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An experimental analysis on driving behaviour for professional bus drivers

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Abstract

In recent years, the analysis of driving behaviour for professional drivers has attracted growing interest from transport operators. This is also witnessed by the importance the recently introduced Driver Qualification Card gives to human factors and the need drivers undergo proper training activities aimed at improving the performance of transport systems both in operational (speed, frequency, reliability, etc.) and safety terms. By discussing the results of an experimental study on driving behaviour involving professional bus drivers, this paper investigates whether any correlations exist between a number of driver characteristics (a.o., age, body weight and driving experience) and the perceived level of discomfort when driving. Analysis of the data performed using Multiple Correspondences Analysis (MCA) shows that a correlation does exist between the perceived level of discomfort in a set of body areas and the age and body weight of the driver.

Keywords: Human factors, Driving behaviour, Bus drivers, Level of discomfort

1. Introduction

Public transport is universally recognized as a more effective and sustainable alternative to private vehicle use. However, the work environment of public transport drivers is beset by adverse conditions, which, emphasized by high mileage, may increase the occurrence of negative safety outcomes, such as traffic accidents, often preceded by risky road behaviour enhanced by stress, anger, and difficult operating conditions (Montoro et al., 2018).

The issue of bus drivers' behaviour has been widely studied in the literature. Different factors affect driving behaviour, including drivers' characteristics and vehicle-, environment-, and road- related features (Gilandeha et al.,

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2018). Bus drivers often work irregular hours or on split shifts and their activity involves high levels of stress. These factors can lead to severe sleepiness and dangerous driving. One of the most relevant processes associated with risky driving behaviour is the fatigue level. Several recent studies correlate work stress and fatigue levels with unsafe and counterproductive work behaviour. Among others, Useche et al. (2017) examine the association between stress-related work conditions of bus rapid transport drivers and risky driving behaviour, while Anund et al. (2018) examine how split shifts may affect sleepiness and performance during afternoon driving.

Eboli et al. (2017) investigate the relationship between personal traits and the level of driving risk taken by drivers during a trip, and also the relationship between driving risk levels and some physical and emotional characteristics of the driver. It is well known that, especially in some jobs, as in the case of bus drivers, mistakes can be very costly, even if the risk of fatalities or serious injuries for bus passengers is actually considerably lower than that of car passengers (Wåhlberg et al., 2019). According to several studies, driving behaviour is the primary cause, alone or in combination with other factors, of most (>80%) road accidents that occur every year. Particularly, driver distraction has now become a major problem in transportation safety as a result of the increasing number of entertainment, assistance and navigation devices used while driving. An attempt to investigate the potential role of distraction enablers in fatal crashes can be found in Qin et al. (2019), who also try to investigate how driver age and gender may affect driving behaviour. The causes of driver inattention can be divided into two main categories, including distraction and drowsiness. Distraction factors can range from a visual, auditory, physical or cognitive stimulus interfering with critical driving activities, to competing activities such as mobile phone usage, interaction with passengers, and daydreaming. If distraction can be defined as the inattention related to the presence of diversion stimuli, drowsiness can be defined as the inattention related to the driver's physiological response. This biological behaviour is typically caused by limited sleep, altered medical conditions, or long periods of driving in a monotonous environment (Ferreira et al., 2019). It is widely known that major bus and truck accidents cause high social costs, and often also victims. Furthermore, not to be disregarded is the fact that road traffic injuries typically involve people who are in the active age group, thus placing a heavy burden on households as well as on national economies. Road traffic injuries are reported to be the leading cause of death among people aged 15–29 worldwide and young drivers have a disproportionately high crash rate (Hayashi et al., 2018). According to the World Health Organization (2015), road traffic injuries cost annually between 3 and 5% of Gross Domestic Product (GDP) in low-and middle income countries, and between 1 and 2% of GDP in developed economies (Hussain, 2019). Evans (1996) further asserted that among human factors, driver behaviour (what the driver chooses to do) has much greater influence on safety than the driver performance (what the driver can do).

Nowadays, several technologies are able to detect driver fatigue and have the potential to dramatically reduce the likelihood of accidents occurring. However, their successful implementation depends on the cause and type of fatigue experienced (May and Baldwin, 2009). Acknowledged that human factors always play a crucial role, it is evident that there is great interest in predicting safe driving performance in professional drivers, chiefly with new technologies that are emerging to assist drivers. In this regard, the paper by Vetter et al. (2018) proposes a modern theoretical framework to assess which psychometric tests are able to predict safe driving performance in today's professional drivers under these new circumstances. Mollicone et al. (2018) develop an analytic approach to predict driver fatigue based on a bio-mathematical model and then estimate hard-braking events as a function of the predicted fatigue. Their curve relating predicted fatigue to hard-braking events shows how the frequency of hard-braking events increases when the predicted fatigue levels deteriorate. As Dorna et al. (2010) suggest, there can be individual differences in driver behaviour when adhering to strict schedules under time pressure. A reliable and valid assessment of these individual differences would be useful for bus operators keen to mitigate the risk of accidents. Bowden and Ragsdale (2018) introduced a fatigue-aware model for determining the optimal working schedule of a driver while maintaining an acceptable level of alertness. A number of studies have examined the relationship between driving skills and driving behaviour (Usami et al., 2018; Zhang et al., 2019). Among them, Xu et al. (2018) investigated the extent to which deficits in driving skill may contribute to accidents. Other studies focused instead on the relationship between road geometry and driver vigilance level in monotonous environments (Farahmand and Boroujerdian, 2018). According to Huang et al. (2018), drivers involved in an accident in the previous three years are reported to have greater self-consciousness than those who were not. These findings suggest that bus and taxi drivers should both receive special training in order to avoid aggressive behaviour and provide a better and safer service to the public. The evaluation of the level of fatigue is also carried out on different types of professional drivers, such as quay crane operators (Leban et al., 2019; Leban et al., 2017). Another factor closely related to driving conditions is driver comfort. Comfort has a significant influence on driving performance. Particularly, driver discomfort may accelerate the level of fatigue, thus compromising the alertness level and driving performance with a consequent reduction of transport safety level. In this regard, it seems important to emphasize that the level of comfort may also depend on the presence of suitable supports in the driver cabin, so as to significantly mitigate the vibrations transmitted during driving (Zhang et al., 1996). Another factor contributing to driver fatigue are the vibrations transmitted through the driver seat; vibrations are often studied also in relation to the route and vehicle driven (Bruzzone et al. 2019).

This paper summarizes and discusses the results of an experimental analysis on driving behaviour that was carried out in October and November 2018 in Cagliari (Italy). The analysis involved 31 professional bus drivers belonging to the regional public transport company of Sardinia. The focus of this study is thus on the driving behaviour of professional drivers. Although several analyses have proven that professional drivers have less-risky behaviour than non-professionals, because of the long periods of driving they are more likely to become involved in traffic accidents (Maslać et al., 2018). The analysis discussed here was performed for the main purpose of investigating whether correlations exist between driver characteristics (age, driving experience, body weight) and the perceived level of discomfort while driving. The final aim of the analysis is to investigate the extent to which some elements seem to impact on driver performance. To this end, the possible involvement of the professional drivers analysed in road accidents in the last five years (both during work and with private vehicles) is considered along with a number of other variables related to the driver and operating and comfort conditions.

The structure of the paper is as follows. After this introduction, Section 2 describes the survey process, the analysed sample and its main features, Section 3 illustrates the main results of the analysis performed using MCA. Finally, Section 4 concludes the paper.

2. Materials and Method

This section describes the main materials and method used to collect the necessary data. All the data gathered were analysed to investigate whether any correlations exist between driver characteristics and the perceived level of discomfort while driving, so as to identify which elements may have the greatest impact on driver performance.

2.1. The survey

The data was collected by means of two questionnaires administered to the selected participants both during and at the end of their work shift. The first questionnaire aimed at investigating driving behaviour of the interviewees and was divided into the following three sections:

a. Demographic factors: including information on age and gender;
b. Work history and driving experience: including information on driving licence, work experience, average driving distance covered per shift and per year, possible involvement in road accidents during the last 5 years, possible difficulties while driving in the dark or when it rains;
c. Description of the last journey made: it includes a subjective description of the work shift just finished.

The second questionnaire was designed to identify driver subjective discomfort level. The questionnaire consisted of 2 parts: Part 1 focuses on local discomfort while Part 2 on overall discomfort (Sammonds et al., 2017). Part 1 includes the 6 points discomfort scale defined in ISO 2631-1 (2003) while Part 2 utilizes a newly developed overall discomfort rating scale adapted from the Borg CR100 scale (Borg, 2002). Part 1 was used as a primer for Part 2, encouraging subjects to systematically consider their discomfort across all body parts. During their shift, about every 60 minutes, participants were verbally required to provide subjective discomfort ratings according to the indications provided in the questionnaire (Fig. 1).

2.2. Sample description and data

A total of 31 professional bus drivers agreed to participate in this study and to take part in the survey consisting of the two questionnaires above. All participants, who were randomly selected, were employed by the main public transport company of Sardinia. Of the 31 participants, only one was female. The average age of the respondents was 42.7 years (SD = 7.2), with an average driving experience of 10.4 years (SD = 7.9).

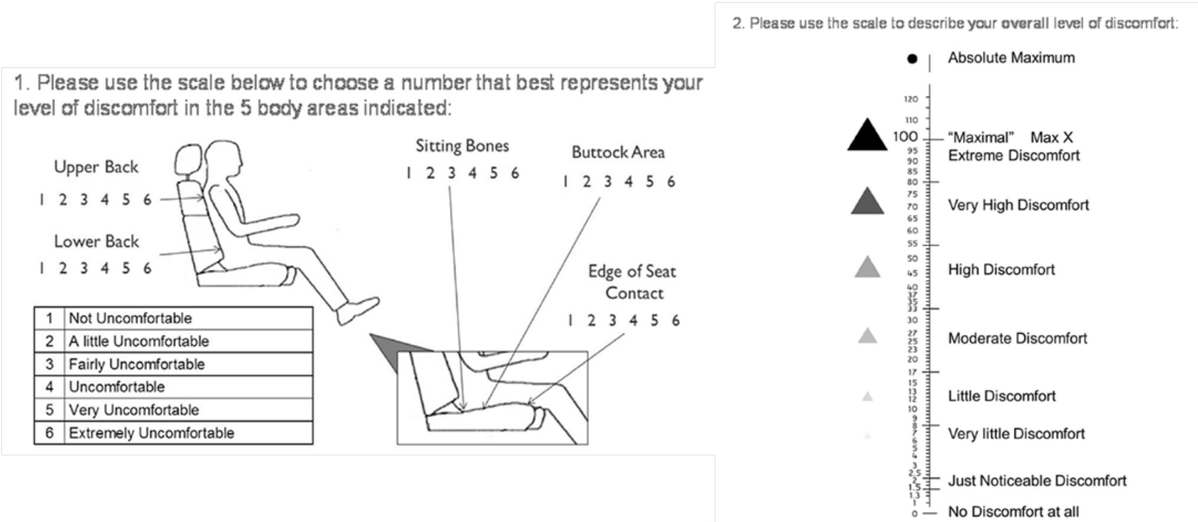

Fig.1 Questionnaire n.2: Part 1 - discomfort scale and description of the body parts. Part 2 - adapted Borg CR100 scale. (Source: Sammonds et al., 2017).

Regarding the description of the last journey made, the speed limit varied from 50 to 100 km/h. All the covered routes passed through small villages with speed limits ranging from 30 to 50 km/h. All participants were involved in both day and night driving shifts. Tables 1 and 2 show the characteristic of the analysed sample in terms of average driving distance covered per shift (mean value: 175.3 km, SD =32.2) and per year (mean value: 41,890 km, SD = 21,093.87).

Of the 31 drivers who answered the first questionnaire, only 13 agreed to also answer the second questionnaire. These participants were aged between 32 and 53 years (mean value: 45; SD = 5.9) and their average experience as a bus driver was 18.2 years (SD =6.2).

Table 1. Average driving distance covered per shift.

Driving distance per shift	**N. of observations**	**Percentage**
100-150 km	10	32.3 %
150-200 km	18	58.1 %
200-250 km	1	3.2 %
Not specified	2	6.5 %

Table 2. Average driving distance covered per year.

Driving distance per year	**N. of observations**	**Percentage**
< 10,000 km	4	12.9 %
10,000 – 20,000 km	2	6.5 %
20,000 – 30,000 km	4	12.9 %
30,000 – 40,000 km	3	9.7 %
40,000 – 50,000 km	7	22.6 %
50,000 – 60,000 km	7	22.6 %
> 60,000 km	3	9.7 %
Not specified	1	3.2 %

The 13 drivers were asked to perform 2 complete trips, on their normal work shift. For each shift, the following information was available: start time, end time, driving time (hours), time for each stop, kilometres travelled. Each trip had a different duration and mileage and could include urban, suburban and non-urban roads. After the first trip, each driver was asked to answer the first questionnaire. Afterwards, once the second trip was completed, drivers were asked to answer again the third section of the questionnaire.

During the trip, about every 60 minutes, participants were verbally required to provide subjective discomfort ratings according to the indications provided in the second questionnaire. Table 3 shows the average values of the scores given by the 13 drivers regarding the level of perceived discomfort (both in the 5 body areas and overall).

Table 3. Discomfort values for each driver.

Driver ID	Upper Back	Lower Back	Sitting Bones	Buttock Area	Edge of Seat Contact	Overall Level of discomfort	Height	Weight	Work experience
1	1.0	1	1	1	1.25	0.5	1.65	78	20
2	2.2	1.2	1.4	1.6	1.8	8.6	1.75	78	18
3	1.0	1.3	1.3	1.3	1.7	1.3	1.79	79	8
4	2.8	2.8	1.2	1.2	1.5	16.8	1.77	99	23
5	2.0	2.3	2.5	2.5	2.5	15.0	na	na	17
6	2.2	2.6	2.6	2.8	2.6	17.0	1.68	65	17
7	2.7	2.5	2.2	2.5	2.3	14.7	1.64	100	8
8	1.0	1.0	1.0	1.0	1.0	15.0	na	na	24
9	1.7	1.8	2.3	2.4	2.2	15.2	1.65	80	28
10	2.0	1.2	1.4	1.8	1.0	3.2	1.65	74	23
11	2.0	3.3	2.8	3.5	2.0	30.3	na	na	10
12	1.0	1.8	1.0	1.0	1.0	1.0	1.8	80	20
13	2.4	2.0	2.0	2.0	2.0	12.4	1.74	66	20
Total Average	1.8	1.9	1.7	1.9	1.8	11.6	1.7	79.9	18.2
SD	0.66	0.75	0.67	0.81	0.58	8.52	0.06	11.68	6.22

As for the level of discomfort perceived by each driver, it emerged that:

- the maximum average discomfort value in the 5 body areas of interest was 3.5 out of 6. The average level of overall discomfort ranges from 0.5 to 30;
- the average perceived overall discomfort value did not decrease during the shift, showing that, on average, overall discomfort increases with driving duration;
- the buttock area (mean value: 3.5) and the lumbar area (mean value: 3.3) are the two body areas characterized by the highest average and maximum discomfort values;
- the edge of seat contact is the body area characterized by the lowest average and maximum discomfort values.

3. Analysis and results

Considering that most of the data collected with the two questionnaires was qualitative (judgments, statements about driving behaviour, etc.), Multiple Correspondence Analysis (MCA) has been used to describe the internal variability of the starting variables. The MCA was performed using the following 14 active variables: age, work experience, driving distance per shift, driving distance per year, start time, driving distance per last shift, buttock area, lower back, upper back, edge of seat contact, sitting bones, overall level of discomfort, weight and height. The number of axes to be retained for analysis was determined by considering the eigenvalues measuring the variance of the axes. In this case, the first three axes cumulatively explain 42.8 % of the total variance (Table 4). The contributions of the active variables on the individual axes are given in Table 5.

The MCA provided the categories of active variables that characterize the individual axes. These variables are shown in Tables 6 and 7. The negative coordinates are listed in the upper part of the table while the positive ones in the lower part.

Table 4. Cloud Variance.

Axis	Variance of the axis (eigenvalue)	% of explained variance	Cumulated % of explained variance	Benzécri's modified rates (%)
1	0.496	14.8	14.8	35.4
2	0.480	14.3	29.1	30.4
3	0.462	13.8	42.8	25.2
4	0.389	11.6	54.4	9.0
5	0.282	8.4	62.8	0.0
6	0.275	8.2	71.0	0.0
7	0.252	7.5	78.5	0.0
8	0.214	6.4	84.9	0.0
9	0.188	5.6	90.5	0.0
10	0.135	4.0	94.6	0.0
11	0.108	3.2	97.8	0.0
12	0.075	2.2	100.0	0.0

Table 5. Contributions of the active variables.

Variable	Axis 1	Axis 2	Axis 3
Age	4.6	9.7	6.2
Body Weight	6.6	7.1	6.5
Buttock area	13.3	11.9	12.6
Driving distance per last shift	5.2	5.9	1.9
Driving distance per shift	4.8	7.3	11.5
Driving distance per year	10.6	6.7	9.0
Driving experience	4.8	4.8	1.9
Edge of seat contact	5.0	10.9	11.1
Height	6.8	6.7	4.2
Lower Back	13.2	4.7	9.4
Overall Level of Discomfort	11.5	1.2	8.7
Sitting Bones	7.7	12.2	7.1
Start shift	0.5	1.1	2.1
Upper Back	5.3	9.7	7.9

Table 6. Categories of active variables (axis 1).

Label of the variable	Label of the category	Coordinate
Driving distance per year	> 60,000 km	-2.923
Lower back	>3	-2.923
Buttock area	>3	-2.923
Overall level of discomfort	> 30	-2.923
Sitting bones	2.5-3	-1.319
Experience	5-10 years	-0.988
Driving distance on last shift	210-240 km	-0.882
Upper back	1.5-2	-0.870
Age	40-45 years	-0.758
Sitting Bones	1-1.5	0.594
Overall level of discomfort	1-10	0.611
Buttock area	1-1.5	0.635
Edge of seat contact	1-1.5	0.697

Table 7. Categories of active variables (axis 2).

Label of the variable	Label of the category	Coordinate
Age	35-40 years	-2.023
Driving distance per shift	220-250 km	-2.023
Sitting Bones	1.5-2	-2.023
Height	1.70-1.75	-1.540
Upper back	2-2.5	-1.336
Buttock area	1.5-2	-1.099
Weight	65-75 kg	-1.056
Edge of seat contact	1.5-2	-0.923
Upper Back	2.5-3	1.176
Weight	> 95 kg	1.176
Lower Back	2-2.5	1.272
Sitting Bones	2-2.5	1.318
Buttock area	2-2.5	1.318
Edge of seat contact	2-2.5	1318
Experience	25-30 years	1.409
Driving distance per year	30,000-40,000 kg	1.409
Age	30-35 years	1.884

Subsequently, correlations between each level of discomfort and the personal and work parameters characterising the drivers were analysed. The highest χ^2 values are reported in Table 8. Of significant importance are the correlations between “Driving distance per year” with “Buttock area” (χ^2 = 33.80) and “Lower Back” (χ^2 = 26.00). Overall, all the discomfort parameters seem to be related to driving distance per shift and driving distance per year. Only the level of discomfort in “lower back” and “sitting bones” areas appears to be related to age while the level of discomfort in the upper back area appears to be related to driver body weight.

Table 8. χ^2 Correlation data.

Label of the variable	**Upper Back**	**Lower Back**	**Buttock area**	**Sitting Bones**	**Edge of seat contact**	**Overall Level of discomfort**
Driving distance per shift	18.99	22.45	24.49	23.06	17.25	9.01
Driving distance per year	17.33	26.00	33.80	19.50	19.50	14.85
Age	-	19.69	-	18.12	-	8.69
Body Weight	19.64	-	-	-	-	9.55

The results of the performed MCA show that:

- Axis 1 is characterised by the relationship between discomfort in “Lower Back” and “Buttock area” and the “Driving distance per year” variable;
- Axis 2 is characterised by the relationship between discomfort in “Edge of seat contact”, “Sitting Bones” and “Buttock area” and the “Age” variable;
- Axis 3 is characterised by the relationship between discomfort in “Edge of seat contact”, “Buttock area” and “Lower Back” and the “Driving distance per shift” variable;
- On the axis 1, the levels of discomfort in the “sitting bones” and “buttock” areas decrease while the overall level of discomfort increases. However, a relationship between the physical and working characteristics of the drivers is not evident;
- On the axis 2, when the age decreases and weight increases, the levels of discomfort in the “edge of seat contact”, “upper back”, “buttock area” and “sitting bones” areas also increase. Therefore, it seems that the discomfort in all body areas is more relevant for young drivers with high body weight.

4. Conclusions

This study aimed to investigate whether any relationships exist between a number of driver characteristics and the perceived level of discomfort while driving. The analysis was based on the discomfort parameters indicated by a sample of 31 professional bus drivers. According to the results, the perceived level of discomfort in a set of body areas appears to be linked to several driver variables, such as age and body weight. Moreover, it also appears that the perceived discomfort in all body areas is generally greater for young drivers with high body weight. These findings can contribute to identifying which factors may impact more on driver performance and can also be of help in designing more suitable driver seats for reducing fatigue levels and improving driving performance. As a future development of the research, further analyses involving a larger sample of drivers will allow us to increase the robustness of the results and investigate the role of additional factors including eye vision and seat vibrations on the perceived level of discomfort.

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