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Driver sitting comfort and discomfort (part II): Relationships with and prediction from interface pressure

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Abstract

Pressure at the driver–seat interface has been used as an objective method to assess seat design, yet existing evidence regarding its efficacy is mixed. The current study examined associations between three subjective ratings (overall, comfort, and discomfort) and 36 measures describing driver–seat interface pressure, and identified pressure level, contact area, and ratio (local to global) variables that could be effectively used to improve subjective responses. Each of 27 participants was involved in six separate driving sessions which included combinations of two seats (from vehicles ranked high and low on overall comfort), two vehicle classes (sedan and SUV), and two driving venues (lab-based and field). Several pressure variables were identified as more effective for assessing sitting comfort and discomfort across a range of individual statures. Based on the results, specific approaches are recommended to improve the sitting experience: (1) lower pressure ratios at the buttocks and higher pressure ratios at the upper and lower back; and (2) balanced pressure between the bilateral buttocks, and between the lower and upper body. Finally, separate analyses supported that human–seat interface pressure was more strongly related with overall and comfort ratings than with discomfort ratings.

Relevance to industry

Several interface pressure variables were identified that showed associations with subjective responses during sitting. Use of these measures is suggested to improve the quality of car seats.

Keywords: Interface pressure; Sitting comfort; Driving posture; Packaging

1. Introduction

A comfortable seat plays an important (though not exclusive) role in the perception of a vehicle's overall quality. As a way of meeting customers' increased need for and expectation of vehicle comfort, car makers have been seeking more effective ways to improve car seats. It is hoped that improving seat comfort will distinguish their product from others in the competitive automotive market. Subjective ratings and objective measures (e.g., joint angles, pressure, electromyography) have been used to determine how to enhance sitting comfort and discomfort (de Looze et al., 2003). Among other factors, a driver's sitting comfort and discomfort have been shown to be influenced by whether there is adequate support for preferred driving postures (Reed et al., 1994), even distribution of contact pressure (Helander et al., 1987; Sanders and McCormick, 1987), and mitigated vibration (Johnson and Neve, 2001). Each of these should be provided by the driver's seat and can be described in terms of driver–seat interface pressure.

Such pressure data were regarded by de Looze et al. (2003) as an objective measure having a clear association with subjective ratings. Previous studies have shown that preferred pressure levels are different between body parts as well as between anthropometric groups (Dunk and Callaghan, 2005; Kamijo et al., 1982; Kolich, 2004; Oudenhuijzen et al., 2003), and that there are associations between interface pressure and sitting discomfort. On the other hand, some studies have failed to find this association. For example, Gyi (1996) indicated that sole use of

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interface pressure was not successful in predicting car seat discomfort. Therefore, use of different types of pressure data, and quantifying comfort instead of discomfort (Kyung et al., in press), may be more successful at identifying associations between pressure and human responses. If so, such associations would facilitate determining seat design and evaluation criteria for diverse groups of people in terms of pressure levels.

As psychological constructs, similar to 'fatigue' or 'effort', comfort and discomfort have been suggested to require treatment as different and complementary entities in ergonomic evaluations and interventions (Sauter et al., 2005). Zhang et al. (1996) found that comfort and discomfort are orthogonal, and therefore should be treated independently. Consistent with the orthogonality between comfort and discomfort, the present study incorporated a separate scale for each of these, and aimed at finding their relationships with objective measures (i.e., interface pressure). The longer-term goal was obtaining effective methods, using pressure variables, for ergonomic intervention and evaluation of sitting comfort and discomfort in driving workspaces.

Precise quantification of in-vehicle sitting comfort/discomfort requires that seat and package geometries, driving postures and visual demands are set close to actual driving situations. Troup (1978) showed that the car seat is one major factor affecting a driver's comfort, and can play a positive role in prevention of back pain by alleviating vibration and road shock. Rebiffé (1969), on the other hand, indicated that ergonomic vehicle packaging, specifically harmonic layout of relevant parts, is more important for overall comfort than the seat itself. Anshel (2005) indicated that visual information in human–machine systems was so dominant that its deficiency could often result in awkward body postures. Driving involves high visual demands (Wierwille and Tijerina, 1996), which can thus change the driving posture and result in postural discomfort (Pheasant, 1992). Seat and package geometries and driving postures, in turn, likely influence interface pressure distributions.

Besides ensuring realistic conditions, in terms of seat, posture, task, and environment, which are necessary (especially in a lab-based study) for their contextual effect on the human response (Annett, 2002), a safety belt should also be incorporated for the same reason. During the past 5 years (2000–2004), safety belt usage rates in the US have risen from 72% to 81% (BTS, 2006). Thus, to better represent driving conditions, a safety belt should be worn during an experiment. Further, without a proper restraining system, participants are more likely to slip forward and to be in (more) slouched postures, which can result in pressure changes.

In general, people have more limited freedom to change their postures in car seats than in traditional chairs. For reasons of musculoskeletal health, however, postural movement is essential. Akerbloom (1948) noted that a comfortable seat should accommodate postural changes. Jenny et al. (2001) stated that facilitation of nutrition and relief of muscle fatigue come from postural movement. Likewise, Dhingra et al. (2003) suggested that changes in body position should be allowed to relieve pressure on muscle groups and to relax them. Such postural change for comfort will also be reflected in pressure data.

Different pressure levels between bilateral lower body parts in a driving posture are expected due to the different task and postural requirements placed on each lower extremity. For example, the right foot, used to control pedals, is required to take more restricted postures with less consistent support, while the left foot, unless a clutch pedal is considered, is relatively free and consistently supported by the car floor or the foot rest. Due to this, the left foot (and the left lower limb) might be involved more dominantly in postural balance, which would result in a bilaterally asymmetric posture and pressure. Indeed, the preferred driving posture has been shown to be asymmetric (Hanson et al., 2006).

Short- and long-term sitting comfort/discomfort need to be distinguished. Sitting discomfort increases over time while sitting comfort tends to remain constant (Helander and Zhang, 1997). Increased discomfort seems largely associated with fatigue, which can result from 1 h of driving (Uenishi et al., 2002). Some authors have suggested long-term test durations for the assessment of seat discomfort. For example, Gyi and Porter (1999) stated that at least 2 h of testing was required to clearly assess discomfort, which seems mainly focused on measuring fatigue in seated postures. Fatigue in sitting, however, could be simply due to "the passage of time" (Helander and Zhang, 1997), and not necessarily due to the seat design. Further, fatigue in vehicles has been shown to be affected by multiple other sources such as temperature, air quality, noise (Gameiro da Silva, 2002), and circadian factors (Brown, 1994; Moore-Ede et al., 2003; Van Dongen and Dinges, 2000). Use of interface pressure does not account for these factors, but rather accounts for the seat's support and pressure distribution characteristics and postural changes. Therefore, in using pressure data for assessment of sitting comfort/discomfort, a method is required that can determine their levels within a relatively short period of time. Moreover, a compiled version of the 1990 Nationwide Personal Transportation Survey (NPTS) data by Reed and Massie (1996) showed that about 82% of trips taken in the US were $\leqslant$20 min. Hence, short-term driving is also more representative of actual driving patterns than long-term driving.

In contrast, more extended durations have been generally used when investigating sitting discomfort (largely due to fatigue). For example, Uenishi et al. (2002) investigated driver fatigue in a lab-based environment and observed its occurrence in 1 h. Gyi and Porter (1999) recommended at least 2 h of testing to clearly assess discomfort (fatigue). As already noted, fatigue in seated postures has diverse contributing factors, and can actually result from other sources than the seat. Even when the seat