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How Does the Seat Cover Influence the Seat Comfort Evaluation?

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Abstract. This study investigates the tactile perceived influence of seat covers. Two identical BMW 3-Series seats are used, one with a leather cover and one with a fabric cover. Thirty healthy subjects participated in an experiment rating the tactile perceived properties of the seats while blindfolded. A discomfort test, a word pair rating and the overall experience of the seats were examined. The study has shown that not only the foam properties and the contour of the seat influences the seat characterisation but also the seat cover material. The leather and the fabric seats were characterised different, but the pressure distribution did not show so much differences. Furthermore, the perceived differentiation of the seats are distinctive for the seat pan and for the backrest. Therefore, further research is needed to investigate other characteristics of the seat like shear force related to various cover properties in combination with different seat components and contour combinations.

Keywords: Seat cover · Seat comfort · Cover materials

1 Introduction

The best time to pick someone's pocket is, when a person reads a book or has another challenging visual search task to perform. The study of Murphy and Dalton [14] has shown that people's ability to notice tactile stimuli is reduced when they are carrying out a demanding visual task. In contrast, the tactile information enables blindfolded people to perceive the environment [17]. The interaction of the senses and the environment affect the tactile perception and the resulting (dis-)comfort rating [18], especially while sitting in a seat with a huge number of contact area. For a subject based evaluation of seat properties it is important to emphasize the tactile senses and minimize all other environmental factors. Schmidt and Thews [16] describe the four most investigated tactile receptors in the skin: Merkel disks for the pressure, Ruffini corpuscles for the stretch and shear stresses, the Meissner's corpuscles for the information about tactile and sensitive changes and the Pacinian corpuscles for vibration. Especially automotive seats have various attributes and shapes depending on diverse factors. Luxury seats are characterised more flat and soft, sporty seats more hard with

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pronounced bolsters [8]. The different seat contours and foam characteristics affect the resulting seat-human interaction while causing individual deformation of the skin and tissue recorded by the tactile mechanoreceptors. The resulting interaction area depends on the individual person sitting in the seat as well as on the seat characteristics causing individual tactile stimuli and a personal subjective (dis-)comfort rating.

Based on the described context research was done to design comfortable seats. The shape and the contour of a seat is an often investigated factor to improve the comfort. Franz et al. [5] developed a light weight seat based on the human contour. Kamp [9] compared the developed seat [5] to existing seat concepts. Kolich [11] compared five seats with different geometry characteristics, concluding that the seat designer should be aware of ergonomic relations. Additionally, the literature mentions ergonomic aspects investigating the right sitting and seat angles with appropriate seat dimensions [15].

The most investigated tactile receptor related to comfort is the pressure distribution. De Looze et al. [2] illustrates and concludes in a literature review that a well-distributed pressure in a seat cushion is linked to the discomfort perception. Mergl [12] and Zenk et al. [19] defined an ideal pressure distribution and Kilinscoy [10] confirms this ideal pressure distribution for rear seats. In comparison, the shear force and friction perception are not investigated sufficiently. Goossens [7] considers various seat pan materials measuring the outcome shear forces and Grujicic et al. [6] correlates a higher cover friction to higher shear forces based on simulative results.

There is also a limited group of studies examining the link between the comfort perception, the tactile perception and the seat properties. Most of these studies focus on the foam properties. Ebe and Griffin [3, 4] investigate the effects of various foam characteristics related to the comfort. Andreoni et al. [1] used a large number of seats with different foam characteristics analysing pressure and comfort, defining a correlation between the shape of the human body and the interface pressure. Zhang et al. [20] illustrates that the discomfort perception is associated with various wordings, like posture, pain, stiffness or strained feeling, which implements that the comfort should also be related to other perceptions like the shear force and additional seat components like the seat cover.

There is to our knowledge no study which considers the influence of the seat cover properties on the perceived comfort, even though it is the top seat layer that has most direct interaction with the human body. The aim of this paper is to highlight the tactile perceived seat cover properties of different seats. Therefore, the research question of this study is raised to: Does a person perceive a difference between two seats with different cover materials and which factors influence the differentiation of these seats?

2 Method

To answer the research question, two identical seats with different seat cover material properties were mounted on a setup, compared and rated by thirty different test persons. The participants performed the experiment blindfolded in order to focus on the tactile perceived properties of the seats.

2.1 Participants

Thirty healthy subjects, twenty males and ten females, participated in the experiment. The mean height of the participants was 1.73 m (1.55 m–1.94 m) with a mean weight of 70.9 kg (47 kg–110 kg). On the torso, the participants either wear a pullover (30%), a shirt (63%) or a dress (6.7%); on the bottom either jeans (70%), leggings/tights (13%), cloth pants (13%) or sweatpants (3%).

2.2 Seats

Two basic BMW 3 Series seats are used for the research with a simple, not distinctive contour in order to emphasize the properties of cover materials while sitting in the seat (see Fig. 1). Furthermore, the seat layout is simple, consisting out of a seat frame, foam, heating mat and cover. The seats only differ in cover material: leather and fabric. Both seats are produced and assembled in the same factory on the same day and during a similar period fulfilling all specified requirements of the manufacturer. The foam hardness of the seat pan is 6 kPa in the main surface and 12 kPa in the bolsters. The backrest has a foam hardness of 5 kPa in the main surface and 10 kPa in the bolsters.

Fig. 1. Setup of the experiment. Leather and fabric seat mounted next to each other in the H-Point-Position

2.3 Setup

Figure 1 illustrates the research setup. The seats are mounted in the H-Point position on a frame next to each other. In front of the seats a platform is mounted for a reproducible positioning of the heels. The seats are placed behind a wall in order to prevent a visual impression of the seats before the test. Considering the differing heat transfer coefficients of leather and the fabric material, this could create a different temperature perception of the materials, both seat were pre-heated to human temperature by having persons sit on it before starting the experiment. The seat position of both seats is not changed.

2.4 Procedure

Before carrying out the test, anthropometric measurements are performed. The subjects are calibrated while sitting on the anthropometric chair for 3 min according to a procedure described in Molenbroek et al. [13]. During calibration, the participant is informed about the questionnaire and is blindfolded during the entire experiment to exclude visual impressions. The participant also did not get any information about the seats. The seats are named during the experiment: seat one and seat two. The order of naming the leather and the fabric seat, seat one and seat two, is changed systematically. The experiment always begins with seat number one. During the experiment the skin of the subject is not allowed to contact directly with the seat surface. An assistant guides the participants to the research setup and helps fill out the questionnaire. Initially each participant may rate the discomfort of both seats (leather and fabric) on a LPD body scale (0–6).

Differentiation of the Seat Characteristics Using Various Covers. In order to investigate how the seat cover influences the perceived experience, the participants have to assess the leather and the fabric seat with the following word pairs:

> *soft-hard; stiff-elastic; close-wide; formative-loose; sportive-lame; supporting-unstable; loose-firm, slippery-coarse*

The word pairs are rated on a Likert scale (−3, −2, −1, 0, 1, 2, 3). The negative rating represents a tendency to the left word pair characterisation, zero is neutral and a positive rate outlines a tendency to the right characterisation of the word pair. For each word pair, the participant is allowed to change seats once, after completing the rating for the current seat. The participant switches to the next word pair if the previous word pair is rated for both seats. The seat pan and the backrest are rated separately.

Overall Impression of the Seats. The subject assesses and characterises the overall impression of the leather and fabric seat with one of the following descriptions:

> *restricted; cosy, sporty; protected, relaxed*

The participant also has to estimate, separately for the seat pan and backrest, whether the contour of the compared seats is the same or different. The participant also has to conclude which of both seats is their favorite. Finally, the pressure distribution of each participant is recorded for the fabric and the leather seat with a FSA Pressure Measurement System from Force Sensing Array (FSA®). The maximum pressure is determined using the post processing tool of the FSA pressure mapping software and the mean maximum pressure of all participants is calculated by Microsoft Excel.

2.5 Statistical Analysis

The statistical analysis of the word pair data is performed using the SPSS-Software. The chi-square distribution test is used to prove an unspecified distribution of the data. A Wilcoxon rank test with a statistical significance of $\alpha < 0.05$ is used for the seat pan and backrest separately, to analyze whether the word pair ranking of the seats differ between the two cover materials.

3 Result

3.1 Subjective Evaluation

The initially performed discomfort rating using a LPD-body map has shown that none of the participants has discomfort complains for neither the leather nor the fabric seat.

Differentiation of the Seat with various Seat Covers. Figure 2 shows the results of the perceived seat pan rating. The left part (a) of the figure describes the results of the rated word pairs for the leather and the fabric seat pan. The mean rating of the leather seat pan differs to the mean rating of the fabric seat pan for every word pair. The right part (b) illustrates a statistical overview of the rating results in boxplots for each word pair and material (leather and fabric). The Wilcoxon signed-rank test has shown that the cover material significantly affects the perception of hardness (**soft-hard: $z = -2.632$, $p = 0.008$**) with an effect size of 0.48, the perception of the elasticity of the material (**stiff-elastic: $z = -3.147$, $p = 0.002$**) with an effect size of 0.57 and the perception of enclosing (**formative-loose: $z = -2.032$, $p = 0.042$**) with an effect size of 0.37. The leather seat pan was assessed to be neutral in hardness (mean value: 0.033, std. dev. = 1.60), stiff (mean value: −0.9, std. dev. = 1.24) and nearly neutral due to the enclosing perception (mean value: 0.2, std. dev. = 1.47). The mean rating of the fabric seat characterises the seat pan as soft (mean value: −1.2, std. dev. = 1.20), elastic (mean value: 0.522, std. dev. = 1.25) and formative (mean value: −0.6, std. dev. = 1.25).

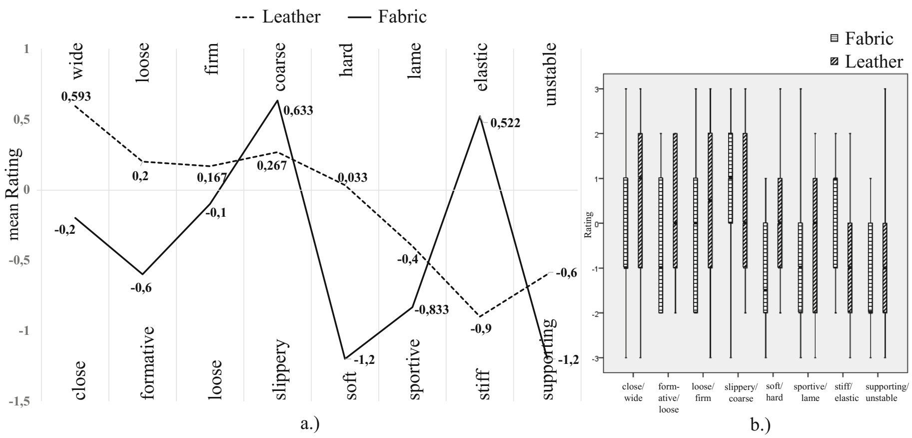

Fig. 2. Comparison of the subjective seat pan ratings. (a) illustrates the mean rates of the word pairs for the leather and fabric cover material. (b) presents the statistical analysis of the ratings in boxplots.

Figure 3 shows the results of the rated word pairs for the backrest. The left part of Fig. 3 represents the differing mean rating of the leather and fabric backrest. The right part of the figure (b) emphasizes the statistical distribution of the leather and fabric backrest results. The Wilcoxon signed-rank test illustrates that the cover material significantly influences the differentiation between both backrests perceiving the elasticity of the material **(stiff-elastic: z = −2.755, p = 0.006)** with an effect size of 0.50, perceiving the surface roughness **(slippery-coarse: z = −2.461, p = 0.014)** with an effect size of 0.45, perceiving the breadth of the backrest **(close-wide: z = −2.147, p = 0.032)** with an effect size of 0.39 and perceiving the support of the backrest **(supporting-unstable: z = −1.959, p = 0.05)** with an effect size of 0.36. The backrest of the leather seat was rated stiff (mean value: 0.567, std. dev. = 1.33), slippery (mean value: −0.233, std. dev. = 1.59), nearly neutral for the backrest breadth (mean value: 0.133, std. dev. = 1.72) and unstable (mean value: 0.667, std. dev. = 1.37). The fabric backrest was characterised as elastic (mean value: 0.467, std. dev. = 1.10), coarse (mean value: 1.067, std. dev. = 1.53), close (mean value: −0.933, std. dev. = 1.55) and supporting (mean value: −1.367, std. dev. = 1.10).

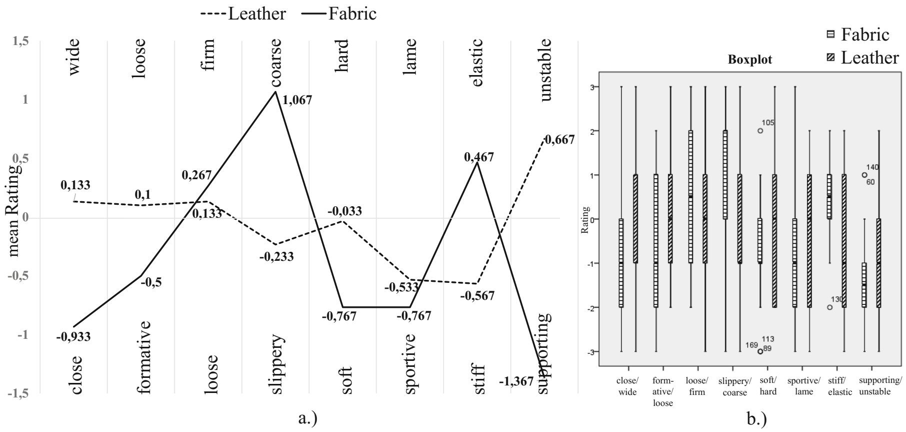

Fig. 3. Comparison of the subjective backrest ratings. (a) illustrates the mean rates of the word pairs for the leather and fabric cover material. (b) presents the statistical analysis of the ratings in boxplots.

General Result. 25 (83%) of thirty (N = 30) participants are convinced that leather and fabric backrests have a different shape. For the seat pan 19 (63%) out of 30 participants assessed the shape of the seat pan as different. Figure 4 illustrates how the participants characterised the seats. For the characterisation of the fabric seat the participants have chosen all offered descriptions equally. The leather seat was mostly rated as relaxed, cosy and sporty. 16 of the participants preferred the leather seat, whereas 14 of the participants preferred the fabric seat.

Pressure Mat. Figure 5 shows the maximum pressure of the thirty participants for the leather and fabric seat, separated for the backrest and the seat pan. The mean max. pressure of the leather seat pan (mean = 1.19 N/cm^2, std. dev. = 0.54 N/cm^2) is 0.19 N/cm^2 higher than for the fabric seat pan (mean = 0.99 N/cm^2, std. dev. = 0.37 N/cm^2). The maximum mean pressure for the leather and the fabric backrest is in both seats nearly the same (leather: mean = 0.58 N/cm^2, std. dev. = 0.22 N/cm^2, fabric: mean = 0.62 N/cm^2,

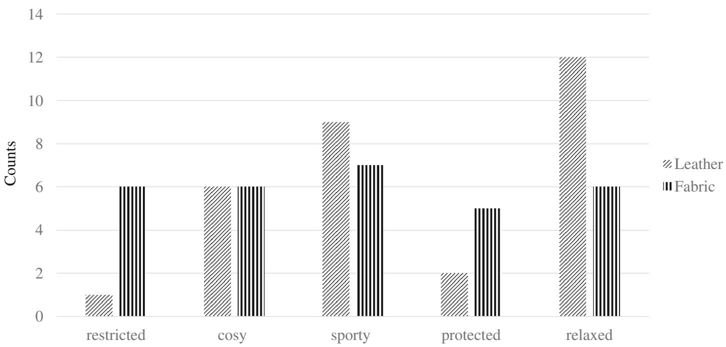

Fig. 4. Overview of the subjective characterisation of the leather and the fabric seat.

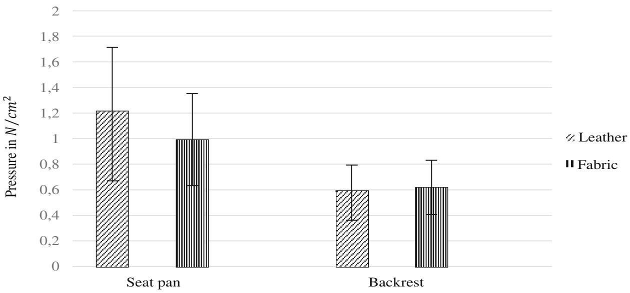

Fig. 5. Overview of the mean max. pressure and std. dev. for seat pan and backrest.

std. dev. = 0.21 N/cm^2). The heaviest person (110 kg) has the maximum pressure points in the fabric (max. pressure = 1.76 N/cm^2) and not in the leather seat pan but the lightest person (47 kg) has the maximum pressure points in the leather seat pan (max. pressure = 1.07 N/cm^2).

4 Discussion

The study has shown that not only the shape, contour and foam influence the comfort of a seat, but also the properties of the cover materials matter. This is in line with previous studies which confirmed that the stiffness, posture and hardness influence the discomfort of a seat. The results of the first test describe that no discomfort in the seats is felt. The other results of this study show the importance of the seat cover material as a component influencing the seat characteristics. Although, the seats were the same apart from the cover material, both were characterised totally different in the subjective rating of backrest and seat pan.

The study also illustrates that the tactile perceived interaction parameters of the seat pan differ from the backrest. The subjects characterised the backrest and the seat pan using different descriptions of perception. The difference in the cover material of the seat pan is perceived due to the factors elasticity, hardness and enclosing factors whereas the backrest differentiates in the perceived elasticity, surface properties, support and breadth of the backrest. The elasticity is the only perception, which is perceived in seat pan and backrest. The rest of the perceived characterisations is different for the seat pan and backrest. On one hand this illustrates that the elasticity of the cover material is an essential factor for the seat charactersation. On the other hand this example emphasises that the backrest and the seat pan is perceived with a totally different focus. The factor 'pressure' is dominant for the seat pan, but not for the backrest, whereas the surface properties are only dominant for the backrest. It can be assumed that with less load the surface properties get more focus. It is noteworthy that the participants had various clothes on their bodies, nevertheless, the results of the study can be seen as significant. Therefore, this relations should be considered when designing seats. Higher bolsters should increase the effect of the various cover material properties (elasticity, surface properties etc.), directly and indirectly. Directly means stretching the Ruffini corpuscles, indirectly stands for influencing the sensitivity of the Merkel disks. Additionally, the elasticity of the cover material influences the mechanical indentation process of the person and effects the workspace of the underlying seat components, like the foam and the seat suspension with consequences to the resulting posture and pressure distributions of the passenger. Therefore, further investigations needs to be done to analyse the effects of the cover materials, in interaction with various foams and contours, on the perceived seat perceptions.

The results of the pressure measurements do not correlate with the results of the perceived seat characterisations. The difference of the mean maximum pressure in the seat pan and backrest for the leather and the fabric seat is much smaller compared to the large rating differences of the perceived seat characterisations of the leather and fabric seat. It can be assumed that additional to pressure, further tactile parameters like the shear force or elongation should be investigated for a better matching of objective measurements and subjective rated perceptions.

The well-balanced distribution of the fabric seat characterisations (see Fig. 4) shows that the seat adapts well to various percentiles who associate this feeling with a wide spectrum of descriptions. The leather does not adapt as good to the specific percentile shapes. Therefore, a more focused selection of the characterisation is associated.

5 Conclusion

This study shows that a seat cover has an important effect on how a seat is experienced. For instance, the fabric covered seat is experienced as more elastic, less wide, less slippery and less unstable than a leather cover in the backrest and in the seat pan the fabric is characterized as less stiff and less hard. The pressure distribution does not show so much differences. So, other factors might play a role here, which should be studied further.

References

1. Andreoni G, Santambrogio GC, Rabuffetti M, Pedotti A (2002) Method for the analysis of posture and interface pressure of car drivers. Appl Ergon 33:511–522
2. de De Looze MP, Kuijt-Evers LFM, van Dieen J (2003) Sitting comfort and discomfort and the relationships with objective measures. Ergonomics 46(10):985–997
3. Ebe K, Griffin MJ (2000) Quantitative prediction of overall seat discomfort. Ergonomics 43 (6):791–806
4. Ebe K, Griffin MJ (2001) Factors affecting static seat cushion comfort. Ergonomics 44 (10):901–921
5. Franz M, Kamp I, Durt A, Kilincsoy Ü, Bubb H, Vink P (2011) A light weight car-seat shaped by human body contour. Int J Hum Fact Model Simul 2(4):314–326
6. Grujicic M, Pandurangan B, Xie X, Gramopadhye AK, Wagner D, Ozen M (2010) Musculoskeletal computational analysis of the influence of car-seat design/adjustments on long-distance driving fatigue. Int J Ind Ergon 40(3):345–355
7. Goossens RHM (2001) Shear stress measured on three different cushioning materials. Delft University of Technology
8. Kamp I (2012) The influence of car-seat design on its character experience. Appl Ergon 43 (2):329–335
9. Kamp I (2012) Comfortable car interiors. Experiments as a basis of car interior design contributing to the pleasure of the driver and passenger, pp 88–105
10. Kilincsoy Ü, Wagner A-S, Vink P, Bubb H (2016) The Ideal pressure distribution for SUV and sedan rear seats
11. Kolich M (2003) Automobile seat comfort. Occupant preferences vs. anthropometric accommodation. Appl Ergon 34(2):177–184
12. Mergl C (2006) Entwicklung eines Verfahrens zur Optimierung des Sitzkomforts auf Automobilsitzen. Dissertation, Technischen Universität München
13. Molenbroek JFM, Albin TJ, Vink P (2017) Thirty years of anthropometric changes relevant to the width and depth of transportation seating spaces, present and future. Appl Ergon 65:130–138
14. Murphy S, Dalton P (2016) Out of touch? Visual load induces inattentional numbness. J Exp Psychol Hum Percept Perform 42(6):761–765
15. Reed MPS, Schneider LW, Ricci LL (1994) Survey of auto seat design recommendations for improved comfort. University of Michigan
16. Schmidt RF, Thews G (1980) Physiologie des Menschen. Springer, Berlin
17. Wong M, Gnanakumaran V, Goldreich D (2011) Tactile spatial acuity enhancement in blindness: evidence for experience-dependent mechanisms. J Neurosci 31:7028–7037
18. Vink P, Hallbeck S (2012) Editorial: comfort and discomfort studies demonstrate the need for a new model. Appl Ergon 43(2):271–276
19. Zenk R, Mergl C, Hartung J, Sabbah O, Bubb H (2006) Objectifying the comfort of car seats. SAE International
20. Zhang L, Helander MG, Drury CG (1996) Identifying factors of comfort and discomfort in sitting. Hum Fact 38(3):377–389