat (Chapter three) to provide a holistic view; the light weight demand (O factor), the comfort experience (hedonic product attribute) and the expectations (product concerns) were considered simultaneously. Figure 8.1 illustrates the connection; the human characteristics, the imprint of the human bodies, was used to create a comfortable and light weight seat. The laws & regulations (O factors) were input for the development of the seat.

In Chapter four the influence of the seat design on its character experience is described. In this experiment the descriptive model was used to investigate how the new seat concept could adjust itself for a specific car. Information was needed what kind of seat design people would expect in a sportive, luxurious and 'relaxed' car. Therefore several seats were tested and the user experience was evaluated (see Figure 8.2).

In Part C, Chapter five the expectations of people were studied. In similar situations (public transport and public leisure situations) the activities and associated postures were observed. The model was used to find a relationship between the human concerns in comparable situations (performed activities and associated postures) and the expectations for cars. In the future these human concerns and expectations can be translated into a car interior that support these activities and postures.

Chapter six was inspired by the expectations and wishes of the user (determined in Chapter five). Based on a benchmark study (O factor) and human concerns found in the experiment described in Chapter six, the road projection was developed. The model assisted in structuring thoughts and provide a holistic view on the information needed for the development of such a system (see Figure 8.4).

Finally, the influence of the model in the study described in Chapter seven was to determine what aspects needed to be studied i.e. what information was needed from the user test. The concept was already developed based the demand for light weight comfort features (see Figure 8.5). Based on the model this research was set-up; information about the expectation of users were gathered as well as feedback on the system.

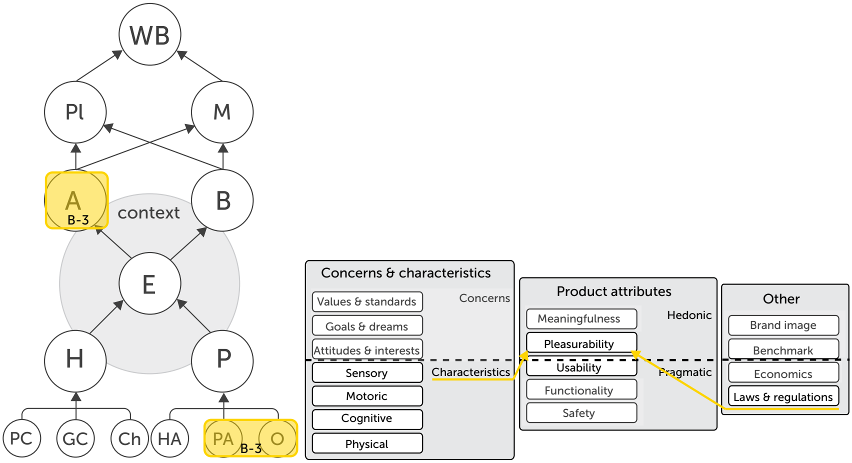


Figure 8.1 *Information from the descriptive model used in the development of the light weight seat concept (Chapter three).*

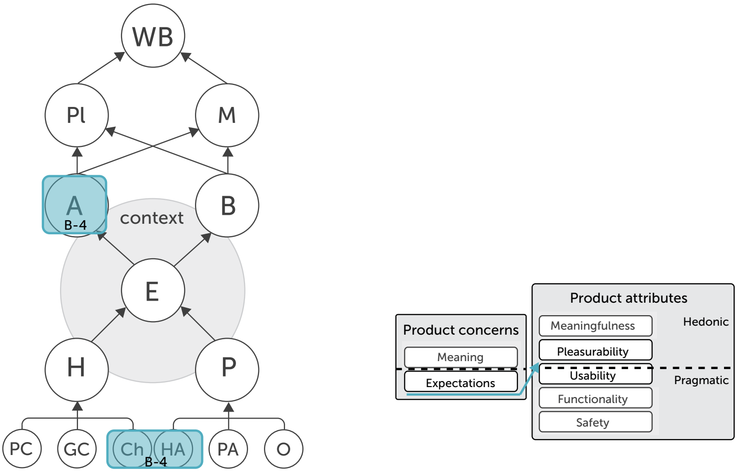


Figure 8.2 *Information from the descriptive model used in the development of the light weight seat concept (Chapter four).*

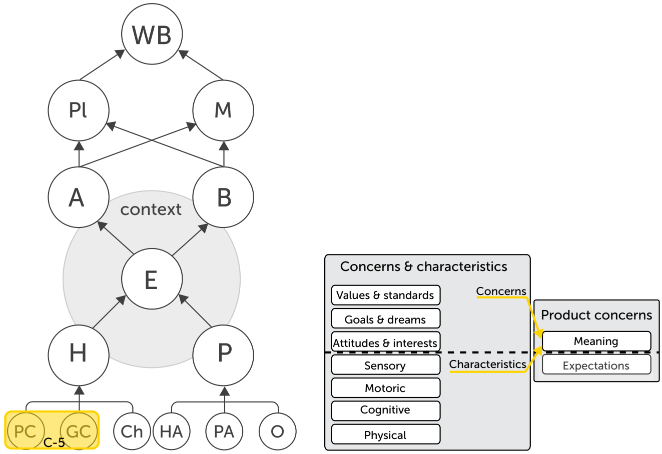


Figure 8.3 *Information from the descriptive model used in the posture & activity experiment (Chapter five).*

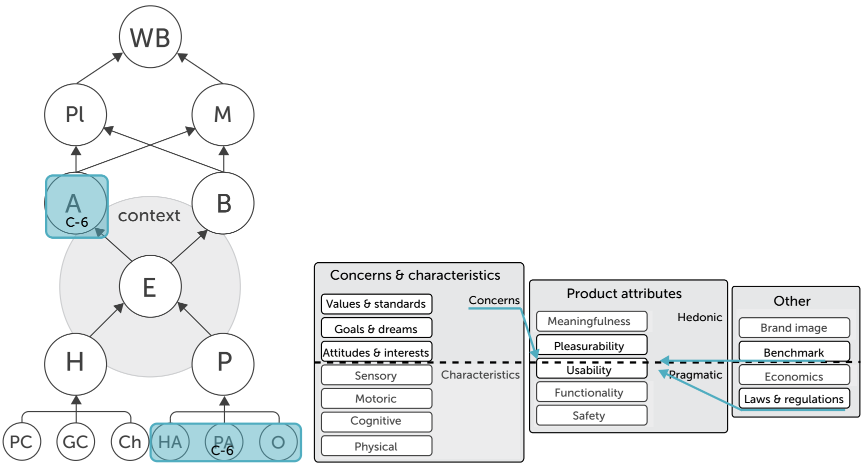


Figure 8.4 *Information from the descriptive model used in the development of the light weight replacement of the current entertainment system (Chapter six).*

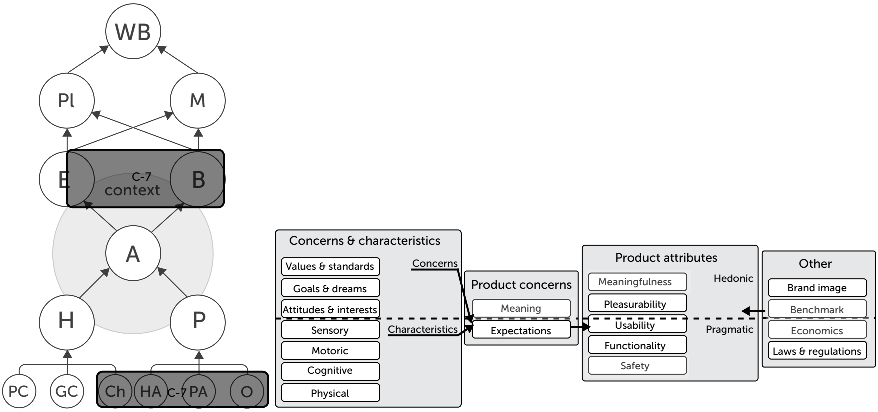


Figure 8.5 *Information from the descriptive model used in testing the active seating concept (Chapter seven).*

Is it possible to develop car interiors that show an improved comfort and pleasure experience for car drivers and passengers while remaining or reducing the costs, weight and other negative environmental effects of cars?

Three different changes focusing on better comfort and pleasure of the car interior were presented in this thesis. The light weight seat shaped by human body contour, the replacement of the current entertainment system with a projector and the extension of the massage system into an active experience are all examples of changes that do not add extra weight to the car.

The lightweight seat prototype reduces the total weight of the car. The prototype seat is 50% lighter than a current comparable BMW seat and is still experienced comfortable. Further development of this seat without adding weight is possible as well e.g. automatic adjustment based on the driving style or on the weight of the person. Of course the costs of developing a new seat should not be underestimated; new tools, new materials, testing for safety and automotive suitability and so on are of course not necessary when keeping the current seats.

The replacement of the entertainment system is another example of reducing the weight of the car. Even though the entertainment system is not contributing as much as the seat to the overall weight of the car, a reduction of approximately 1.5 kilograms per entertainment system is quite a lot in the automotive industry. The following enhancements of this system without adding extra weight are possible; in car communication where the driver is projected onto the back of the front seat, road projection, net meeting conferences, gaming and adjusting the interior to e.g. the weather circumstances. Again costs for developing and adjusting the projector for automotive use have to be taken into account. But the development of even smaller projectors (there are already telephones with integrated projectors) is continuing and the costs of these products are decreasing. The last tested prototype, the active seating, is not adding extra weight to the car. The current BMW 7 series already has a massage system in the rear seats. Adding sensors of a few grams will not increase the weight dramatically and the results of the preliminary tests on EMG show that there is an increase in muscle activity and variability. Active seating is comparable to moderate intensive activity according to the heart rate study. The driving test showed that discomfort ratings are very low for all activities (reading, laptop work, active seating and gaming on an iPad) and by using the active seating system subjects feel significantly more challenged, fit and refreshed. Here the costs of development should be taken into account as well, however, all parts used in the prototype were standard automotive parts, and therefore new tools are not needed. The extension of this system is possible without much extra weight; extra sensors in the armrest and/or under the feet can create a more active and challenging activity.

The answer to the research question based on the aforementioned discussion is that it is possible to create car interior features that contribute to the pleasure of drivers and passengers without adding extra and even reducing the overall weight of the car.

Implications for car interior development

Creating car interiors that are comfortable and pleasurable without adding extra weight or other negative effects on the environment is possible (this thesis). It is not only advantageous (e.g. Mugge, 2008; Aaker et al., 2010) for a company like BMW to create such interiors, it is a necessary element for competition on the global market (Jordan, 2000; Bonapace, 2002). To create such interiors effort in understanding the users' concerns, expectations and meaning of a car should be made. Examples of how this can be done are presented in part C chapter five. Other approaches to do this are described in literature like context mapping (Sleeswijk-Visser, 2009; Boatwright, 2010) and using personas and storyboards (e.g. Cooper et al., 2007).

It is not always necessary to start with the human being when developing innovations. Based on the experiments presented in this thesis it seems that often the O (other) factors trigger a change. The lightweight requirement for the interior is a challenge and at the same time it is an opportunity to improve the experience of the car interior. The fact that the O factors are triggers for innovation is not as passive as it may seem; the costs for developing new concepts and testing them thoroughly to make them fulfil all safety regulations, temperature tests and so on are high in the automotive industry and is only supported if there are numerous advantages. Only the intangible promise that it will increase the (very subjective) product experience is often not enough. This project contributes to make the process of creating pleasurable car interior experiences more tangible.

The light weight seat concept clearly evoked comfort experiences comparable to a seat which is rated high regarding comfort (see Figure 8.6). The seat was developed further at BMW and the body contoured seat shell was used in the concept car for Efficient Dynamics. This confirms that the seat is comfortable and fits perfect in a super sports with exceptionally low fuel consumption.

During the observations of train and lounge subjects it was clear that most people enjoy spending time talking to other people, relaxing or observing the landscape in train journeys or (unplanned) lounge situation (see Figure 8.6). A possible explanation for this is that while on your way (and not at home or work), colleagues, friends and family do not expect you to work; they know that you cannot. Therefore it is one of the few moments in busy lives to legitimately do nothing.

Almost 50% of the subjects in the projector study showed clearly that it would be fun to drive this way. They described the experience as ‘fun’, ‘interesting’ and ‘cool’. Major advantages for them were the increased involvement in the driving activity, a better back seat experience now the seat was ‘invisible’ and three persons indicated that they were pleased they did not have to lean forward or sideward for a better view.

It was clear in the active seating experiments that users had pleasure (see also Figure 8.6). The results also show that people are significantly challenged by the active seating system and feel significantly fitter and refreshed afterwards.

Figure 8.6 *From left to right; the human contour seat shell in the BMW Efficient Dynamics concept car, a current comfortable BMW car seat comparable in experience with the new light weight concept seat, relaxing people during (unplanned) lounging situation, a participant in the active seating experiment.*

It can be concluded that for a comfortable and pleasurable car interior experience it is important to know the concerns of your target group and translate these concerns into hedonic product attributes. Younger people for example are looking for more action oriented features (active seating, active involvement through road projection) whereas older users are less likely to appreciate this. In the future when autonomous driving is allowed and developed further drivers are able to do activities currently only possible for passengers. This situation already exists in traffic jams and long straight highway travels. Relaxing or activation during breaks can also contribute to the pleasurable experience of a driver. Passengers look for a convenient, comfortable, efficient and fun way to pass time. People want to do different things and the interior should enable these activities and associated postures. Getting refreshed out of a car is a good end of a pleasurable drive; Kahneman (2010) found that the last phase of an experience is remembered best therefore it is important to pay attention to this part of the drive.

Further research

This thesis is a first approach to deliberately develop car interiors that elicit comfortable and pleasurable experiences. The elements relevant for designing such interiors are discussed in part A. In part B and C several experiments are presented on how to find input for the design phase, develop comfortable, sustainable and pleasurable interiors, and assess car interiors. However, there are still some important aspects that need more research.

Firstly, the influence of time on pleasurable and comfortable products is a relevant and important aspect. In the model presented in this thesis, currently no time effects are included. The first time you drive in your new car can be very exciting and thrilling, but from experience most of us can tell that this feeling fades with time and you get accustomed to it (or even get bored). This effect can perhaps partly be avoided if the product gains a special meaning to the user or when constantly new experiences are offered. Including this item separate into the model is a worthwhile investigation. Studying literature on how to create products people love (Boatwright, 2010; Russo, 2010) or get attached to (Mugge, 2008) is a promising start for incorporating this aspect into the model.

Another interesting approach is to see whether products in general and cars in specific can contribute to the eudemonic part of well-being. This thesis focused on the hedonic aspect pleasure, however the other aspects described in the model influencing well-being (environmental mastery, self-acceptance, autonomy, purpose in life, personal growth, positive relations) are not included. Even though these are very abstract concepts to develop a product (let alone a car interior) for, a first promising attempt is described in for example the master thesis of Ruitenberg (2010). He translated the theoretic strategies of Lyubomirsky (2005) into simple tangible products that stimulate meaningful behaviour.

From the active seating and road projection studies it can also be concluded that the current studied car interiors already manage to avoid discomfort. With the developed prototypes and the described studies it was shown that the comfort and pleasure experience can be improved for the driver as well as for the passengers. However, for all concepts there is still work to do (integrating into the car for the projector, developing a more suitable game for the active seating etcetera) before they are ready to be implemented into production.

There is a need for more environmental friendly products in general and cars in specific. Vink & Hallbeck (2012) indicate "... as environmental and sustainability issues become more important, we need to reduce the weight of products like cars, train and air plane seats like in the paper of Kamp (2011) or make smaller offices or hand tools that are lightweight and consume less energy. For this reason it is important to know what the minimum requirements are for user feelings of comfort and what makes a product comfortable, which is another new area of research. The first studies in this field have already started (e.g. Franz, 2010) in defining the minimal support needed to design a comfortable lightweight car seat."

Reflection

Reflecting on all experiments and literature studied in this PhD study several lessons are identified. Firstly, reviewing the literature on well-being, pleasure and comfort and creating a descriptive model appeared to be a helpful way to structure thoughts, theories, ideas and experiments. Some differences between the concepts well-being, pleasure and comfort are clarified. Additionally, the review was supportive on how these concepts fit into a design process and in evaluating the changes made to the car interior.

Secondly, testing ideas in an early phase with relatively simple set-ups, proved to be helpful in evaluating and communicating these to other developers and managers. An example is described in Chapter six where early tests in the development of the replacement of the current LCD screens proved a creative and valuable source for new ideas. However, when testing with potential users the prototypes should have a certain level of quality. For some participants in the road projection test it was hard to judge and evaluate the entire concept without being distracted by the flaws in the prototype like the unsteady images, the hum of the projector and "add-on" look of the prototype.

Sometimes it is possible to quickly test whether the prototype quality is good enough for an evaluation by users. In most of the experiments a pilot test was done and this worked well. A pilot test with maximal five participants who are not involved in the project proved to be useful in following experiments: chosen postures during different activities, beamer in a Beamer and the effect of active seating on comfort experience. It already identified the flaws in the research set-up. Not only the quality of the prototype is then assessed, but the entire set-up like questionnaire length, activities that need to be performed, understandability of the questions asked and so on. The experiment to determine the influence of seat design on its character experience (Chapter four) was done with pilot subjects that were involved in the project and this did not yield good results; they did not identify the flaws in the questionnaire and test set-up which resulted in a false experiment. A complete new experiment had to be designed, which is described in Chapter four. The problems with the false experiment were wrong questionnaires and too many conditions.

From the observation done in trains and during leisure situations it was learned that it is not always necessary to observe users in a car setting. Looking beyond the to-be-developed product (in this case the car interior) and take on a broader approach appeared to be helpful. To identify the postures and activities in cars several different approaches were discussed and tested (video recording people in cars, interviewing people) and some carried out (photographing people in cars). Unfortunately the results were not convincing because of poor visibility (photographing car interiors from outside), unnatural behaviour (video recording people in cars) or gathering responses of people, who answer according to the interviewers expectation or try to please the researcher. Looking beyond cars in trains and leisure situations was helpful in finding the desired activities and the supports needed for the postures during these activities.

A possible critique on the projects in this thesis is that the changes made to the interior are not highly innovative. The expectation could be that changes based on the users' concerns ask for more drastic alterations of the current interiors. There are three reasons that make drastic changes difficult. The first reason is that within a company there are many stakeholders with different and sometimes contrasting interests. Engineers differ in their opinion on drastic changes from marketing managers and both are involved in developing new features. Especially because a pleasurable interior is a very subjective concept, without tangible proof it is hard to convince all stakeholders of the necessity. High level management commitment is necessary for a drastic new can interior concept.

The second reason is the user. Because cars are a well-known product, there are many expectations and deep grounded beliefs of the usability and functionality of a car. These expectations are even growing with advancing technology; people are not surprised by safety measurements like airbags and safety belts anymore, they expect them. If a drastic change ensures that a commonplace feature is no longer present, the acceptance level of the new feature is low. Even so, if a feature is offered that people do not associate with a car, like fitness exercises, it is difficult to convince people with simple prototypes. Unfamiliar, new products are not affected by these associations and expectations.

The third reason has to do with the investments. Radical changes ask for investments as making innovative product in such a way that the user can evaluate it costs design and engineering efforts and using the right materials.

Lastly, there are several disadvantages of the methods used in the discussed experiments. The Emocard method used in several researches is an easy and elegant way to ask subjects' emotions. However, Desmet (2002) indicated that the Emocard method was developed to measure emotions elicited by the produced product design. It is not clear if they are valid for asking current moods and comfort ratings. This problem is partly overcome in the studies presented in this thesis by asking a reference question; e.g. in testing the comfort of the developed light weight seat concept, subjects had to indicate their desired emotion for the perfect seat at the beginning of the test. In this way a reference for the optimal emotion was obtained.

Observing people is a good way to unobtrusively find hidden user problems and context issues. However, the interpretation is done by researchers and photographs or video recordings do not tell whether the activities were desired and/or postures were comfortable for the observed subjects. Furthermore the observations in the experiment "Chosen activities and postures during transport" covered a short period of time for each subject, it really was a snapshot. This means that activities done for a short period of time received as much attention and weight in the analysis as activities done for a longer period, making the short term activities and postures perhaps more important then they really are.

Keywords and Likert scales used in the beamer in a Beamer experiment and the influence of seat design on its character experience were useful. However, the danger of using keywords is, that too many keywords are used/questioned with too little differences in meaning (which happened in the experiment described in Chapter four before the pilot test was done). As a result some subjects might lose their attention and are more likely to give a neutral response. When only a few, clearly distinct keywords are used, then the answers are probably better considered. In Table 8.2 an overview of do's and don'ts are summarized.

There is a need for more objective measurement tools. In this project several different tools, objective as well as subjective have been used (Emocards, LPD, EMG, questionnaires), however, only subjective results are often not enough to convince decision makers to implement a (costly) innovation or start a development project.

Table 8.2 *The Do's and Don'ts learned from this PhD project.*

DO:	DON'T:
Pilot tests with five objective subjects.	Skip pilot tests or use people that are involved in the development process.
Make quick mock ups to test first ideas with the development team.	Use the same quality mock-ups for experts AND potential users.
Ask feedback from (potential) users in an early phase; make sure (with a pilot test) that the level of the prototype is good enough for users to evaluate.	Start a research too impulsive; determine clear goals and don't ask everything you can, but only what you need to know.
Use both objective & subjective methods in the development process of pleasurable products; only objective data will not give information on the human concerns and only subjective information is often not convincing for decision makers to invest.	Use only subjective or only objective data.
Set-up a questionnaire and/or research that is easy to understand questions and not boring, this results in an active involvement of subjects and data that is thoroughly considered answers	Make boring and difficult to understand questionnaires; the response rate is low and data not always useful; make experiments fun & rewarding.

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SUMMARY

One of the main challenges for car manufacturers is complying with the stringent environmental regulations without compromising driving comfort and pleasure. Reducing the overall weight of a car reduces fuel consumption and increases acceleration. However weight reduction seems in contradiction with another important aspect of car-sales; comfort. In this PhD thesis five experiments are presented proving that weight reduction and comfort improvement can go hand in hand. In these studies specific details for car interior design are described and a conceptual model is created to generalize the outcomes.

First the concepts comfort, pleasure and well-being are discussed and a model is created to describe, develop and understand products contributing to the well-being of humans. This model is illustrated in two studies focusing on improving the driving experience of the driver while reducing the overall weight of the car. In the first study a rather comfortable seat based on the human surface anatomy is developed with a new patented technique using 3d scanning of the human contour. A seat form following this contour is developed and compared to a traditional seat. Occupants liked the "contour seat", which was almost half the weight of a normal seat. In the second study an additional experiment was performed. To improve the driving experience, a seat should elicit the same feeling as the car exterior communicates e.g. a seat in a sports car should feel sporty. This study describes the contours of three different car seats objectively and records the corresponding emotional and tactile experiences of people sitting in them. The results show that hard seats with rather high wings in the seat are rated sporty and seats that are softer are rated more luxurious.

Three other studies focus on the passenger. The goal of these studies was to make the rear seat more pleasurable without adversely affecting the weight of the car. What people want to do and how they sit

during travel and leisure situations was investigated in the first study. Low and medium level activities like watching, talking/discussing and reading were observed the most. The analysis suggests a significant relationship between the activity and the position of the head, trunk and arms during transportation situations. When designing rear seats facilitating low level activities like sleeping and relaxing, adequate support for head and arms is important. For medium level activities the back seats should offer freedom of movement. The next study describes the development of a new lightweight way of entertaining the passenger in the rear seat. To create a new environment experience the road ahead was projected onto the back of the front seat. A test with a simple prototype showed that driving with road projection was rated more pleasant and the interior was experienced as less confined. However the feeling of safety decreased. In future research an improved, more automotive specific prototype should be tested on various road-conditions, but the results of this first user test are promising. Another innovation which was intended to improve the passengers' driving experience, was an extension of the current massage system. With this new system the passenger can control a game with his upper body by pressing the shoulder in the back seat. The effects of these movements were compared to normal car activities and a difference in muscle activity and variability were found. It is comparable to moderate intensive activity based on a preliminary heart rate study. The discomfort ratings of all activities are low but subjects felt more challenged during the ride and fitter and more refreshed afterwards only when using the active seating system. Although improvements for the current prototype were discovered during this study the results show that active seating has much potential for improving comfort.

Connecting the studies to the conceptual models at the beginning of the thesis leads to the conclusion that, opposed to the more general character of discomfort, comfort is very personal. Hard seats and bad smells are experienced as uncomfortable by most drivers and passengers. However it depends strongly on the personal goals, values, wishes (concerns) etc. of users whether road projection or active seating makes a car comfortable or pleasurable. So, generalisation of this statement is more difficult. Therefore the advice for product design in general and car manufacturers in particular is to look at the human concerns of the target group and try to develop hedonic product attributes to create personal products or systems that can be turned on and off. Another conclusion is that limitations in a design process, such as stringent environmental regulations in the car industry, can also be seen as great triggers for innovation. It is not only challenging for designers, but higher management is often very committed to innovations based on external forces like regulations or better competitive products. This thesis has given examples of design-ideas that can improve the comfort and pleasure experience for drivers and passengers while reducing the weight of the car and therefore contribute to environmental friendlier cars with comfortable car interiors.

SAMENVATTING

Een van de belangrijkste uitdagingen voor autofabrikanten is te voldoen aan de strenge milieuregels zonder afbreuk te doen aan het rijcomfort en -plezier. Vermindering van het totale gewicht van de auto vermindert het brandstofverbruik en verhoogt de acceleratie. Maar gewichtsreductie lijkt in tegenspraak met een ander belangrijk aspect voor de auto-verkoop; comfort. In dit proefschrift worden vijf experimenten gepresenteerd waaruit blijkt dat gewichtsreductie en comfort verbetering hand in hand kunnen gaan. In deze studies worden specifieke details voor auto-interieur ontwerp beschreven en een conceptueel model wordt gepresenteerd om de resultaten te generaliseren.

Als eerste worden de begrippen comfort, plezier en welzijn besproken en een model voor het beschrijven, ontwikkelen en begrijpen van producten die bijdragen aan het welzijn van de mens wordt gepresenteerd. Dit model wordt geïllustreerd in twee studies gericht op het verbeteren van de rijbeleving van de bestuurder waarbij tegelijkertijd het totale gewicht van de auto vermindert wordt. In de eerste studie wordt de ontwikkeling beschreven van een lichtgewicht autostoel op basis van de menselijke anatomie. Hierbij wordt gebruik gemaakt van een nieuwe gepatenteerde techniek die de menselijke contour met behulp van 3D-scanning omzet in een stoel ontwerp. Een autostoel die ontwikkelt is op basis van deze techniek wordt vergeleken met een traditionele autostoel. Participanten beoordeelden de “contour stoel”, die bijna de helft van het gewicht van een normale stoel heeft, als comfortabel. In het tweede onderzoek werd een aanvullend experiment uitgevoerd. Om de rij-ervaring te verbeteren, moet een autostoel hetzelfde gevoel ontlokken als het autoexterieur communiceert; een stoel in een sportwagen moet sportief aanvoelen om de rij-ervaring te ondersteunen. Deze studie beschrijft de contouren van drie verschillende autostoelen objectief en de bijbehorende emotionele en tactiele ervaringen van mensen die deze stoelen getest hebben werden gemeten. De resultaten tonen aan dat harde stoelen met veel zijdelingse steun als sportief worden ervaren en stoelen die zachter zijn worden geclassificeerd als luxueus.

Drie andere studies richten zich op de passagier. Het doel van deze studies was om de achterbank nog aangenamer te maken zonder het gewicht van de auto negatief te beïnvloeden. De eerste studie richt zich op de verwachtingen en wensen van gebruikers om richting te geven aan het ontwerp proces. In deze studie wordt onderzocht wat mensen tijdens reizen en gedurende het verblijf in openbare ruimtes voor activiteit willen doen en wat daarbij de houding is. Observeren, praten/discussiëren en lezen, “low/medium level activiteiten”, werden het meest waargenomen activiteiten. De analyse suggereert bovendien dat tijdens transport situaties er een significante relatie bestaat tussen de meeste activiteiten en de positie van het hoofd, de romp en de armen. Om een achterbank te ontwikkelen die geschikt is voor low-level activiteiten zoals slapen en relaxen, is voldoende steun voor hoofd en armen daarom erg belangrijk. Om medium-level activiteiten mogelijk te maken is het van belang dat de achterbank meer bewegingsvrijheid biedt. De volgende studie beschrijft de ontwikkeling van een nieuwe lichtgewicht manier om de passagiers op de achterbank te vermaken. Om een nieuwe omgevingsbeleving te creëren werd de gereden weg geprojecteerd op de achterkant van de voorstoel. Hoewel bij een eerste test met een eenvoudig prototype veel positieve commentaren gehoord werden, bleek ook dat bij het rijden met deze projectie het gevoel van veiligheid bij voornamelijk de oudere deelnemers afnam. Toekomstig onderzoek zal zich moeten richten op experimenten waarbij met een verbeterde en automotive geschikt prototype, de ervaringen op verschillende wegomstandigheden worden getest. Een andere innovatie die tot doel had rijervaring van passagiers te verbeteren, was een uitbreiding van het huidige massage systeem. Met het nieuw ontwikkelde systeem kan de passagier een spel spelen door met zijn bovenlichaam druk op de stoel uit te oefenen. De effecten van deze bewegingen werden vergeleken met normale activiteiten en een verschil in spieractiviteit en EMG variabiliteit werd vastgesteld. Bovendien blijkt uit een eerste oriënterende hartslag studie dat dit zogenaamde “active seating” vergelijkbaar is met een matig intensieve activiteit. Gedurende alle activiteiten werd er weinig discomfort ervaren, maar alleen met het "active seating" systeem voelden de proefpersonen zich aanzienlijk meer uitgedaagd tijdens de rit en fitter en verfrist na de rit. Tijdens deze studie kwamen enkele verbeteringen van het systeem aan het licht, maar de resultaten tonen aan dat "active seating" veel potentie heeft om het comfort en plezier te verbeteren.

De belangrijkste conclusies zijn dat in tegenstelling tot het algemene karakter van discomfort, comfort persoonlijker is. Harde stoelen en vieze geuren worden als niet comfortabel ervaren door bijna alle bestuurders en passagiers. De vraag of weg-projectie of "active seating" het comfort en/of plezier in het algemeen verhoogd is sterk afhankelijk van de persoonlijke verwachtingen, waarden, wensen en ervaringen van bestuurders en passagiers. Daarom is het advies voor product ontwerpen in het algemeen en voor autofabrikanten in het bijzonder om naar de persoonlijke belangen van de doelgroep te kijken en zo hedonistische producteigenschappen of systemen die kunnen worden in-en uitgeschakeld te ontwikkelen om persoonlijke producten te creëren. Een andere conclusie is dat de beperkingen in een ontwerpproces, zoals de strenge milieuregels in de auto-industrie, belangrijke drijfveren voor innovatie zijn. Het is niet alleen uitdagend voor ontwerpers, maar het management is vaak erg gemotiveerd om innovaties op basis van externe krachten, zoals regelgeving of betere concurrerende producten, te financieren en te ondersteunen. Dit proefschrift geeft voorbeelden van ontwerp-ideeën die het comfort en plezier voor bestuurders en passagiers kunnen verbeteren terwijl het gewicht van de auto verminderd wordt en dus bijdragen aan milieu-vriendelijkere auto's met comfortabele interieurs.

CURRICULUM VITAE

Irene Kamp (Rotterdam, 1982) completed her secondary school education at the Coornhert Gymnasium in Gouda and subsequently started her studies at the Delft University of Technology, faculty of Industrial Design Engineering. In 2006 she completed her graduation project "the future comfortable office chair" at Interstuhl Büromöbel in Tieringen, Germany, for her masters Integrated Product Design. After graduation she started as a freelance designer and researcher. During this period she cooperated with different companies and institutions such as TNO, TU Delft and Senz Umbrellas. Her main activities involved developing prototypes and conducting comfort related research in the field of aircraft interiors and consumer products. Besides working as a freelance designer and researcher she was part of the Health, Safety, Security and Environment team for Exploration and Production at Shell, Rijswijk, the Netherlands.

In 2009 she started her PhD project at BMW in Munich, Germany. At BMW she developed and studied car interior features that increase the pleasure and comfort experience of the driver and passengers without adversely affecting the weight of the car. She organized and participated in creative workshops as well as user centred research. At BMW she had the opportunity to combine her main interests: user centered design research and product development in industry in order to assist design professionals create successful, competitive products without compromising and possibly improving the well-being of people.

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