DRIVERS' WORKLOAD MEASURES TO VERIFY FUNCTIONALITY OF FERRY BOATS BOARDING AREA

Gaetano BOSURGI[1], Stellario MARRA[2], Orazio PELLEGRINO[3], Massimo VILLARI[4]

[1,2,3] Department of Engineering, University of Messina, Italy

[4] Department of Scienze matematiche e informatiche, scienze fisiche e scienze della terra, University of Messina, Italy

Abstract:

Functionality of a square used for ferry boats boarding has repercussions on safety and comfort of users, as well as on the efficiency of maritime transport. Inadequate use of the infrastructure causes driving errors followed by corrective manoeuvres, loss of time and potential accidents with consequences for community and the maritime transport company. The wide diversification of traffic components and payment methods are generally managed through a traditional horizontal and vertical signage system that does not refer to any current legislation. Therefore, the purpose of this research is to investigate driver's behaviour and the interaction that takes place between the latter and the environmental context. In particular, the authors focused on the study of the driver's workload in a simulated environment, considering a users' sample and different driving scenarios inside the boarding area, concerning traffic conditions (isolated vehicle or presence of disturbing vehicles) and signs position. All this, in order to evaluate whether any change in a virtual context could bring real benefits to drivers, before being transferred to the real context. The results obtained, in terms of subjective workload and performance measures, have made it possible to judge the different solutions proposed in a simulated environment through synthetic indices referring to the entire boarding place or at certain parts of it. In this way, the manager can decide to change the circulation of the entire square or only some aspects of detail, such as some signals, in the event that they manifest an evident difficulty in the transfer of information. The use of the simulated environment allows greater speed in identifying the best solution, lower costs (avoiding the creation of a critical configuration for circulation) and greater user safety, since risky manoeuvres are identified and corrected by the simulator. The proposed procedure can be used by managers for a correct arrangement of the signs, for the purpose of correctly directing the flows and maximizing the flow rate disposed of.

Keywords: workload measures, driver behaviour, driving simulation, road safety, complex environment

To cite this article:

Contact:
1) gbosurgi@unime.it [https://orcid.org/0000-0002-0782-5510], 2) smarra@unime.it [https://orcid.org/0000-0001-8118-8989],
3) opellegrino@unime.it [https://orcid.org/0000-0002-7990-3581] – corresponding author,
4) mvillari@unime.it [https://orcid.org/0000-0001-9457-0677]

1. Introduction

Particularly complex context conditions could lead drivers to compromise their performance. In these situations, driver will therefore be more prone to make mistakes that can be reflected in a reduction in functionality and safety of the surrounding environment. In this work, a boarding area for ferry boats was examined. This scenario, due to the complex geometry and the different payment methods, requires users a wide visual and cognitive demand. For this reason, it is important to study the impact of the individual elements in the boarding area on the driver's response.

In a complex road system, the Workload (*WL*) can describe effectively and concisely the human component and the interaction between driver, vehicle and surrounding environment (Bongiorno et al., 2017). According to O'Donnel and Eggemeier (1986), the WL could be seen as the amount of capacity used by the driver to complete a specific task. In particular, the Mental Workload (*MWL*) is very complex to analyze, because it depends on both subjective user characteristics – such as experience, fatigue, ability, age, drug use, etc. – and on the external context – such as traffic flows, road, ergonomics, vehicle automation (De Waard, 1996; Patten et al., 2006). The driver should experiment an optimal value of *MWL* – not too high or too low – to ensure good driving performance (Brookhuis and De Waard, 2010).

The *MWL* can be measured subjectively, for example through suitable questionnaires or instrumental measures. Both measurement methods are mainly influenced by the complexity of the driving environment, therefore by the tasks that the driver have to carry out during the driving activity and by the amount of information that he has to process. It has been shown that the estimate of *MWL* depends on the capacity required during the driving task and on the complexity of the road environment (Pellegrino, 2009). Furthermore, it has been found that the *MWL* of drivers increases as the complexity of the driving situation enhances, while driving in a simulated environment (Cantin et al., 2009).

Paxion et al. (2014) reported a review that investigates the effects of *MWL* while driving, focusing on the dependence on the complexity of the surrounding environment and the driver's experience. Many studies have been carried out with the aim of showing how the environmental context can influence the MWL and the driving performance (De Waard, 1991; Cnossen et al., 2000; Steyvers and De Waard, 2000). To do this, generally, different levels of complexity have been tested on the basis of road geometry and traffic flow (Fastenmeier, 1995; Fastenmeier and Gstalter, 2007), or based on the presence of a single or a double task. The interaction between road users, vehicles and environment could affect to driver's behaviour. The missed combination between these factors can lead to various road injuries (Muslim et al., 2018). O'Hern et al. (2019) demonstrated that as the complexity of the external environment increases, so does the driver demand. Two studies have revealed that the increase in the complexity of the situation leads to an increase in the subjective *MWL* and a decline in the performance. In fact, passing from a single task to a double task (for example, driving and answering the phone), some typical driving performance indices such as the Standard Deviation of Lateral Position (*SDLP*) and the Standard Deviation of the Steering-Wheel Movements (*SDSTW*) increase (De Waard et al., 2001).

O'Donnel and Eggemeier (1986) identified three different groups of workload measurements:

− Subjective measures or self-report;
− Performance measures;
− Physiological measures.

The first ones are obtained by filling in questionnaires that evaluate the subjective level of *MWL* while driving. The technique related to the use of questionnaires is faster, however (Rubio et al., 2004; Paubel, 2011), it does not investigate the variation of *MWL* during the performing of the task (Cegarra and Chevalier, 2008). At this regard, the most famous and the most frequently used procedure is the NASA TLX questionnaire, a multi-dimensional rating scale in which the combination of six factors allows to estimate workload (Hart and Staveland, 1988; Costa et al., 2019). The two main ways to estimate workload by means of performance are primary task and secondary task measurements. The performance measures related to the primary task allow to define the workload on the basis of the driver's ability to perform the main task (Rehmann, 1995). It is assumed that, as the workload increases, there will be some changes in driver performance (usually degradation). It is found that the measurement of the changes in driving performance can provide a workload index referred to the task (O'Donnel and

Eggemeier, 1986). The performance measures related to the secondary task are additional values to the primary task. According to the Multiple Resource Theory, primary task performance uses a certain amount of driver's resources, therefore the rest are used on the secondary task performance (Wickens et al., 1998). Physiological measures are, instead, indirect measures that allow a continuous evaluation of the *MWL*. These measures can be used to complete the previous ones. The positive aspect of measuring the physiological parameters of the driver, in the context of driving simulation, is due to the fact that they are easily deductible during the tests. On the other hand, this procedure requires good research, technical skills and time expenditure (Brookhuis and De Waard, 2010). In addition, they are non-intrusive measures, generally applicable in the testing environment under the supervision of an operator who checks that there are no factors that can influence the signal, such as temperature, light, etc. They can provide a detailed analysis with a specific sensitivity to the different dimensions of the *MWL* (Kramer, 1991). The study of eye movements can be included in the third group of measures, as some authors believe that these measures may be related to *MWL* (Pellegrino, 2012; Bosurgi et al., 2013; Marquart et al., 2015; Liao et al., 2018; Anh Son et al., 2019) and to fatigue's level (Kurosawa et al., 2020). Furthermore, Li et al. (2020) identified a correspondence between subjective workload data and eye movement data. It can be stated that it is advisable to use combined methods for the assessment of *MWL* (Butmee et al., 2019)

During driving activity, the main source of information for the drivers is the external environment (road signs, traffic devices, other road users, onboard units). Loss of attention, even partial, to the different sources of information could reduce the driver's reliability, which in turn will increase the probability of an accident (Afanasieva and Galkin, 2018). For example, inadequate road signs' design could lead driving errors followed by corrective manoeuvres, loss of time and potential accidents with consequences for community and the maritime transport company. Traffic accidents cause increase travel-times and congestion. The cost due to the extra travel time and the consequent fuel consumption is huge (Lee et al., 2017). In a complex environment, where the wide diversification of traffic components

and payment methods are managed through a tradiional horizontal and vertical signage system, it is interesting to understand how the configuration of the traffic signs affects the performance related to the primary driving task and to the secondary visual task. Two configurations were studied to identify the optimal one. For this purpose, it was necessary to consider the individual signs as elements of interest, to study how they impact the drivers' *MWL*. The authors have chosen to use the following types of *MWL* measurements:

1. Subjective measures;
2.a. Performance measures related to the primary task;
2.b. Performance measures related to the visual secondary task.

Regarding the performance measures, on the one hand the travel times and the number of driving errors were recorded, in order to define some primary task performance indexes. Instead, regarding the secondary task (visual monitoring task), the driver's ability to acquire information from the road signs was assessed. At the end of each test, the users filled out the questionnaire NASA TLX to measure their subjective workload.

This procedure could be interesting due to the absence of applications within a boarding area in literature and to optimize the road signs' design by means of different measures of workload.

2. Method

The proposed methodology consists of the following phases:

– reconstruction of the driving environment using two-dimensional and three-dimensional modelling;
– transformation of the 3D model into a system responsive to the physics' laws;
– description of the instrumentations used; experimentation design; definition of the sample of users;
– identification of indicators representative of the driver's behaviour, obtained from the combination of data referring to the drivers' performance and from the NASA-TLX questionnaire;
– processing of output data.

2.1. Simulated environment

The driving environment was rebuilt using the AutoCad and Infraworks Autodesk® software to model

the geometry of the boarding area, as well as all the road infrastructure with the horizontal and vertical signs. The models thus obtained were imported into the graphics engine in which the driving simulation is developed. The driving simulator in which the experiment was carried out was built with the Unity 3D® platform. This software is a graphics engine that allows the development of video games and other interactive content, such as architectural visualizations or 3D animations in real time. Unity 3D® allows the creation of new projects or even the import (in .obj and .fbx formats) of models created on any 3D modelling software. After importing the driving environment, the Mesh Colliders were inserted. These tools that, overlapping the model, transform it into a real system that takes into account the physics' laws such as gravity and collisions. After that, a realistic vehicle model was inserted that, like a rigid body, reacts with surrounding objects and can faithfully reproduce the realistic behaviour thanks to a "Vehicle Controller" script (Figure 1). This script manages: the mechanical aspects of the vehicle (steering wheel, engine, transmission, wheels, suspension, etc.), the sound aspects (noise from the engine, from the transmission, from contact with the road pavement, from impacts, from braking actions etc.) and the visual effects (signs of braking on the pavement, light sources, light diffusion angle, etc.). Most applications in Unity 3D® need scripts to respond to user inputs and to manage events in the scenario, in such a way that they happen at the right time. Scripts can be used to create graphic effects, control the physical behaviour of objects or even to implement AI systems for elements into the scene. The scripts are created and edited with Microsoft Visual Studio 2017® software, using the C# programming language. Through scripting (C#) it was also possible to acquire the telemetry data (position, speed, acceleration, etc.). Furthermore, different traffic vehicles (cars and heavy vehicles) that transit through the boarding area following specific waypoints, at a speed of 20 km/h (to simulate the slow traffic condition), were also included in the model.

The configuration of the Logitech G27 system (steering wheel and pedal) with the Unity 3D software was carried out for vehicle control purposes. The Logitech system interfaces directly with the Unity Input management script, allowing the calibration of the sensitivity along the steering axis and along the acceleration and deceleration axis.

Fig. 1. 3D model of the boarding area

2.2. Instrumentations

The hardware equipment used consists of:
− a single monitor (27") for the reproduction of the driving environment;
− Logitech G27® system, including steering wheel and pedal for the vehicle control (the gearbox is to be considered automatic);
− Tobii Glasses Eye Tracker® (v. 1.0) for tracking and processing the eye movements' data;
− computer with specifications suitable for the smooth running of driving simulations.

The hardware equipment used for this study is to be considered not definitive, but this does not affect the quality of the methodology proposed.

2.3. Experimental design

Four scenarios were created, with the aim of making a comparison between the different proposed conditions. In particular, after rebuilding the real scenario detected, a design proposal was made, in which the existing horizontal and vertical signage was modified. After receiving the main information regarding the driving tests, the participants wore the Tobii Glasses Eye Tracker. Following a first phase of calibration of the glasses, necessary to obtain an adequate accuracy in the tracking of eye movements, the experimentation was started. Each of the participants made four guides in a simulated environment inside the Caronte & Tourist boarding area in Villa San Giovanni (RC). The first guide also includes a first section of the motorway, 3 km long, in order to get the driver used to the controls (accelerator, steering wheel and brake). Once this route was completed, the driver found himself in the boarding area object of the experimentation. Participants took an average of 5.5 minutes for the first guide (including the test track) and 2.5 minutes for the other ones.

The users carried out the driving tests with two traffic scenarios (no traffic, slow traffic) and two signs

conditions (real condition, design condition). The features of each test are listed on below:

− Test 1: no traffic + real condition;
− Test 2: slow traffic + real condition;
− Test 3: no traffic + design condition;
− Test 4: slow traffic + design condition.

Following each guide, participants were asked to complete the NASA TLX questionnaire and to provide some information relating to the critical issues encountered during the simulation tests.

2.4. Drivers

The sample selected includes 11 drivers, including 7 males and 4 females. Participants have an average age of 26.8 years old, a driving experience of not less than 3 years and declare that they do not suffer from visual disturbances at the time of the simulation. Before the guides, each participant was explained how the experimentation would take place and the main commands needed for the vehicle control. All the participants are part of the academic context and give their consent to the use and processing of their personal data. Each of them takes part in the experimentation for free.

2.5. Measures and Indicators

For the purpose of the study, some main variables were identified as representative of the users' driving behaviour, such as:

− travel times, representative of the difficulty perceived by the drivers in performing the task;
− driving errors, which are represented by incorrect manoeuvres, taking wrong lanes and collisions;
− visual acquisition, which represents the driver's ability to acquire information from traffic signs.

Based on these measures some performance indexes have been assessed.

2.5.1. Travel Time Performance Index (TTPI)

The travel time is the time interval between t_0 (instant when the vehicle enters the boarding area) and t_f (instant when the vehicle leaves the boarding area). *TTPI* represents the drivers' difficulty during the tests: lower *TTPI* values are correlated with a lower difficulty of the task and, on the contrary, higher *TTPI* values are correlated with a greater difficulty of the task. The index is calculated as follow:

$$TTPI = \left(\frac{t_{ij}}{tmax_i}\right) \cdot 100 \qquad (1)$$

Where t_{ij} is the travel time measured for the *i*-user during the *j*-driving test, while $tmax_i$ is the maximum travel time measured for the *i*-user.

2.5.2. Driving Errors Performance Index (DEPI)

A particularly complex driving environment, such as the one studied in this paper, requires adequate design of the road signs to avoid/minimize driving errors that can be identified in the following actions:

− take the wrong lane;
− incorrect maneuvers;
− collisions.

These errors could cause traffic jam and slowdown in the boarding area, thus reducing the functionality and road safety perceived by users. *DEPI* represents the amount of driving errors committed in the tests: lower *DEPI* values are correlated with a lower error rate and, on the contrary, higher *DEPI* values are correlated with a higher error rate. The index is calculated as follow:

$$DEPI = \left(\frac{N_{ij}}{Nmax_i}\right) \cdot 100 \qquad (2)$$

Where N_{ij} is the number of driving errors identified for the *i*-user during the *j*-driving test, while $Nmax_i$ is the maximum number of driving errors identified for the *i*-user.

2.5.3. Driver's Visual Acquisition (DVA)

The *DVA* index represents the percentage of time in which the driver does not gaze the road to acquire information from traffic signs: lower *DVA* values are correlated with a lower visual acquisition and, on the contrary, higher *DVA* values are correlated with an higher visual acquisition. The index is calculated as follow:

$$DVA = \left(\frac{f_{ij}}{t_{ij}}\right) \cdot 100 \qquad (3)$$

Where f_{ij} is the total fixation time at the road signs measured for the *i*-user during the *j*-driving test, while t_{ij} is the travel time recorded for the *i*-user during the *j*-driving test.

2.5.4. NASA TLX

In addition, the overall workload (*OW*) was assessed through NASA-TLX questionnaire. The NASA TLX is a multidimensional procedure to evaluate the

Overall Workload (*OW*). This procedure is useful to quickly gather measurements of subjective mental workload referring to specific tasks. Every participant after each test, have filled the questionnaire to measure their mental effort.

2.6. Processing of raw data
The raw data extrapolated from the driving tests were processed with the Analysis of Variance (Two-way Anova) to understand how the different conditions affect the drivers' mental workload and the driving performance. Based on the results of the ANOVA tests, some comparisons were made. These comparisons permit to observe the trend of the output indicators (*TTPI, DEPI, DVA, OW*) as a function of the input variables (traffic interaction and road sign design).

3. Results
In this study the authors want to evaluate the effects of the two variables (traffic interaction and vertical and horizontal signs) on the driver's *MWL* in order to verify the functionality of a Ferry Boats Boarding Area. Some ANOVA (two ways) analysis were carried out to understand if the aforesaid variables have significant effects on the drivers' mental workload.

The data recorded from the simulation tests have been divided in three main categories for a better reading:
- Performance Indexes related to the primary task:
    a) Travel Time Performance Index (*TTPI*);

b) Driving Errors Performance Index (*DEPI*);
- Performance Index related to the visual secondary task: Driver's Visual Acquisition (*DVA*);
- Subjective Workload estimated with NASA-TLX questionnaire.

The results are listed below.

3.1. Travel Time Performance Index (*TTPI*)
In this field significant effects were found for both traffic condition ($F(1,40) = 184.24$, $p < 0.05$) and traffic sign ($F(1,40) = 8.23$, $p < 0.05$) but no effects were found for interaction between the two variables. The results are shown in the Figure 2.

3.2. Driving Errors Performance Index (*DEPI*)
In this regard significant effects of the traffic signs were found ($F(1,40) = 29.64$, $p < 0.05$), but no effects of the interaction among vehicles were noticed. The results are shown in in the Figure 3.

3.3. Driver's Visual Acquisition (*DVA*)
In this field significant effects of both traffic ($F(1,40) = 7.55$, $p < 0.05$) and traffic signs design ($F(1,40) = 6.63$, $p < 0.05$) were found, but no effects of interaction between the two variables. The results are shown in the Figure 4.

3.4. Overall Workload (*OW*)
In this field significant effects of the traffic signs design ($F(1,40) = 12.83$, $p < 0.05$) were found, but no effects of traffic and interaction were noticed. The results are shown in the Figure 5.
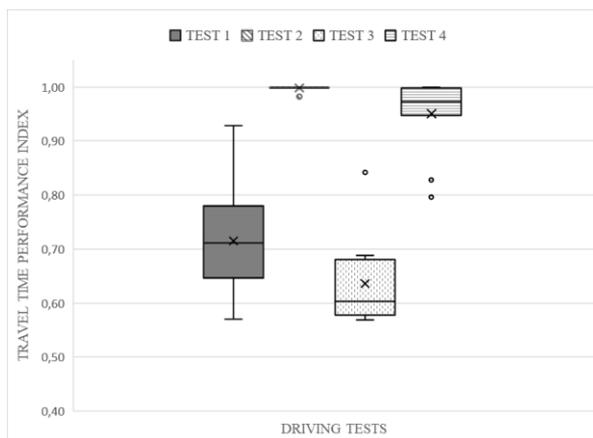
Fig. 2. Boxplot of the *TTPI* values measured during the tests
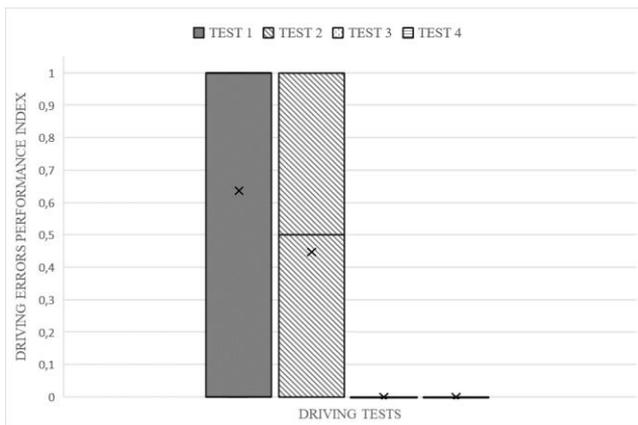
Fig. 3. Boxplot of the *DEPI* values measured during the tests
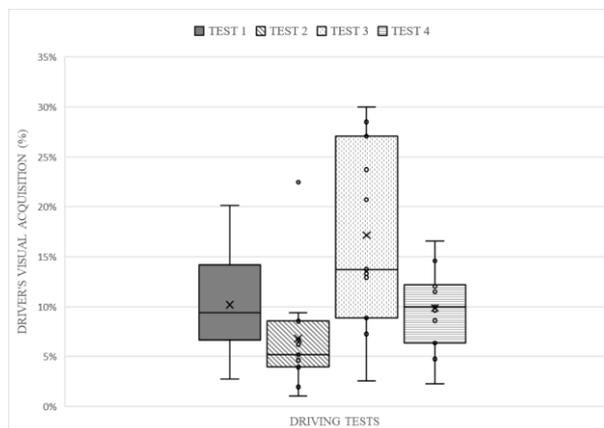
Fig. 4. Boxplot of the *DVA* values measured during the tests
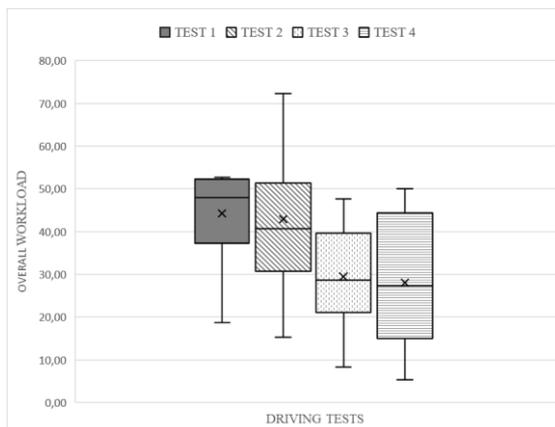
Fig. 5. Boxplot of the *OW* values measured with NASA-TLX

4. Discussion and conclusions

Based on the results shown in the previous paragraph, could be interesting to make some observation to better understand how the different traffic signs' configuration impact on the driving behaviour.

4.1. Travel Time Performance Index (*TTPI*)

ANOVA analysis have shown significant effects of both traffic and vertical signs design. It's possible to make the comparisons between the average *TTPI* recorded in:

– Tests 1-3 (sign design effects – no traffic): mean reduction of 11% passing from the starting condition to the project condition;
– Test 2-4 (sign design effects – with traffic): mean reduction of 4,7% passing from the starting condition to the project condition;
– Test 1-2 (traffic effects – starting condition): mean increase of 39,6% passing from the no traffic condition to the traffic condition;
– Test 3-4 (traffic effects – project condition): mean increase of 49,4% passing from the no traffic condition to the traffic condition.

From these observations, it is possible to notice the travel times reduction passing from the real condition to the design condition. This aspect suggests that the drivers – in the project condition – have a better understanding of the track and, as a result, they are able to complete the task faster. Moreover, it is possible to notice a significant travel time's increase due to the presence of traffic vehicles that transit into the boarding area at low speed. This was expected since all the participants respected the line, not committing dangerous overtaking.

4.2. Driving Errors Performance Index (*DEPI*)

ANOVA analysis have shown significant effects due to the sign's design. It is possible to make the comparisons between the average *DEPI* recorded in Test 1-3 and Test 2-4 (sign design effects): passing from the starting condition to the design condition, in both cases (traffic and no traffic) all the errors have been cleared.

From the previous observation about *TTPI*, it could be possible to think, at first, that a faster execution of the task could lead the users to an increase of mistakes and driving errors. However, drivers were not only faster, but also drastically reduced driving errors in the project condition. This result confirms

that users were more aware about the track and the choices to be taken in this latter condition.

4.3. Driver's Visual Acquisition (*DVA*)

ANOVA analysis have shown significant effects due to the traffic and sign's design. It is possible to make the comparisons between the average *DVA* recorded in:

– Tests 1-3 (sign design effects – no traffic): mean increase of 7% passing from the starting condition to the project condition;
– Test 2-4 (sign design effects – with traffic): mean increase of 3% passing from the starting condition to the project condition;
– Test 1-2 (traffic effects – starting condition): mean reduction of 3% passing from the no traffic condition to the traffic condition;
– Test 3-4 (traffic effects – project condition): mean reduction of 7% passing from the no traffic condition to the traffic condition.

In general, it is possible to conclude that the presence of traffic leads to a reduction of *DVA*. This result could be expected because the *DVA* is intended as the percentage of time spent from the drivers to acquire information about the signs. The interaction with other traffic vehicles captured some of the fixations previously directed to the signs and, as a result, *DVA* decrease.

It is also possible to conclude that the project condition lead to an improvement of driver visual acquisition (*DVA* increase). It could be considered a positive effect, in fact, more information acquired lead the drivers to a better understanding of the track, lower travel times and zero driving errors.

4.4. Overall Workload (*OW*)

ANOVA analysis have shown significant effects due to the sign's design. It is possible to make the comparisons between the average *OW* measured in Test 1-3 and Test 2-4 (sign design effects): passing from the starting condition to the design condition, in both cases (without traffic and with traffic), it's possible to notice a significant reduction of the mean Overall Workload measured with NASA-TLX.

In particular, in the first condition (no traffic) it results in a mean reduction of 33,3%, in the second condition (with traffic) I results in a mean reduction of 34,6%. The two values are very similar and, both suggest that a better design of the traffic signs in

complex driving environment could significantly reduce drivers' mental effort.

5. Conclusions

Finally, based on the results and the discussion, it is possible to conclude that a better signs' design into a complex driving environment – as a boarding area – it's fundamental to improve the functionality and safety perceived from the users. As a result, the users will be faster to understand the track and the choices to be taken, reducing travel times, errors and mental effort.

The traffic vehicles that interacted with the users did not affect the errors and the mental workload. However, the presence of traffic could attract the users' fixations, distracting them from the signs, but without very important consequences.

References

[1] AFANASIEVA, I., GALKIN, A., 2018. *Assessing the information flows and established their effects on the results of driver's activity*. Archives of Transport, 45(1), 7-23. DOI: https://doi.org/10.5604/01.3001.0012.0938.

[2] ANH SON, L., SUZUKI, T., AOKI, H., 2019. *Evaluating driver cognitive distraction by eye tracking: From simulator to driving*. Transportation Research Interdisciplinary Perspectives, 4.

[3] BONGIORNO, N., BOSURGI, G., PELLEGRINO, O., SOLLAZZO, G., 2017. *How is the Driver's Workload Influenced by the Road Environment?* Procedia Engineering, 187, 5-13.

[4] BOSURGI, G., D'ANDREA, A., PELLEGRINO, O., 2013. *What variables affect to a greater extent the driver's vision while driving?*. Transport, 28 (4), 331-340.

[5] BROOKHUIS, K.A., DE WAARD, D., 2010. *Monitoring driver's mental workload in driving simulators using physiological measures*. Accident Analysis and Prevention, 42, 898-903.

[6] BUTMEE, T., LANSDOWN, T.C., WALKER, G.H. 2019. *Mental workload and performance measurements in driving task: A review literature*. Proceedings of the 20th Congress of the International Ergonomics Association: IEA 2018 (Advances in Intelligent Systems and Computing, Springer), 823, 286-294. https://doi.org/10.1007/978-3-319-96074-6_31.

[7] CANTIN, V., LAVALLIÈRE, M., SIMONEAU, M., TEASDALE, N., 2009. *Mental Workload when driving in a simulator: Effects of age and driving complexity*. Accident Analysis and Prevention, 41, 763-771.

[8] CEGARRA, J., CHEVALIER, A., 2008. *The use of Tholos software for combining measures of mental workload toward theoretical and methodological improvements*. Behav. Res. Methods, 40, 988–1000.

[9] CNOSSEN, F., ROTHENGATTER, T., MEIJMAN, T., 2000. *Strategic changes in task performance in simulated car driving as an adaptive response to task demands*. Transportation Research Part F, 3, 123–140.

[10] COSTA, N., COSTA, S., PEREIRA, E., AREZES, P.M., 2019. *Workload measures-recent trends in the driving context*. Studies in Systems, Decision and Control, 202, 419-430.

[11] DE WAARD, D., 1991. *Driving behavior on a high-accident-rate motorway in the Netherlands. Man in Complex Systems.* Eds Weikert, C., Brookhuis, K.A., Ovinius, S. Proceedings of the Europe Chapter of the Human Factors Society Annual Meeting (Work Science Bulletin 7, Work Science Division, Department of Psychology, Lund University, Lund).

[12] DE WAARD, D., 1996. *The measurement of drivers' mental workload.* PhD thesis, University of Groningen, Haren, The Netherlands.

[13] DE WAARD, D., BROOKHUIS K.A., HERNANDEZ-GRESS, N., 2001. *The feasibility of*

detecting phone-use related driver distraction. Int. J. Veh. Des., 26, 85–95.

[14] FASTENMEIER, W., 1995. *Die verkehrssituation als analyseeinheit im verkehrssystem (The road traffic situation as analysis unit in the road traffic system)*. Autofahrer und Verkehrssituation en: Neue Wege zur Bewertung von Sicherheit und Zuverlässigkeit Moderner Straßenverkehrssysteme, ed. Fastenmeier W. (Köln: Verlag TÜV Rheinland), 27–78.

[15] FASTENMEIER, W., GSTALTER, H., 2007. *Driving task analysis as a tool in traffic research and practice*. Saf. Sci., 45, 952–979.

[16] HART, S.G., STAVELAND, L.E., 1988. *Development of NASA-TLX (task load index): results of empirical and theoretical research*. Adv. Psychol. 52, 139–183.

[17] KRAMER, A.F., 1991. *Physiological metrics of mental workload: a review of recent progress*. Multiple-Task Performance, ed. Damos, D. L. London: Taylor and Francis, 279–328.

[18] KUROSAWA, Y., MOCHIDUKI, HOSHINO, Y., YAMADA, M., 2020. *Measurement of Fatigue Based on Changes in Eye Movement during Gaze*. IEICE Transactions on Information and Systems. E103.D. 1203-1207. 10.1587/transinf.2019EDL8162.

[19] LEE, Y., WEI, C.-H., CHAO, K.-C., 2017. *Non-parametric machine learning methods for evaluating the effects of traffic accident duration on freeways*. Archives of Transport, 43 (3), 91-104.

[20] LI, X., VAEZIPOUR, A., RAKOTONIRAINY, A., DEMMEL, S., OVIEDO-TRESPALACIOS, O., 2020. *Exploring drivers' mental workload and visual demand while using an in-vehicle HMI for eco-safe driving*. Accident Analysis & Prevention, 146.

[21] LIAO, Y., LI., G., LI, S.E., CHENG, B., GREEN, P., 2018. *Understanding Driver Response Patterns to Mental Workload Increase in Typical Driving Scenarios*. IEEE Access, 6, 35890-35900, doi: 10.1109/ACCESS.2018.2851309.

[22] MARQUART, G., CABRALL, C., DE WINTER, J., 2015. *Review of Eye-related Measures of Drivers' Mental Workload*. Procedia Manufacturing 3. 10.1016/j.promfg.2015.07.783.

[23] MUSLIM, N. H. B., SHAFAGHAT, A., KEYVANFAR, A., ISMAIL, M., 2018. *Green Driver: driving behaviors revisited on safety*. Archives of Transport, 47(3), 49-78. DOI: https://doi.org/10.5604/01.3001.0012.6507.

[24] O'DONNELL., R.D., EGGEMEIER, F.T., 1986. *Workload assessment methodology*. Handbook of Perception and Human Performance, 2, Cognitive Processes and Performance. In Boff, K.R., Kaufman, L., Thomas, J.P., (1st Edition). New York: Wiley.

[25] O'HERN, S., STEPHAN, K., QIU, J., OXLEY, J., 2019. *A simulator study of driving behavior and mental workload in mixed-use arterial road environments*. Traffic Injury Prevention, 20 (6), 648-654.

[26] PATTEN, C.J.D., KIRCHER, A., ÖSTLUND, J., NILSSON, L., SVENSON, O., 2006. *Driver experience and cognitive workload in different traffic environments*. Accid. Anal. Prev., 38, 887–894.

[27] PAUBEL, P.-V., 2011. Evaluation d'un Système de Résolution de Conflits, ERASMUS. *Apport de l'Oculométrie Comme Mesure de la Charge Mentale Chez les Contrôleurs Aériens En-route*. Ph.D. thesis, Université Toulouse le Mirail-Toulouse II, Toulouse.

[28] PAXION, J., GALY, E., BERTHELON, C., 2014. *Mental Workload and Driving*. Frontiers in Psychology, 5, 1-11.

[29] PELLEGRINO, O., 2009. *An analysis of the effect of roadway design on driver's workload*. Baltic Journal of Road and Bridge Engineering, 4 (2), 45–53.

[30] PELLEGRINO, O., 2012. *Prediction of driver's workload by means of fuzzy techniques*. Baltic Journal of Road and Bridge Engineering, 7 (2), 120–128.

[31] REHMANN, A.J., 1995. *Handbook of Human Performance Measures and Crew Requirements for Flightdeck Research*. DOT/FAA/CT-TN95/49.

[32] RUBIO, S., DÍAZ, E., MARTIN, J., PUENTE, J.M., 2004. *Evaluation of subjective mental workload: a comparison of SWAT, NASA-TLX, and workload profile methods*. Appl. Psychol., 53, 61–86.

[33] STEYVERS, F.J., DE WAARD, D., 2000. *Road-edge delineation in rural areas: effects on driving behavior*. Ergonomics, 43, 223–238.

[34] WICKENS, C.D., GORDON, S.E., LIU Y. 1998. *An Introduction to Human Factors*. Engineering., 392-395.