A field study of mental workload: conventional bus drivers versus bus rapid transit drivers

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Manuscript metrics:
Abstract: 138 words
Narrative text: 4049 words
References: 66
Tables: 4
Figures: 2

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Abstract

Road traffic accidents are increasing worldwide and cause a high number of fatalities and injuries. Mental Work Load (MWL) is a contributing factor in road safety. The primary aim of this work was to study important MWL factors and then compare conventional and BRT (Bus Rapid Transit) drivers' MWL. This study evaluated bus drivers' MWL using the Driving Activity Load Index (DALI) questionnaire conducted with 123 bus drivers in Tehran. The results revealed significant differences between conventional and BRT drivers' mental workload. Moreover, data modelling showed that some organizational and environmental factors such as bus type, working hours per day, road maze, and route traffic volume contribute to drivers' mental workload. These findings suggest some essential customized factors that may help measure and offer practical solutions for decreasing the level of bus drivers MWL in real-world road driving.

Keywords: Mental workload, DALI, Real-world driving, conventional bus driver, BRT bus driver.

Practitioner summary:

Mental workload is affected by several contributing factors. Depending on the working context, some of these contributing factors have a more significant influence on the level of the experienced MWL. Therefore, the main factors influencing the MWL of BRT and conventional bus drivers were assessed in their real-life environment.

1. Introduction

Mental workload (MWL) is a multidimensional concept. It is defined as the ratio between task demands in a specific environment and the mental resources of the task performer (Bläsing and Bornewasser 2021). This shows that different people may experience different MWL levels under the same circumstance because of intrinsic capabilities, demographic and work-related factors such as work experience and traffic conditions, which explains the contextual dependency of MWL (Charles and Nixon 2019; Tao et al. 2019). Mental workload can be assessed in several ways, including 1) subjective measures, 2) objective performance outcomes, and 3) physiology or neurophysiology (Das Chakladar et al. 2020; Dehais et al. 2020). Each measurement category has specific strengths and weaknesses (O'Connell et al., 2009). In terms of subjective measures, the user's perceived mental workload can be evaluated by a questionnaire. The National Aeronautics and Space Administration Task Load Index (NASA-TLX) and subjective workload assessment technique (SWAT) are examples of MWL measures (Hart and Staveland 1988; Reid and Nygren 1988). The measures of performance can be classified into two sub-categories consisting of primary and secondary tasks. The primary task measures of MWL evaluate the performance of the primary task to estimate changes in user workload. Secondary task measures involve the inclusion of an additional task to the primary one. This dual-task paradigm can assess whether allocating more resources to the primary task maintains performance but reduces the spare capacity to handle a secondary task (Butmee, Lansdown, and Walker 2018; Marquart, Cabrall, and de Winter 2015). In driving, lane-keeping, lateral position and headway are examples of primary tasks (Pereira da Silva 2014). In the design of the secondary task, it is essential to use a task that requires the same resources as the primary task to measure the MWL (Longo 2015; M. S. Young et al. 2015). Measures such as the n-back, oddball task and reaction time tasks are examples used as secondary tasks (von Janczewski et al. 2021; Solís Marcos and Kircher 2019). The physiological and or neurophysiology measures refer to body responses derived from the operator's physiological responses. Examples of these physiological responses are eye activity, such as blinks and pupils size (Čegovnik et al. 2018; Charles and Nixon 2019; Y. Zhang et al. 2019), cardiovascular activity (including electrocardiogram (ECG), heart rate, mean arterial pressure) (Tattersall and Hockey 1995), respiratory activity, neuroendocrine function, verbal activity, and brain activities using electroencephalography (EEG, functional magnetic resonance imaging (fMRI), functional near-infrared spectroscopy (fNIRS)) (Das Chakladar et al. 2020; Tao et al. 2019).

Driver safety is an essential theme in road traffic engineering (H. Wang, Liu, and You 2019). Road traffic accidents are increasing worldwide and are a major public health issue (Barua and Tay 2010; Z. Zhang et al. 2019), which causes a high number of fatalities and injuries (Global status report on road safety 2018 2018; Melchor et al. 2015). One mode of transportation, which is low cost and affordable, are buses. They have become an essential part of the urban passenger transportation system (Yang et al., 2021). Road safety is important in public transport systems, as millions of passengers, especially in developing countries, use the conventional transportation system to commute (Z. Zhang et al. 2019). Several research studies refer to contributing factors causing both the frequency and severity of road accidents and also MWL. These include, but are not limited to: (a) human-related factors: risky driving behavior (Ma et al. 2010; Sullman, Stephens, and Kuzu 2013; Z. Zhang et al. 2019), individual characteristics (H. Wang, Liu, and You 2019), visual impairments (Maag et al. 1997), driving skill (Z. Zhang et al. 2019), fatigue (Z. Zhang et al. 2019), and mental stress (Mann et al. 2010); (b) organizational factors: irregular shifts (Y. Wang et al. 2015), lower-income (Lim and Chia 2015), and (c) internal (vehicle) environment: speed (H. Wang, Liu, and You 2019), interfaces and interactions such as speaking with pedestrians (Tillman et al. 2017), using mobile phones and interaction with In-vehicle Information System (IVIS) (Caird et al. 2018; Janitzek, T., Brenck, A., Jamson, S., Carsten, O., & Eksler 2010; Solís Marcos and Kircher 2019; H. Wang, Liu, and You 2019); (d) external environment: average traffic volume, pedestrian traffic volume, traffic signal priority, parking position (Lajunen, Parker, and Summala 2004; Shahla et al. 2009; Vayalamkuzhi and Amirthalingam 2016), road geometry (Kraus et al. 1993), weather (H. Wang, Liu, and You 2019), bus line location, the existence of parking lot at the roadside (Chimba, Sando, and Kwigizile 2010), and time of the day and year (Kraus et al. 1993; H. Wang, Liu, and You 2019).

Generally, there are two types of public transportation by bus, namely Bus Rapid Transit (BRT) and Conventional Bus (CB). BRT systems have gained popularity worldwide as a cost-effective alternative. There are several differences between these two types of passenger transportation systems, such as differences in lanes, speed, fare collection and technology, which may affect the driver's mental workload and safety. Urban buses share lanes with other traffic, whereas the BRT system involves dedicated bus lanes and separation by vehicle type. Also, the bus speed is faster in BRT than conventional buses, and

intelligent transportation systems (ITS) such as Automated Vehicle Location (AVL), passenger information systems, traffic signal preferences, vehicle docking/guidance systems are present in BRT but do not exist in conventional buses (Cervero, 2013).
Driving in narrow lanes on BRT buses leads to a change in task demands and priority goals for BRT drivers compared to conventional buses. For example, focusing on lateral bus control is one of the main tasks of drivers on BRT buses, and this may alter the workload. Also, the interaction between the operator and the (automated) support technologies may also increase task demands (Ward et al., 2006).

Bus Driving is a repetitive and intense task performed in a highly dynamic environment with little flexibility in departure schedule and having various organizational, legal, and other requirements (Dalziel and Job 1997; Li et al. 2020; Z. Zhang et al. 2019), which increase task demands. These features are more common in BRT buses than in conventional buses.

Moreover, driving has a high cognitive demand as the operator must integrate visual function, auditory function, decision-making, and manual control of the vehicle (Just, Keller, and Cynkar 2008; K. Young, Regan, and Hammer 2007). Based on multiple source theory, the driver has limitations in overall mental capacity and performing simultaneous dual tasks (Stelzel, Brandt, and Schubert 2009; Wickens 2002). Additionally, using available mental capacity is potentially more limited by human sensory inputs such as visual attention (Li et al. 2020; H. Wang, Liu, and You 2019). Many MWL studies have been conducted using driving simulators. Hence, very limited real dynamic environmental factors are present in this type of study. Moreover, despite similarities between BRT and CB, in terms of their purpose and supervision, their working conditions are different from each other. The present study, therefore, was conducted using public transportation system (BRT and conventional bus) drivers in their real-world working environment and aimed to (a) compare the mental workload of these two transportation systems and (b) study the influential factors on bus drivers' MWL in their natural dynamic working environment, in order to improve human factors relevant to road safety.

2. Methodology

2.1. Participants

A total of 123 drivers, including 50 Conventional Bus drivers (called feeders) and 73 BRT drivers, participated in this study in Tehran, Iran. Tehran is the capital of Iran and is the largest city both in population and metropolitan area. The age of drivers was between 33-57 (SD=5.348) years of age, with a mean of 44.01 years. The average driving experience of these bus drivers was 13.93 (SD=5.358) years. Inclusion criteria for participation were that they drove buses regularly; they had at least three years of driving experience and had a normal or corrected-to-normal vision.

2.2 Procedure

The participants were required to answer a questionnaire implemented in google forms presented in an interactive structured interview at the transport company's facilities. Before the form completion, the data collector presented a brief description of the study's purpose and answered any questions. The drivers were asked to consider a typical driving day at work when answering the DALI questions to collect their general perceived MWL. The information sheet confirmed the participants' anonymity and emphasized that the data were only to be used for research purposes.

2.3. Description of the Questionnaire

The questionnaire was administered in the Persian language and contained two parts. In the first one, demographic variables (age, height, weight, education, marital status) and work-related variables (bus type, work experience as a bus driver, average working hours per day, number of services per day, name/ number of line, accidents resulted in loss during last two years, fines during last two years, shift work, sleeping time duration, quality of sleep, job satisfaction, exercise, reading, and the traffic flow). The second part of the questionnaire collected information about mental workload using the Driving Activity Load Index (DALI) (Pauzié 2008), validated by Zakerian et al. (Zakerian et al. 2018) which in the current study collected information on the perceived typical driving MWL of the drivers. The reported internal consistency (test reliability) of this questionnaire showed that among a group of Iranian drivers, all six scales met the minimum reliability standard, the Cronbach's α coefficients ranging from 0.71 to 0.90 except for the interference scale (α=0.61). The DALI is a subjective rating method for comparative assessment of mental workload in various situations. This method development began in 1994 and was derived from NASA-TLX. This method assesses subjective workload during the driving task and contains six factors: Attention (Q: how much attentional demand is present- to think about, to decide, to choose, to think for), visual (Q: how much visual demand is present), auditory (Q: how much auditory demand is present), temporal (Q: how much temporal demand is present), interference (Q: how much disturbance occurs during your driving activity simultaneously with any other supplementary tasks such as phoning, using systems, radio or …) and situational stress (Q: how great is your level of stress/ constraints while driving-fatigue, insecure feelings, irritation, discouragement etc.). After arriving at the main terminal, the participants were asked to rate the demand level of each dimension based on their typical driving on a scale from 0 (low) to 5 (high). Each of these dimensions contributes to MWL, and the overall mean is referred to as the DALI index.

2.4 Road analysis

In terms of the relationship between subjective workload and driving performance indicators, some studies have used steering wheel angle (Brookhuis et al. 2009; von Janczewski et al. 2021) in the driving simulator to estimate driver performance and even to find a possible effect of this factor on MWL. Driving on a maze road causes slower mean speed, more variability in lane position, and the number of steering wheel corrections increased, which suggest a higher level of driver's workload (Hamish Jamson and Merat, 2005; Faure, Lobjois and Benguigui, 2016). In order to consider this parameter in the real environment, the road maze was used as an indicator of steering wheel movement. To do this, and as these lines were not equal, each line on the map was adjusted for the length of each line path. The research team followed these steps using MATLAB R2018a and the Tehran Public Transport map:

1. Specify the selected line path for both BRT and Conventional buses.
2. Cut the image's margins, wherever it is on the unwanted path's pixels, such as the station and the street's name, removing by matching it with the path (Fig 1).
3. Read the path's color and specify all the points in the image with the path's color.
4. Count the number of pixels in the path and divide it by the number of required parts. This number will be the number of pixels in each part of the path, starting from the beginning of the path and moving forward in

small steps until the number of travelled pixels equals the number of pixels in each part. Save this point and continue to get all the points at the beginning and end of the path sections (Fig 2).

5. The angle between lines is obtained from the following equation:

$$\tan(\alpha) = \frac{m - m'}{1 + mm'}$$

6. Calculate the bus path's maze, justified by the length of the path; the larger the number obtained, the less the maze of the path.

$$Radius: \frac{path\ length(km)}{The\ radius\ of\ the\ circle\ represents\ the\ path}$$

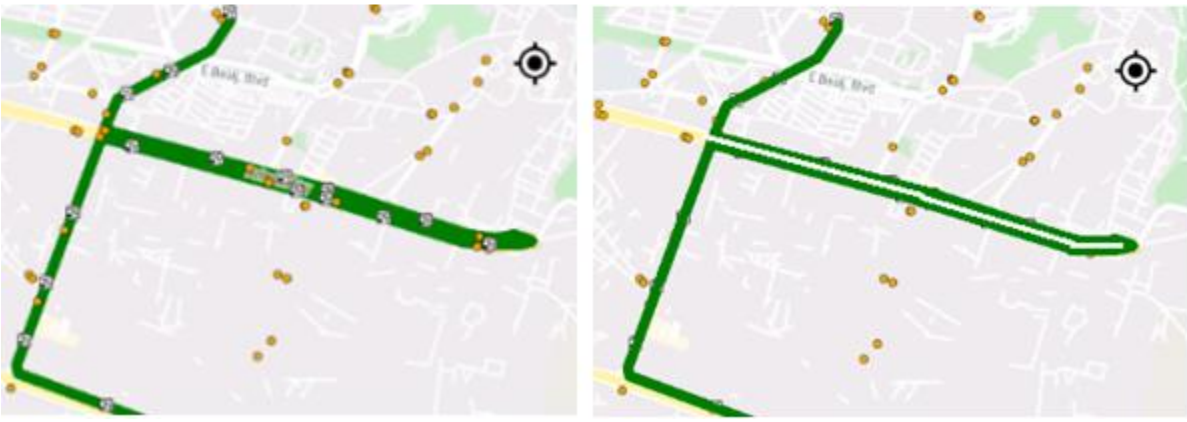

Figure 1: Cutting margins and remove unwanted pixel path

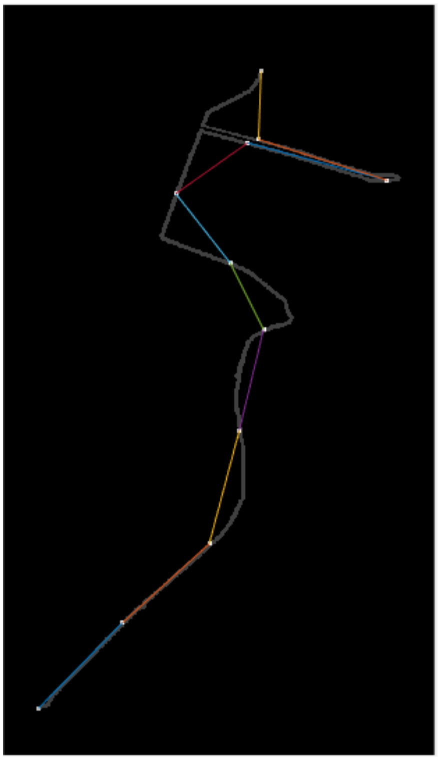

Figure 2: Sectioning of the path

2.5. Data analysis

Analysis and modelling of study data were performed using IBM SPSS software version 22.0, and the significance level in this study was considered as $p < 0.05$. The normality of the data was assessed using the One-Sample Kolmogorov-Smirnov Test, which showed that these data did not have a normal distribution ($p < 0.05$). Quantitative and qualitative variables were compared between the two groups of BRT and conventional bus drivers using Mann-Whitney U and chi-square tests, respectively. As to use regression, the normal distribution of the dependent variable is not a necessary condition, but the normal distribution of error values is the main condition. So, in this study, after fitting the model, the distribution of residual error values was investigated, and since they had a normal distribution, multivariate linear regression analysis was used for assessing the effects of different variables on the dimensions of the mental workload and the final DALI index

3. Results

In this study, 123 bus drivers were studied and evaluated. The results of this study are focused on the type of bus. In this study, 73 (59.3%) BRT bus drivers and 50 (40.7%) conventional bus drivers were evaluated. Results of comparative evaluation of two groups of BRT and conventional bus drivers based on quantitative variables are shown in table 1. Analyses using the non-parametric Mann-Whitney U test showed drivers age, work experience, BMI, sleeping hours per day, working hours per day, mean road maze score, and the number of stations were higher in the BRT buses compared to CB buses. The analyses also showed that the average working hours per day, number of services per day, number of accidents leading to injury, number of accidents resulting in fines, and bus age in the group of conventional buses were higher than the BRT buses group. Furthermore, these differences were also statistically significant ($p < 0.05$). Despite the higher average number of working days per week in conventional bus drivers than BRT bus drivers, this difference was not statistically significant ($p = 0.422$).

Table 1: Results of comparative evaluation of two groups of BRT and conventional bus drivers based on quantitative variables

Variable	Bus Type	Mean	Std. Deviation	p-value	Mann-Whitney U
Age (year)	BRT	45.30	4.827	0.002*	1212.000
	CB	42.12	5.554		
Work experience (year)	BRT	16.71	3.120	0.001**	531.500
	CB	9.86	5.361		
BMI	BRT	26.22	3.28240	0.001**	1133.000
	CB	24.65	1.84029		
sleeping hours per day	BRT	6.10	1.426	0.001**	890.500
	CB	4.98	1.152		
Working hours per day	BRT	9.15	0.981	0.001**	121.500
	CB	13.88	1.734		
Working days per week	BRT	6.63	0.565	0.422	1694.000
	CB	6.64	0.631		
Number of driving per day	BRT	5.44	0.897	0.001**	89.000
	CB	10.78	2.306		
Number of injuries	BRT	0.38	0.543	0.046*	1500.000
	CB	0.60	0.639		
Number of driving fines	BRT	0.38	0.568	0.001**	1062.500
	CB	0.96	0.755		
Road Maze Mean (km/r)	BRT	36.79	11.93	0.001**	113.000
	CB	4.31	5.53		
Number of stations	BRT	26.12	0.33	0.001**	616.000
	CB	21.42	3.45		
Age of bus (year)	BRT	8.92	0.00	0.001**	0.000
	CB	12.22	0.00		

*p ≤0.05, **p ≤0.001, BRT: Bus Rapid Transit, CB: Conventional Bus.

Analyses compared the BRT and Conventional bus drivers based on categorical variables such as marital status, level of education, satisfaction with sleep quality, job satisfaction, exercise, study status, and traffic volume using a chi-square test. These analyses, using non-parametric Chi-Square tests, showed that there were no significant differences between the groups in terms of marital status, level of education and exercise (p >0.05). These results also showed that satisfaction with sleep quality, job satisfaction, and study status were significantly higher in BRT drivers than Conventional bus drivers (p <0.05). Also, these results showed that the number of Conventional bus drivers who estimated the volume of the route as heavy (66.0%) was significantly higher than the BRT bus drivers (19.2%; p <0.05).

Table 2: Results of the evaluation of two groups of BRT and Conventional bus drivers based on qualitative variables

Variable		Bus Type		p-value	Pearson Chi-Square
		BRT	CBD		
Marriage status	Married	73	49	0.407	1.472
		59.8%	40.2%		
	Single	0	1		
		0.0%	100.0%		
Education	Diploma	71	49	0.684	0.759
		59.2%	40.8%		
	B.Sc.	1	1		
		50.0%	50.0%		
	Master	1	0		
		100.0%	0.0%		
Satisfaction of Sleep quality	yes	39	4	0.001**	26.929
		90.7%	9.3%		
	no	34	46		
		42.5%	57.5%		
Job satisfaction	yes	49	10	0.001**	26.402
		83.1%	16.9%		
	no	24	40		
		37.5%	62.5%		
Exercise	yes	22	11	0.408	1.001
		66.7%	33.3%		
	no	51	39		
		56.7%	43.3%		
Study	yes	32	6	0.001**	14.087
		84.2%	15.8%		
	no	41	44		
		48.2%	51.8%		
Route traffic volume	Light	10	1	0.001**	28.494
		90.9%	9.1%		
	Medium	49	16		
		75.4%	24.6%		
	High	14	33		
		29.8%	70.2%		

**p ≤0.001

The amount of mental workload of the two BRT and Conventional bus drivers based on the DALI index was estimated to be 23.95 ± 2.09 and 25.33 ± 0.77, respectively. A comparative evaluation of mental workload dimensions of two groups of BRT and Conventional bus drivers based on the six variables of DALI tools including Attention, Visual, Auditory, Stress, Time and Interference, as well as the final DALI index, was made using the non-parametric Mann-Whitney U test. The results of the analyses showed that the mean of most dimensions, including Visual, Auditory, Stress, Time and Interference, as well as the final DALI index, were higher in the Conventional bus drivers than the BRT bus drivers. The mean Attention dimension score was equal in both groups (5.0 ± 0.0). These results showed that the differences between the two groups of drivers for the dimensions of Auditory, Time, and Interference and the final DALI index were statistically significant (all p's <0.05). The differences between the two groups of drivers studied for the dimensions of Attention, Visual, and Stress were not statistically significant (Table 3).

Table 3: Results of comparative evaluation of two groups of BRT and Conventional bus drivers based on DALI index and its dimensions

DALI Variables	Bus Type	Mean	Std. Deviation	p-value
Attention	BRT	5.00	0.00	1.0
	CB	5.00	0.00	
Visual	BRT	4.97	0.16	0.240
	CB	5.00	0.00	
Auditory	BRT	4.40	0.70	0.028*
	CB	4.68	0.47	
Stress	BRT	4.78	0.77	0.233
	CB	4.94	0.31	
Time	BRT	4.16	1.18	0.001**
	CB	4.94	0.24	
Interference	BRT	3.84	1.05	0.001**
	CB	4.62	0.53	
DALI Score	BRT	23.95	2.09	0.001**
	CB	25.33	0.77	

*p ≤0.05, **p ≤0.001

The regression analyses with the different dimensions of mental workload (Attention, Visual, Auditory, Stress, Time, and Interference) and the final DALI index as dependent variables are shown in Table 4. The results of this modelling showed that the variables Bus Type and Working hours per day had a significant effect on the Auditory dimension. Bus Type and the Road Maze Mean variables had a significant effect on the Time dimension. Three variables, namely Bus Type, Road Maze Mean and Route traffic volume, had a significant effect on the Interference dimension. Four variables, namely Bus Type, working hours per day, Road Maze Mean and Route traffic volume, had a significant relationship with the final DALI index (p <0.05).

Table 4: Regression analysis of DALI index and its dimensions

Dependent variable	Independent variable	Beta	Standardized B	Standard Error	$CI_{95.0\%}$ for Beta	p-value
Auditory	Bus Type	7.30	5.70	1.99	(3.4, 11.2)	0.005*
	Working hours per day	0.44	1.87	0.14	(0.17, 0.71)	0.042*
Time	Bus Type	13.71	6.80	2.90	(8.03, 19.4)	0.021*
	Road Maze Mean	0.76	1.92	0.36	(0.06, 1.47)	0.045*
Interference	Bus Type	14.03	7.22	2.73	(8.68, 19.38)	0.010*
	Road Maze Mean	0.33	1.37	0.11	(0.11, 0.54)	0.036*
	Route traffic volume	1.75	1.14	0.03	(1.69, 1.81)	0.032*
DALI index	Bus Type	20.46	5.58	0.87	(18.76, 22.17)	0.001**
	Working hours per day	0.83	1.23	0.08	(0.67, 0.98)	0.012
	Road Maze Mean	0.68	2.45	0.3	(0.09, 1.26)	0.048*
	Route traffic volume	5.83	2.01	0.35	(5.14, 6.51)	0.001**

*p ≤0.05, **p ≤0.001

4. Discussion

In this study, demographic, work-related, and personal variables of conventional bus and BRT bus drivers in their actual working context were examined in order to identify factors affecting MWL using the DALI index. Results showed that the auditory load was high among both BRT and conventional bus drivers. DALI auditory scores obtained show a positive association with bus type and working hours per day. Results showed that although auditory demand among both groups was high, conventional bus drivers experienced more auditory demand than BRT drivers. This finding may reflect that bus driving in conventional areas is a demanding auditory task, whereas, on the other hand, BRT drivers who work on a dedicated lane experience less auditory demand. According to some studies, allocating more resources to an auditory task is possible when there is a low visual processing demand (Solís Marcos and Kircher 2019). As both visual and auditory demand was at the almost highest level among CB drivers, so they have less spare resources to dealing with high auditory demand compared to BRT drivers. Auditory demand may also result from drivers' tactical approach to improve their performance or at least maintain it to a near-optimal level. Some studies show that drivers who simultaneously perform secondary tasks, as well as driving tasks, could perform the tasks more rapidly and accurately by providing multi-modal feedback that merges audio-visual information compared to processing each visual or auditory modality alone (Jakus, Dicke, and Sodnik 2015). This is in line with the current study's auditory and visual demand scores. Another influential factor in auditory demand was working hours per day. This could explain the effect of a working hour per day on auditory load, which result in auditory fatigue. Dalziel et al. report that auditory fatigue is not a unique phenomenon and refers back to cognitive fatigue and emotional exhaustion. Moreover, high working hours among drivers (Dalziel and Job 1997) cause a decrement in the quality and quantity of sleep. Some studies have found that high working hours each day are the most common and important factor in driving fatigue and burnout (Friswell and Williamson 2013; Z. Zhang et al. 2019).

Some well-known mental workload assessment tools, like the NASA-TLX (Hart and…1988), mention temporal demand as one crucial contributing factor to the overall workload perceived by an operator (Hart and Staveland 1988). These increased demands on information processing speed affect the allocation and multi-task performance, and as a result, cause a higher mental workload (Solís Marcos and Kircher 2019). Our results show that temporal demand (time constraints) has a relationship with bus type (BRT or CB) and road maze. Conventional bus drivers experience more time pressure than BRT bus drivers, which may be related to their road conditions such as the road maze and unpredictable situations, including traffic lights, route traffic volume. This supports the idea suggested by another study, which concludes that uneven roadway design can cause unexpected dynamic change, leading higher to workload for the driver (Lyu et al., 2017).

The results from the current study results revealed bus type, road maze, and road traffic volume contributed to driver interference. A possible bus type characteristic that influences interference would be the driver cab. In BRT buses, the cabs provide the drivers with greater separation from the passengers, decreasing driver-passenger conversations. This finding is in line with previous studies which have concluded that cellular phones and conversation increase mental workload (Oviedo-Trespalacios et al. 2016; Zokaei et al. 2020). According to Stutts (Stutts et al. 2001), passengers are a contributor to approximately 11% of distraction-related road traffic accidents. The imposed MWL, both for natural and phone conversation, is related to the conversation context (Dula et al. 2011; Zokaei et al. 2020), which means that simple, complex, and emotional conversations produce different cognitive loads (Briggs, Hole, and Land 2011; Zokaei et al. 2020). Some studies have shown that the complexity of the conversation is a secondary task that impairs driver's road and environmental scanning, which results in a greater focusing of attention by the drivers (Harbluk, Eisenman, and Noy 2002).

Steering angle variability is significantly correlated with temporal demand, performance and total workload (Shakouri et al. 2018). In this study, both road maze, an indicator of steering wheel movement, and road traffic volume impact driver performance. One reason for this may be that both road maze and route traffic volume occupy visual attention and compete for this resource (Wickens 2002), and dividing attention leads to increases in workload (M. S. Young et al. 2015). Solis-Marcos (Solís Marcos and Kircher 2019) found that using a display while driving causes further visual and mental load as both visual tasks uses the same visual information sources. Stelzel et al. introduced a model called the "psychological refractory period", which defined the overlapping of information in the brain (Stelzel, Brandt, and Schubert 2009). According to this model, the processing of secondary stimuli can be slowed because the first stimuli are still being processing. Solís Marcos et al. also demonstrated that performance is not be impaired when there is simultaneous performing of tasks that do not use the same mental resources, such as auditory and visual tasks (Solís Marcos and Kircher 2019). Another study (von Janczewski et al. 2021) has obtained conflicting results and reported that forward velocity, the standard deviation of forward velocity and steering wheel variability measures are not sensitive to cognitive load. A reason for these conflicting data could be the shorter driving period in simulation-based studies compare to a real driving test and reduce the effect of fatigue. Another reason would be different measurement tools and study setup, which can affect the final results.

In the final regression model, bus type, working hours per day and road maze were associated with the DALI index. Almost all of the independent variables for each of the dimensions remained in the final model except for road traffic volume. A possible interpretation is that the effect of road traffic volume on the DALI index, as a global score, is not important as the other variables. Another possible interpretation would be in accordance with some studies which concluded that measurement of subjective mental workload via the NASA-TLX questionnaire should rely on each dimension rather than global score (Cain 2007; Galy, Paxion, and Berthelon 2018), especially when the goal is to represent practical solutions.

Limitations

This study has some limitations that need to be pointed out. Using more detailed qualitative information would allow a deeper understanding of work characteristics. However, a social desirability bias in self-reporting surveys may cause some variance between the bus drivers' responses and what they believe or feel. Secondly, the sample size of this study was not large. When the sample size increases, the results can be more accurately generalized. Another limitation is that few psychosocial and socio-technical factors were included in this study. In this sense, and as a suggestion, it is worth including as many factors as possible using existing standardized questionnaires and carry out an interview with drivers to obtain a more detailed profile of factors that influence mental workload.

Conclusion

This study investigated conventional bus drivers' and BRT bus drivers' mental workload, both as separate groups and combined. It was found that both groups had a high level of MWL but that it was higher in conventional bus drivers compare to the BRT group. Travel time, affordability, higher passenger safety, and more relaxing trips for the drivers using BRT significantly affect the choice of BRT as a transportation system. Our findings present a picture of the context that influences MWL, and the use of the present methodology has led to a more detailed map of challenges due to MWL. In addition, the present approach makes it easier to find and implement efficient, practical solutions. There are several procedures that one can take to reduce the level of mental workload. The authors suggest the ranking of each dimension, based on their scores and model output, from the highest to the lowest, and active participation of drivers and managers using root cause analysis methods such as Five Whys (Ohno 1988), to find the root cause/causes of each of the DALI dimensions, followed by brainstorming techniques such as Delphi which can lead to a tailor-made solution for this environment. This then needs to be implemented and its effectiveness evaluated.

Acknowledgements

The authors would like to thank the Shiraz University of Medical Sciences that provided the basis for this study and Tehran and Suburbs Bus Company for their collaboration and coordination. We also appreciate the volunteers for their patience and support with our study.

Disclosure statement

No potential conflict of interest was reported by the authors.

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