Applied Ergonomics 50 (2015) 153–159

Contents lists available at ScienceDirect

Applied Ergonomics

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

Driver discomfort in vehicle seats – Effect of changing road conditions and seat foam composition

Neil Mansfield*, George Sammonds, Linh Nguyen

Environmental Ergonomics Research Centre, Loughborough Design School, Loughborough University, LE11 3TU, UK

ARTICLE INFO

Article history:
Received 10 July 2014
Accepted 10 March 2015
Available online 1 April 2015

Keywords:
Comfort
Vibration
Driving

ABSTRACT

Discomfort in vehicle seats is a multi-factorial problem with contributions occurring from effects of sitting duration, seat design, and the dynamic environment to which the occupant is exposed. This paper reports laboratory studies investigating the extent to which reports of discomfort are affected by vibration commencing or ceasing, and whether methods of assessment are sensitive enough to detect small changes in foam composition. Study 1 measured discomfort ratings for two conditions of 60 min each, comprising 30 min of vibration exposure followed by 30 min of static sitting in a car seat, and vice-versa. Study 2 measured discomfort ratings for three conditions over a period of 40 min each, whilst participants were sitting in one of two car seat compositions, and either exposed to vibration or not. In both studies participants operated a driving simulator. It is shown that exposure to vibration increases the rate of discomfort onset in comparison to periods of static sitting. When vibration stopped, there was an acute improvement in comfort but discomfort did not drop to the levels reported by those who had been unexposed. When vibration started after 30 min of static sitting, there was an acute increase in discomfort but not to the levels reported by those who had been exposed to 30 min of vibration. After 40 min of continuous exposure it was possible to detect significant differences in overall discomfort between the two seat compositions, although trends could be observed in less time.

1. Introduction

Inevitably, a proportion of the readers of this paper will be doing so whilst travelling, perhaps on a train, aircraft, bus, or being driven by their chauffeur. Some of them might be facing a long journey ahead, during which time they might become conscious of feelings of discomfort. All types of vehicular travel involve a finite duration of movement as the vehicle travels from origin to destination. Depending on basic properties of average speed, route taken and distance travelled, the duration of the movement would typically range from a few minutes to a few hours. In some cases (e.g. work vehicles; vehicles with on-board accommodation such as some ships or trains) the duration of travel could last significantly longer.

Many factors could contribute to the feelings of comfort whist sitting in a vehicle seat. Ebe and Griffin (2000a,b) produced a model of seat discomfort comprising 'static' and 'dynamic' factors. The foundation of the model was the concept that some factors were a result of the overall design of the seat and did not change rapidly, such as stiffness, pressure distribution and shape, but other factors (dynamic) were caused by the instantaneous dynamic environment (vibration) which the seat was experiencing. There could be an intentional trade-off between the static factors and dynamic factors such that some seats could be optimised dynamically and some statically, although large differences in seat design do not always result in significant improvements in vibration exposure (e.g. Jonsson et al., 2014). An additional dimension of the causes of seat discomfort is the time for which an individual has been seated. Previous studies (e.g. El Falou et al., 2003; Porter et al., 2003; De Carvalho and Callaghan, 2011, Smith et al., 2015) have shown analytically that sensation of overall discomfort increases over time. Through a series of studies involving motion and long-duration sitting, Mansfield et al. (2014) showed that discomfort increases both with vibration magnitude and with sitting duration, and that the presence of vibration causes an increase in the rate of discomfort onset. A regression model was proposed that allowed for projection of future overall discomfort depending on short-term ratings of seat discomfort, duration of sitting, and the vibration magnitude.

Whilst previous research has shown differences in discomfort ratings between test conditions, the differences between test

* Corresponding author.
E-mail address: n.j.mansfield@lboro.ac.uk (N. Mansfield).

http://dx.doi.org/10.1016/j.apergo.2015.03.010
0003-6870/

parameters have tended to be simplified. For example, where different seat designs have been considered, the differences between the designs have been relatively great, such as using seats from different classes of vehicle, therefore changing several design parameters at once. Where motion has been a key independent variable, the characteristics of the motion have usually been kept constant within a trial, rather than replicating the variations in motion that would occur when driving on different road surfaces during a journey or replicating intermittent motion such as could occur in traffic or on public transport. This paper reports two related studies that consider (a) the effects of changing the motion environment half way through a long-term discomfort test, and (b) the effects of changing the composition of the seat construction.

2. Methods

This paper reports results from two repeated measures studies using similar equipment, seats and protocols. Studies were conducted at the Environmental Ergonomics Research Centre, Loughborough University. Both studies were approved by the University Ethics Committee, participants provided informed consent, and a pre-trial health screening questionnaire was administered. Participants were required to be aged between 18 and 65 and to hold a full UK driving licence to ensure posture and task required during the study would be familiar.

The first study investigated the effect of changing the magnitude of vibration mid-trial; the second study aimed to determine whether the method used was sensitive enough to detect differences between two identically shaped seats but with different foam composition.

Fig. 1. Laboratory set up including driving rig, seat, steering wheel, pedals and driving simulator.

2.1. Driving rig

A rig was built on a six degree-of-freedom multi-axis vibration simulator (MAViS) with closed loop control. It comprised a driving package replicating the dimensions from a current production car. The corresponding car seat was mounted in the rig, as was a representative steering wheel and pedals that were used to control a driving simulator (Fig. 1). Subjects were free to adjust the seat into a comfortable driving position before the start of the trials. The seat had its fabric cover removed such that the foam was in direct contact with the clothing of the subjects. This was to ensure that effects of foam composition (Study 2) were not masked by the presence of the seat cover.

A pre-recorded vibration file that had been previously measured in a car driving on a rough road was used to produce motion from 1 to 20 Hz. Vibration on the surface of the seat was calibrated during a system characterisation procedure whereby Biometrics accelerometers were placed on the seat surface in a standard flexible disc and the simulator gain adjusted to provide the desired vibration magnitude prior to the start of the experiment. This equalisation was completed for each participant on each visit to the laboratory. Pilot work showed high degrees of system stability during a trial; the calibration required was less than 10% in all cases. Where vibration was present, the magnitude was set to 0.5 m/s^2 r.m.s. (root sum of squares, 0.22x, 0.33y, 0.31z, weighted according to ISO 2631-1), typical of driving on a moderately rough road. The vibration file was a loop of a 3 min measurement, which ensured a constant exposure during the vibration conditions.

2.2. Discomfort scores

Discomfort ratings were collected for both body part and overall discomfort, using two separate rating scales. Body part discomfort was collected using a body map and utilising a 6-point discomfort scale with verbal anchors taken from ISO 2631-1 (1997), with 1 being ‘not uncomfortable’ and 6 ‘extremely uncomfortable’ (Fig. 2). These data were primarily designed as priming questions for the overall rating of discomfort which was elicited using an adapted Borg CR-100 scale (Borg and Borg, 2002; Fig. 2). Subjects were trained in the use of the scales before starting the experiments.

2.3. Study 1

In Study 1, participants sat on Foam A, a mass-produced lightweight foam which is used in typical mid-range production cars. Participants were required to drive in a simulation including light traffic. The route comprised driving on highway (motorway), urban, and rural roads. Directions were given via a simulation of a navigation system. Before the trial participants were given 5-min practice time without vibration to familiarise themselves with the simulator.

Ten healthy males were recruited from Loughborough University. Participants' range (mean and ±s.d.) for age, height and weight were as follows: 22–38 years old (mean age 28.9 ± 5.6), 170–195 cm (mean height 180.8 cm ± 7.1) and 69–124 kg (mean 83.74 kg ± 15.6), respectively. Participants attended the laboratory on two different occasions to complete two experimental conditions:

A (0, 0.5) 60 min of driving: Foam A – no vibration over time 0–30 min; continuous vibration over time 30–60 min.
A (0.5, 0) 60 min of driving: Foam A – continuous vibration over time 0–30 min; no vibration over time 30–60 min.

Notation for each condition is presented with a reference to foam type followed by parenthesis containing and the order of presentation of vibration conditions. E.g. A (0, 0.5) refers to foam A exposed to zero vibration followed by vibration at 0.5 m/s^2 r.m.s.