Applied Ergonomics 43 (2012) 329–335

Contents lists available at ScienceDirect

Applied Ergonomics

journal homepage: www.elsevier.com/locate/apergo

The influence of car-seat design on its character experience

Irene Kamp [a,b,*]

[a] BMW AG Forschungs- und Innovationszentrum, Knorrstrasse 147, D-80788 München, Germany
[b] Faculty of Industrial Design Engineering, Delft University of Technology, Landbergstraat 15, 2628 CE Delft, The Netherlands

ARTICLE INFO

Article history:
Received 12 March 2010
Accepted 31 May 2011

Keywords:
Car seats
Emocard
Tactile experience
Comfort
Seat contour

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.

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., in this issue; Zenk et al., in this issue). 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

* Corresponding author. BMW AG, Forschungs- und Innovationszentrum, Knorrstrasse 147, D-80788 München, Germany. Tel.: +49 89 382 55118; fax: +49 89 382 45399.
E-mail address: Irene.Kamp@bmw.de.

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doi:10.1016/j.apergo.2011.06.008

Fig. 1. New car-seat concept based on the human body contour developed at BMW (Franz et al., submitted for publication).

et al., 2006; Franz et al., 2008, 2011; Frohriep and 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 favored. 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 Fig. 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?

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.

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 Fig. 5), one seat that is less contoured (contour 2, the middle shade in Fig. 5) used in luxurious cars and a new seat concept based on the human body contour (contour 3, the darkest shade in Fig. 5). 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 (Fig. 2a);
- *Steepness of back- and seat wings*. To determine the steepness, the angle of the wings is measured ($\tan\alpha =$ height wing/width

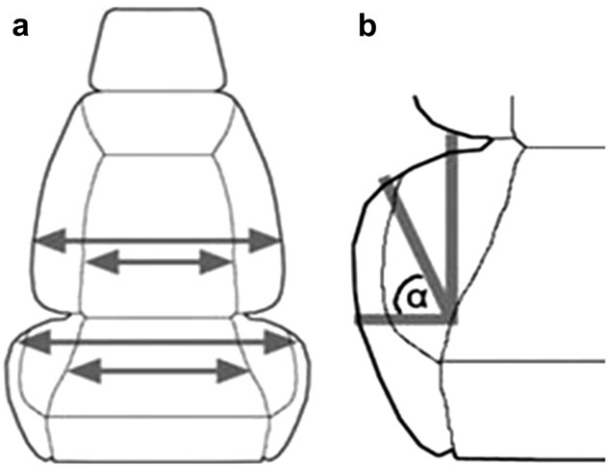

Fig. 2. a. Measurement of backrest and seat width. b. Measurement of steepness of wings.

Fig. 3. 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.

wing) (see Fig. 2b) at the place where the wings was the highest;
- *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.

2.2. Subjective research

2.2.1. 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.

2.2.2. 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°) and seat angle (14°), which resembles the optimal seating angle found by Harrison et al. (2000).

2.2.3. Set-up

The subjective validation 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 set-up. The subjective part of the research was carried out in a laboratory environment. In the laboratory three car seats formed a circle (Fig. 3). To avoid that the appearance of the seats influenced the comfort experience of the participants, all seats were covered with a thin blanket.

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 non-verbal 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 Fig. 4). 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.

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.

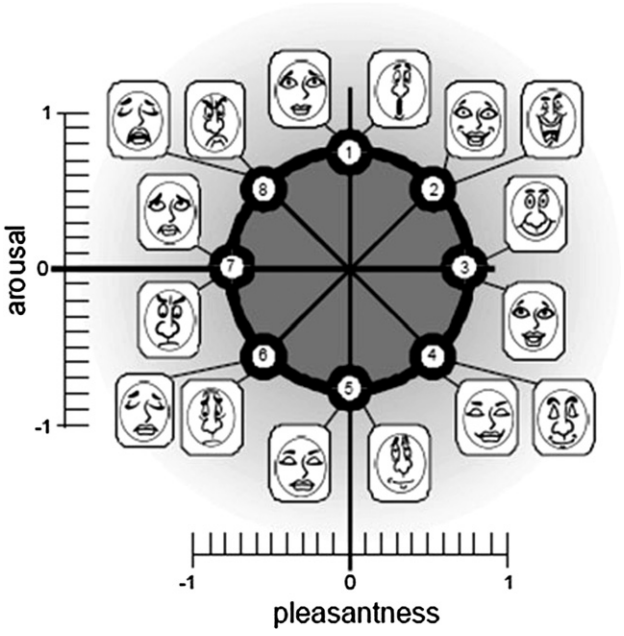

Fig. 4. The 16 Emocards placed on Russell's circumplex of emotions.

Table 1
Contour description of the seats.

	Seat width (cm)	Seat wing (°)	Seat 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)	Backrest wing (°)	Backrest contour (seams & lordosis)	Foam hardness backrest
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 Fig. 2)	6 kPa 25 mm

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).

3. Results

3.1. Objective – seat contour

The contours of the three car seats used in this experiment are described in more detail in Table 1. Fig. 5 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. (submitted for publication).

3.2. Subjective – comfort experience

3.2.1. 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 Fig. 6). The Emocard chosen by 71% of the participants shows a pleasant emotion, but medium level of arousal.

3.2.2. The overall elicited emotion per car seat

Participants rated the overall elicited emotion per seat. In Fig. 7 the results are graphically presented for all seats, representing only the desired emotions for the perfect seat (see Fig. 6). The intensity of the color 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%).

3.2.3. Which contour is the most…?

Each seat had to be rated separately on the following feelings: comfortable, luxurious, sporty, protected, and relaxed. In Table 2 the results are shown of the seats that were significantly experienced as comfortable, protected, sporty, relaxed and luxurious.

3.2.4. Positive and negative remarks

In the questionnaire, participants could indicate the positive and negative seat aspects and optionally add comments. Table 3 gives an overview of the most often given remarks (positive and negative).

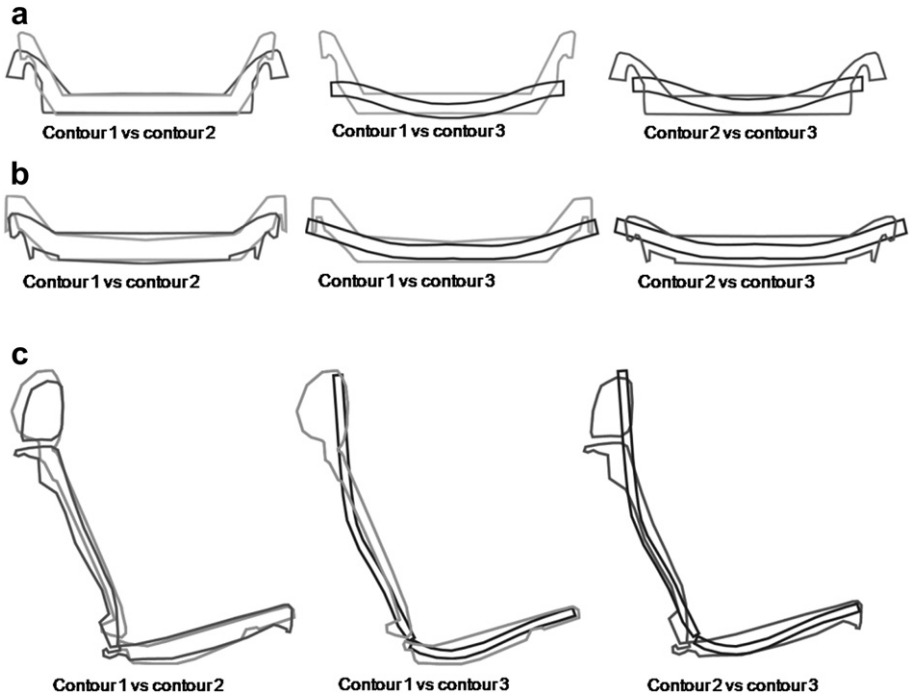

Fig. 5. a. Horizontal cut through the backrest to see the difference in contours. b. Horizontal cut through the seat surface to see the difference in contours. c. Vertical cut through the seat to see the difference in contours.

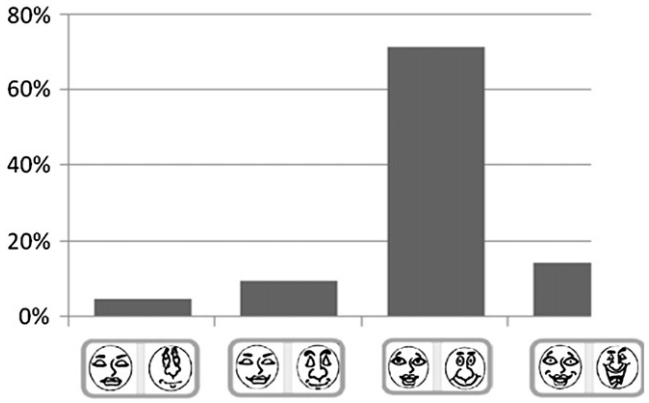

Fig. 6. Desired emotion for perfect car seat.

3.2.5. 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 Fig. 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 Fig. 8).

3.2.6. Desired seat

When the participants had to choose one of the tested seats for their own car, contour 1 (38%) was favored 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.

3.2.7. 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. Fig. 9 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. 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. (in this issue) 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.

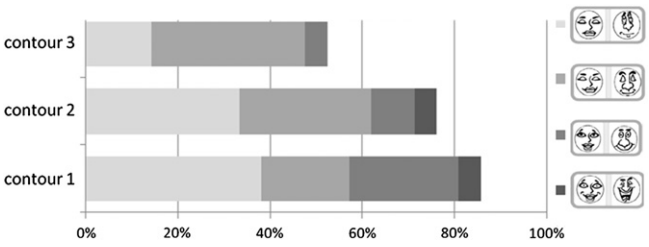

Fig. 7. Overview of all car seats and their overall positive elicited emotion.

Table 2
Overview of significant relation between seat contour and experience keyword.

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

Table 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 too little side support

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 ingress 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.

4.2. 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

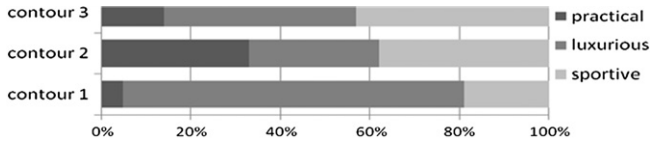

Fig. 8. Overview of car-seat contour per expected car segment.

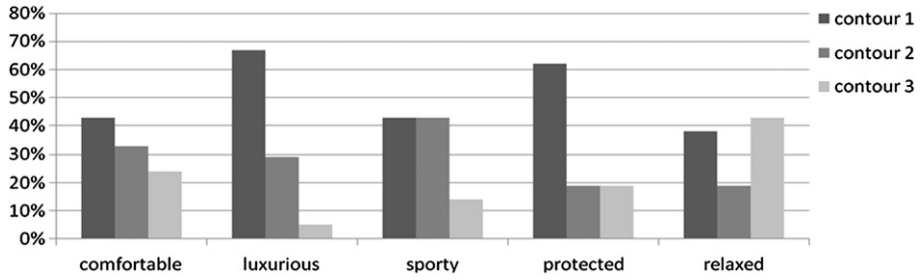

Fig. 9. Overview of mentioned seat contours per keyword.

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. (in this issue) and Vink et al. (submitted for publication), 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. (in this issue) 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.

Table 4
Overview of significant relation between seat aspect and elicited feeling.

Segment	Aspect	Significant ($p \leq 0.05$)
Comfortable	Width	No, $p \leq 0.487$
	Contour	No, $p \leq 0.6221$
	Steepness wings	No, $p \leq 0.487$
	Hardness	No, $p \leq 0.3575$
Luxurious	Width	**Yes, $p \leq 0.001086$**
	Contour	No, $p \leq 0.1094$
	Steepness wings	**Yes, $p \leq 0.001086$**
	Hardness	**Yes, $p \leq 0.001526$**
Sporty	Width	**Yes, $p \leq 0.01011$**
	Contour	**Yes, $p \leq 0.04248$**
	Steepness wings	**Yes, $p \leq 0.01011$**
	Hardness	**Yes, $p \leq 0.04248$**
Protected	Width	No, $p \leq 0.1984$
	Contour	No, $p \leq 0.1984$
	Steepness wings	No, $p \leq 1$
	Hardness	No, $p \leq 0.05688$
Relaxed	Width	No, $p \leq 0.1984$
	Contour	No, $p \leq 0.2439$
	Steepness wings	No, $p \leq 0.1984$
	Hardness	No, $p \leq 0.8536$

5. 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.

6. Statement on conflicts of interest by the authors

This paper is part of the PhD research of Irene Kamp and has an independent status. The scientific quality of the study has the highest priority and an independent committee of the Delft University of Technology has checked the scientific quality. The research is not influenced by commercial goals. The goal of this paper was to define the comfort experience of the new seat with respect to other available seats. The outcome of the study is used by BMW in the decision how to develop this seat further. This decision on further development has not been made at the date the paper is submitted and could therefore not have influenced the outcome of the study.

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