Applied Ergonomics 74 (2019) 214–220

Contents lists available at ScienceDirect

Applied Ergonomics

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

Engineering movement into automotive seating: Does the driver feel more comfortable and refreshed?

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ARTICLE INFO

Keywords:
Driving
Comfort
Car seat design
Musculoskeletal
Ergonomics methods

ABSTRACT

The concept of introducing movement in automotive seating was investigated. Three seat conditions, a control (no movement) and two movement conditions (fore-aft and cushion-backrest) were compared. Movement was introduced at a fixed speed, slow, smooth and within a small range. Ten participants took part in a 60 min simulated drive for each condition - single blind, repeated measures, and balanced order. Discomfort ratings were collected for six body areas and overall discomfort, together with a wellbeing questionnaire. Driver posture and Seat Fidgets and Movements (SFMs) were captured. There was a trend for lower ratings of discomfort, overall and in the neck, shoulders, lower back, buttocks, and ankles with both seat movement conditions. Wellbeing ratings were also better with movement. Significant differences were found at minute 60 for buttock discomfort - less discomfort with seat movement. Overall discomfort and SFMs frequency increased with time driving. Generally, passive seat movement was well received.

1. Introduction

Good vehicle seat design can positively impact driver musculoskeletal fatigue and lead to improved driver comfort, performance, wellbeing and safety. Fatigue results from the complex interaction of environmental, psychological, biological and vehicle factors exacerbated by conditions such as vibration, long duration sitting or high-workload driving (Jagannath and Balasubramanian, 2014). Grieco (1986) used the term ‘postural fixity’ to describe the static head, neck and trunk postures of individuals that sit in the same position for long periods of time without significant postural movement. The concept can be applied to drivers, whose posture is fixed by the pedals, steering wheel, seat belt, visual demands of the task and the seat itself (Kolich and Taboun, 2002b). Fixed postures from prolonged driving involve static muscle work and consequently blood vessel constriction, particularly in the spine, buttocks and thighs. This static loading of the driver requires musculature to be enlarged, which causes vasoconstriction and consequently blood flow restrictions (Kolich et al., 2001; Sheridan et al., 1991). As a result, local circulatory disruptions occur such that oxygen delivery, nutrient reserves and the removal of metabolic by-products are compromised. It is now believed that even low level sustained contractions (less than 5% of maximum), such as the ones drivers experience, can be problematic (Kolich and Taboun, 2002a). In addition, intervertebral discs have no direct blood supply and consequently depend on low level but frequent pressure changes, to stimulate the pumping of intercellular fluid into and out of the disc to provide nutrients and remove waste products (Kolich et al., 2001).

Static postures can cause local musculoskeletal discomfort (pain, aches, cramps, numbness), psychological fatigue and in the long-term chronical musculoskeletal problems. Indeed, driving for extended periods of time inevitably leads to musculoskeletal symptoms (Porter and Gyi, 2002) and has also been associated with disorders of the spine (Kolich et al., 2001). Other diseases such as deep vein thrombosis can occur in advanced cases (Parakkat et al., 2006). In a well-designed seat the trunk is supported by the backrest, the muscles relax and the lumbar spine is supported. On the contrary, in a poorly designed seat, slouching occurs due to the lack of muscular effort in the trunk, resulting in a loss of lordosis and increase in kyphosis (Gyi, 2013).

Movement provides a useful function of pumping blood into and out of the musculoskeletal system. In the design of the office furniture, the health and comfort benefits of dynamic seating are well established (Groenesteijn et al., 2012). Indeed, Vergara and Page (2002) identified that there should be shifts in posture (macro-movements) approximately every 5 min. There are benefits in driving studies too, for

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https://doi.org/10.1016/j.apergo.2018.08.024
Received 8 November 2017; Received in revised form 18 May 2018; Accepted 29 August 2018
0003-6870/

example, in a recent study of drivers by Sammonds et al. (2017b), a short break from driving (a 10 min walk) had beneficial effects on symptoms of discomfort. It is not always possible to take a break from a vehicle, but it has been found that even passive posture changes have positive effects on driver wellbeing (van Veen et al., 2015). Franz et al. (2011) conducted an experimental study where they investigated the effect of a low-intensity massage system in the backrest of car seat. They found that as well as improving driver comfort without distracting the driver, EMG measurements of muscle activity in the shoulders and upper back were reduced. Automotive dynamic sitting can be induced through support mechanisms denominated in literature as micro-adjustment or massage (Kolich et al., 2001) and active seating (e.g., Active Lumbar Systems (Holmes et al., 2013) applied on the lumbar or thoracic region of the spine (Gruevski et al., 2016). Seat configuration variation can also be used to promote passive posture changes, for example, van Veen et al. (2015) conducted a study using a driver seat with varying configuration, 1.5° movement backwards of the backrest and 1° upwards and downwards tilt of the seat cushion. The movement condition was better received by participants in terms of less reported discomfort than the static condition. The static no-movement seat also presented more driver fidget movements as well as more discomfort. Maradei et al. (2017) investigated the effect of seat tilt motion from $+5^\circ$ to -5° and vice versa on low back discomfort on participants with and without low back pain. In this study, a significant decrease in discomfort, due to lumbar pain in the dynamic condition was found.

To sum up, fixed postures and long-term sitting are known to have negative effects on the body as they compromise nutrient exchange. The key to improving driver comfort is to combine good design together with driver behaviour, i.e., design to facilitate a small change of posture to prevent concentration of load and restore blood flow to pressure areas (Gyi, 2013). However, there are few studies focussing on this in terms of current car seat design.

In this research it was hypothesized that postural movement is beneficial for reducing local musculoskeletal fatigue and discomfort. Engineering movement into the driver seat itself will lead to passive posture variation of the driver: active movement (whereby the driver is encouraged to move) is not suited to the driving task. This concept was investigated through a repeated measures, single blind experimental study involving 1 h of simulated driving under three seat conditions - a control (no movement) and two seat movement conditions (fore-aft and cushion-backrest). The movement engineered into the seat changed body contact points with the seat in order to positively affect driver comfort. Therefore, the study aimed to explore musculoskeletal discomfort, feelings of refreshment, wellbeing and comfort in order to ultimately improve the driving experience.

2. Methods

2.1. Sample

Permission to conduct the study was granted by Loughborough University Ethical Advisory Committee in August 2016. Participants were recruited in the Leicestershire area through local advertising (e.g., posters, email). Ten healthy participants (5 males and 5 females) were recruited with the aim of obtaining a good anthropometric spread. There was no age requirement, but they needed to hold a full UK driving license with at least one full year of driving experience and be regular drivers in the last 12 months.

Participants were asked to wear comfortable, close fitting clothing (no heeled shoes) and not to exercise 1 h before the session. In the first session, on participants' arrival, their height and weight were measured.

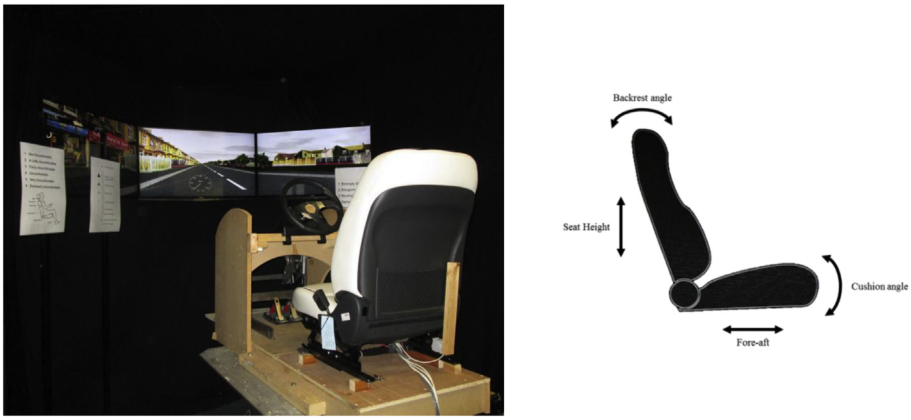
2.2. Experimental rig development

A driving rig was manufactured to provide a repeatable simulation of the driving environment replicating the driving workspace dimensions of a production car. Automatic pedal transmission and a non-adjustable steering wheel were used to control the driving simulator, which was mounted on to a motion platform fixed to a 6 Degrees of Freedom Multi Axis Vibration Simulator (Rexroth Hydraudyne B.V Micro Motion 600-6DoF-200-MK5 MAVIS) with closed loop control. A blackout driving environment was provided and the driving simulation task involved a 3-screen set-up, with four different 'follow driver' scenarios, including town and motorway routes, set up in a fixed sequence. With these scenarios, the participant is required to follow a car; our pilot work indicated that this was preferred to verbal instructions.

Before the first session, a short fitting trial was conducted involving a standard iterative process (Porter and Gyi, 1998), in order to capture participant's self-selected optimum driving position. The seat start position was standardized for these fitting trials (mid fore-aft, mid backrest recline, mid cushion tilt, maximum seat height). Participants 'optimal' seat set-up was then used in all of the experimental conditions. Following this, a system characterisation was carried out with each participant using a Larson Davis Human Vibration Meter 100 (HVM100) to ensure they were exposed to the same target level of seat surface vibration, replicating a UK normal drive.

2.3. Seat movement development

A high-end leather seat from the Nissan Infiniti Q30 (Fig. 1a), with four directions of electronic adjustment - fore-aft, seat height, cushion angle and backrest angle (Fig. 1b) and a memory function was configured for use in the study. It was mounted on to the rig as close as



(a)

(b)

Fig. 1. (a) Simulated driving environment; (b) adjustable directions of seat movement.