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Anton Fuchs
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Future Interior Concepts

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Preface

Today's vehicle occupants place increasingly challenging demands on the interior of the vehicle cabin. Comfort—with all its peculiarities, such as thermal, acoustic, haptic, olfactory, safety and security and trust in new technologies and how to interact with the car—is for sure the central momentum for car manufacturers to differentiate, since cabin comfort is the first impression when buying a car and is most disturbing and annoying, when expectations and needs are not met.

Thus, future interior design requires to deal with a large number of technical fields, influencing factors, perception and psychology, covering, e.g., digitalization and human–machine interfaces, communication, smart surfaces and sensors, passenger monitoring, new vehicle safety aspects, sustainable materials, etc. A comprehensive investigation of the interior concepts also comprises highly subjective parameters such as well-being, the effect of colors or sounds or trust.

New requirements for multi-functional and adaptive spaces that "follow" the driver and passenger foster innovations. When a driver changes seat position in future highly automated driving mode, it requires heating ventilation and air conditioning (HVAC) systems, restraint and safety systems, in-vehicle entertainment and communication, operation and control systems, etc. to react and adapt as well.

The "comfortable vehicle" includes a wide range of topics and domains from thermal comfort, noise, vibration, and harshness (NVH) and driver assistance systems and requires innovative thoughts from different directions.

Supported by improving comfort in our daily work and leisure time in fields such as ambient assisted living, building automation, or smartphone technology, the expectations concerning comfort have increased as well and gained specific importance in mobility. Automated driving—and autonomous driving—will make the passenger compartment even more a place of relaxing transport, communication, and efficiently working in the future.

Defining "comfort" typically includes rather subjective impressions. It is mostly associated with the feeling of relaxation and well-being. Developing the vehicle comfort for a large group of customers and future passengers means to design a well-balanced sum of individual aspects and measures—each of them with individual weight but all relevant (a car might also perceive comfort needs of its individual drivers and passengers and may adapt to it).

What will be the value of a perfect thermal comfort in the passenger compartment, when it is distorted by an annoying fan noise or an undesirable smell of the HVAC system? And so would the insufficient ease of use of a human–machine interface (HMI) reduce the comfort impression of advanced driver assistance systems (ADAS).

This book will highlight selected fields and development methods for future interior concepts in automotive industry, VIRTUAL VEHICLE, and institutions contributing to this book are researching. It comprises a chapter on seat–human interaction and perception, vibro-acoustic metamaterials for improved interior NVH performance, active sound control, psychological HMI aspects, and investigations for the vehicle interior as well as a comprehensive thermal management and comfort consideration.

Graz, Austria
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Seat-Human Interaction and Perception: A Multi-factorial-Problem

M. Wegner, C. Reuter, F. Fitzen, S. Anjani, and P. Vink

Abstract This study investigates the tactile perceived seat-human interaction of four types of BMW 5-series seats with the same foam properties and contours but different seat cover and seat suspension properties; 38 healthy subjects participated in an experiment rating and ranking the tactile perceived properties of the seats while blindfolded. A discomfort test, a seat characterizing rating on a scale of word pairs, and the overall experience of the seats were examined in four different sitting positions. The results of the experiment were related with the outcome of an objective measurement method: a pressure measurement mat and the measurement tool of Wegner et al. [19]. The study showed that the perception of the surface while interacting with the seat is independent from the sitting position. In contrast, the perception of the hardness and the elasticity of the seat is position-dependent. The results of the seat characterization are in line with the results of the measurement tool of Wegner et al. [19]. Further research is needed to investigate the mutual interdependence of the various measurement points of the measurement tool and to improve the prediction accuracy of the seat characteristics.

Keywords Pressure measurements · Shear force · Discomfort · Seat perception

1 Introduction

Most individuals, and particularly those with sedentary jobs, sit for nearly ten hours each work day and eight hours during their own, independent leisure time [14]. Typically, as long as the individual feels comfortable and supported, the seat on which an individual is seated is of little importance. Regardless of what seat and

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what position a person takes, the seat or chair should allow to vary and shift the posture easily. In this context Sammonds et al. [16] showed that movements and seat fidgets correlate with the discomfort rating of a seat. The micro and macro movements rise over the duration of time as well as the poor subjective discomfort ratings.

The development of seats for automobiles that allow passengers to move and switch to various positions from sitting through to lying is crucial to the automotive industry. This could become even more important in autonomous driving cars as more seat positions will be possible when there is no driving task. For an individual to be comfortable in the car, a car seat must support the passenger in a dynamic driving situation but moreover provide enough space for postural changes in various loading situations. Hence, it should be considered to change loading of the area of the seat being in contact with the passenger as well as the interaction area including various sensitivity areas. A study by Vink and Lips [18] proved that the pressure sensitivity of the area touching the shoulder and the area touching the front of the cushion close to the knees is significantly higher than all other body areas in contact with the seat. Furthermore, some parts of the body need more support than others. Biedermann and Guttmann [1] claimed, inter alia, that the natural physiological curve of the spine should be supported in the lumbar area. There are more influencing factors [20] making the discomfort and comfort perception of an automotive seat a multi-factorial problem with contributions occurring from effects of the seat layout including the foam properties, the contour, the cover properties, and the dynamic environment as well as effects on the human senses including the sitting, position, the sitting duration, pressure, shear force, and blood flow.

Most studies focus on the driver position and on the discomfort ratings of seat contours and seat foams relating the findings to pressure parameters (e.g. [9, 12, 21]). However, the multi-factorial problem is often reduced to a mono-problem, not taking the seat cover and other seat components into account. Most studies neglect to address other interactions parameters of the human senses than pressure. Mansfield et al. [13] investigated the extent of which foam properties affect the discomfort rating. For his study he removed the seat cover in order to enable the foam being in direct contact with the subject's clothing. Also, Hiemstra-van Mastrigt [11] compare the foam hardness of two train seats and checked the effect on comfort experience. Zenk et al. [21] used various foams to evoke different pressure distributions and thus different discomfort ratings. In reference to this approach an ideal pressure distribution was developed and after validated in a long-term rating. The results represent that there is a link between the cushion, the discomfort rating, and the pressure distribution of the cushion. Notably, the correlation between the backrest was not significant. Both, Mansfield et al. [13] and Zenk et al. [21] excluded the surface, cover properties of the seat, and the interaction of the seat components.

In contrast, Zuo et al. [22] revealed that the sensory properties of materials are relevant for the interaction between users and should be considered in the course of the material selection process. Regarding the gathered information he developed a method for an intelligent choice of materials based on holistic perceptional information of different materials. Likewise, Wegner et al. [20] showed that the seat cover material has fundamental influence on the perception and the characterization of a seat. The study compares two seats with the same contour and the same foam properties but with different cover materials.

With reference to the human mechanoreceptors explained by Schmidt and Thews [17], not only the pressure is an important tactile sensor but also the shear and the elongation have to be taken into account. Chow and Odell [2] linked the pressure to shear stress stating that interface shear force significantly affects the pressure distribution. Based on simulative results Grujicic et al. [6] correlated a higher cover friction to higher shear forces. Also, Goossens and Snijders [5] showed that the shear force could be reduced by changing the seat position and seat angles on the one hand. On the other hand, Goossens [7] presented that the shear force can be reduced by using the right cushion material, a LiquiCell cushion. Thus, not only the ideal seat angle [10], seat pan angle of 10° and backrest angle of 120° is important but additionally the angle position in combination with the applied seat components.

In this study the seat perception is considered as a multi-factorial problem including various seat components as well as the seat-human interaction parameters: pressure, elongation and shear force [17]. The aim for this study is to investigate how occupants rate and perceive seat characteristics and discomfort of car seats with equal foam properties and contours but different cover properties and seat suspensions in various loading states. Next, the study investigates whether the objective measurement methods with the pressure measurement mat and the measurement tool of Wegner et al. [19] sufficiently explain the seat ratings.

2 Methods

In this section the study approach: the scope of participants, the seats used for the study, the procedure of the study, and the statistical analysis are presented. The description of the procedure also includes the presentation of two objective seat measurement methods: first, the pressure measurement mat and second the seat measurement with the measurement tool of Wegner et al. [19].

2.1 Participants

38 subjects, 17 males and 21 females, participated in the experiment. The mean body height of the participants was 1.69 m (1.53–1.86 m) with a mean body weight of 66.2 kg (48–98 kg). On the torso, the participants either whore t-shirts (60%), pullovers (16%), long sleeve t-shirts (11%), polo shirts (8%), or dresses (5%); on the bottom either jeans (55%), cloth pants (40%), or leggings (5%).