State of Alertness During Simulated Driving Tasks

C. D'Anna[1], D. Bibbo[1], M. Bertollo[2], S. di Fronso[2], S. Comani[2], M.R. De Blasiis[1], V. Veraldi[1], M. Goffredo[1], and S. Conforto[1]

[1] Department of Engineering, Roam Tre University, via Vito Volterra 62, 00146 Rome, Italy
[2] Behavioral Imaging and Neural Dynamics Center BIND - "G. d'Annunzio" University, Chieti, Italy

Abstract— **Literature has shown the importance of studying alertness and attention in drivers by means of electroencephalographic (EEG) indexes. Moreover, many kinematic parameters can be used to give information about the safety of the road depending on the traffic flow.**

To our knowledge, no study, has focused the attention on the relationship between alertness indexes and kinematic parameters. The aim of this study was to analyse the influence of traffic conditions on alertness by assessing an EEG index (EI) and the relationship between EI and kinematic parameters.

Nine volunteers participated in the study. The experiment was carried on by using the STISIM driving simulator. Three scenarios were simulated. Each scenario was characterized by a different traffic flow. From STISIM two kinematic parameters were considered: mean velocity and distance from the central line during driving.

EEG data were recorded during driving simulations and the EI was derived from the power spectral bands of EEG.

The results showed significant different values for EI among the three conditions, with the highest level of alertness in urban scenario. Significant differences for the kinematic parameters were also found. The mean velocity decreased when the traffic conditions were more demanding, and the capacity to maintain the vehicle in the centre of the road decreased when the traffic conditions were less demanding.

The analysis suggests that when the mean velocity increases, the alertness decreases with a consequent increased risk of collision; conversely when the mean velocity decreases, also EI decreases so demonstrating a greater level of alertness accomplished by driving on the centre of the road, so reducing the probably of collision. These results suggest that the alertness of the drivers is influenced by the traffic flow.

Keywords— **Alertness, Driving, Engagement Index, EEG, Kinematic parameters.**

I. Introduction

Drivers' distraction and inattention are the main factors of influence in about 30% of traffic accidents [1], so that recent research has shown the importance of studying the various aspects that influence the driving alertness by monitoring the drivers in real and simulated tasks.

Young et al. [1], have shown that additional tasks (i.e. reading road signs, navigating, etc.) can divert the focus of attention from driving. The study conducted by Atchley and Dressel [2] highlighted that the visual attention decreases when the driver engages a conversational task, while a successive research has shown the positive effect of a secondary task on driving performance [3]. McEvoy et al. [4] have shown that the drivers who engaged a cell phone conversation have more probability to crash. Instead, Connor et al. [5] have identified the fatigue as one of the major causes of traffic accidents: the decrement of performance is due to a decline in vigilance, determined by a psychological fatigue [6].

To quantify and to evaluate the state of alertness and fatigue, during driving in real and simulated tasks, different approaches of analysis have been developed. Physiological signals have been acquired (EEG, EMG) to assess the alertness and the muscle fatigue, and kinematic parameters have been extracted to evaluate the driving performance and to give information about the safety of the road [7, 8].

Typically, the variations of the state of alertness are associated with changes in EEG power spectrum. In particular, an increase of the beta activity reflects a higher degree of alertness [9] and it is directly related to the task engagement; conversely, a decrease of alpha and theta activities reflects a less alertness, with a decrease of information processing [10, 11]. Pope al. [12] have shown that it is possible to define an Index of Engagement (EI) by a combination of the alpha, beta and theta activities. This index reflects a general alertness and is useful for monitoring attention during vigilance tasks [13].

Numerous studies focused on the analysis of drivers' ability to maintain a stable lane position in the center of the roadway [3, 14]; variations of this behavior are associated with an increased risk of collision with vehicles in the adjacent line. These variations, especially in monotonous driving conditions, are also attributed to task-induced fatigue.

Among the several factors influencing the alertness during drive, the change of traffic flow has not well been evaluated yet. Therefore, the aim of this study was to analyze the influence of traffic conditions on alertness by assessing the EI and

The original version of this chapter was inadvertently published with an incorrect chapter pagination 907–912 and DOI 10.1007/978-3-319-32703-7_177. The page range and the DOI has been re-assigned. The correct page range is 913–918 and the DOI is 10.1007/978-3-319-32703-7_178. The erratum to this chapter is available at DOI: 10.1007/978-3-319-32703-7_260

E. Kyriacou et al. (eds.), *XIV Mediterranean Conference on Medical and Biological Engineering and Computing 2016*,
IFMBE Proceedings 57,
DOI: 10.1007/978-3-319-32703-7_178

studying the relationship between the EEG index and the kinematic parameters, in particular the mean velocity and the distance by the central line of the roadway.

II. Methods

A. Participants

Nine healthy young males (age range 25-35 yrs), volunteered in the study. None of them reported neurological disorders, neuropathies at the peripheral level, or vestibular pathologies; they had normal visual acuity and no colour blindness.

All subjects had a valid driving license and had an average of 12 years of driving experience (SD= ±5 yrs).

They were instructed for the experimental procedure that will be described in the following, and gave a written informed consent according to the declaration of Helsinki.

B. Materials

Electroencephalography recording: The eegosports™ System (ANT-Neuro, Netherlands) was used to acquire EEG signals during driving simulations. The EEG signals (32 channels WaveGuard™ cap) were sampled at 512 samples/s, and stored for off-line processing.

Driving Simulation and Scenarios: Driving simulations were implemented by using the STI driving simulator System (STISIM) located at the laboratory of the Inter-university Research Centre of Road Safety (CRISS) [15-17].
With the aim to study the effect of different traffic flow, three different scenarios, in a virtual reality environment, were simulated:

- *Suburban* (S): curve radius range from 150 m to 800 m and straights range from 240 m to 1100 m; trees at the roadside; buildings far from the road side; low-speed vehicles transiting in the opposite direction.

- *Urban* (U): curve radius range from 370 m to 750 m and straights range from 100 m to 500 m; high density of buildings at the roadside; pedestrians on the sidewalk; pedestrian crossings; vehicles parked on the roadside.

- *Hybrid* (H): mix of suburban and urban scenarios.

It is also possible to identify some common characteristics to the different scenarios:

- *Grip Condition*: grip condition of dry road pavement in order to have a better performance and a lower driver's stress during driving.

- *Road Section:* single carriageway with two lanes and two way traffic, complying with Italian regulations.

- *Road Geometry:* although the scenarios have different geometries – in term of curves and straights- homogeneity criteria were observed in all the scenarios, in order to ensure a correct perception of the road stretches while driving.

The scenarios were projected onto three big screens providing a 135° field of view, the resolution was 1024 x 768 pixel [18].

Each scenario was characterized by a path length (S (10 km), H (10 km), U (5 km)) and a traffic flow. Kinematic parameters were stored for off-line analysis.

A trigger was used to synchronize the start of the two acquisitions (STISIM and EEG).

C. Procedure

No information was given to the participants about the typology of the scenarios and about the posture to be taken while driving.
Before starting the experiment, the subjects underwent a 10 minutes training. This allowed familiarization with the driving conditions and in particular with the controls of both the steering and the pedals.
Each participant drove in the three scenarios characterized by different traffic flows (S, H, U). The sequence of the scenarios was assigned randomly. To reduce the fatigue effects, a period of rest (5 min) among the three simulations was done. The entire experiment lasted approximately 40 minutes.

D. Data processing

EEG data: The signals were acquired and recorded continuously during the task execution. The toolbox EEGLAB (The Mathworks, Inc.) [19] was used to process the signals: the EEG signals were filtered with a high pass filter (f_t=3) and Independent Component Analysis (ICA) was used to minimize artifacts duo to ocular blinking and muscle activity.

The arrangement of epochs was performed automatically considering epochs of one second.

The EEG data were filtered in the frequency range from 3 to 48 Hz, the spectral power density (SDP) was estimated and the EEG bands (alpha [8-13Hz], beta [13-30Hz], theta [4-8 Hz]) were computed.

The alertness was measured by using a combination of the power values extracted by alpha (α), beta (β) and theta (θ) spectral bands [20]. The formula of the index, known as Engagement Index (EI), is the following:

$$EI = \frac{\alpha + \theta}{\beta}$$

The decrease of EI suggests an increased alertness. The index was calculated for each epoch considering the central and parietal (C_z, P_3, P_z and P_4) sites according to Pope et al. [12].

Kinematic parameters: The kinematic parameters were calculated and stored automatically by the STISIM. For each scenario and each participant, we analyzed the mean velocity (V_m) and the mean distance from the central line (DCL).

As demonstrated by previous studies [3,14], the DCL is associated with the risk of collision: in this study a value equal to one indicates that the drivers maintain the car in the center of the roadway, a value less than one indicates that the driver get closer to the center of the roadway.

E. Statistical analysis

For each parameter descriptive statistic was calculated and one-way Anova test was done considering the scenarios as factors. Post hoc comparison using the Bonferroni test was performed. The level of significance was set at 0.001.

III. RESULTS

A. Engagement Index (EI)

The effect of the different scenarios on the alertness was studied by comparing the EI in the three simulated driving tasks. The statistical analysis shows a global significant difference ($p<0.001$).

The post-hoc test showed significant differences for all the comparisons that were carried on (*Suburban/Hybrid* ($F(1,8)=11.78, p<0.001$); *Suburban/Urban* ($F(1,8)=11.78$, $p<0.001$); *Urban/Hybrid* ($F(1,8)=5.37$, $p<0.05$).

The EI value in *Urban* scenario is lower than the ones obtained in *Hybrid* and *Suburban* scenarios.

The values of the EI for each subject and for each scenario are shown in Figure 1. Mean, standard deviation and the statistical significance are shown in Figure 2.

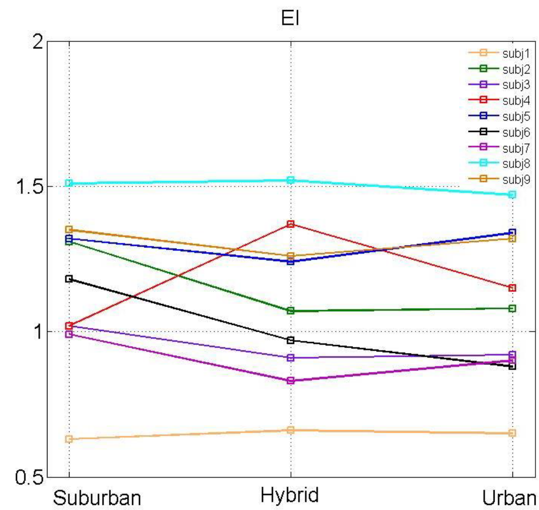

Fig.1: EI values for each subject and each scenario.

A. Kinematic parameters

Mean velocity (V_m): The numerical results show that, for all the subjects, the mean velocity decreases when moving from Suburban to Hybrid and then to Urban scenario (Fig. 3). The Anova test shows global significant difference ($p<0.001$). The post hoc-test shows significant difference in all the comparisons (*Suburban/Hybrid* ($F(1,8)=27.75$, $p<0.001$); *Suburban/Urban* ($F(1,8)=156.65$, $p<0.001$); *Urban/Hybrid* ($F(1,8)= 170.24$, $p<0.05$). Mean, standard deviation and the statistical significance are shown in Figure 4.

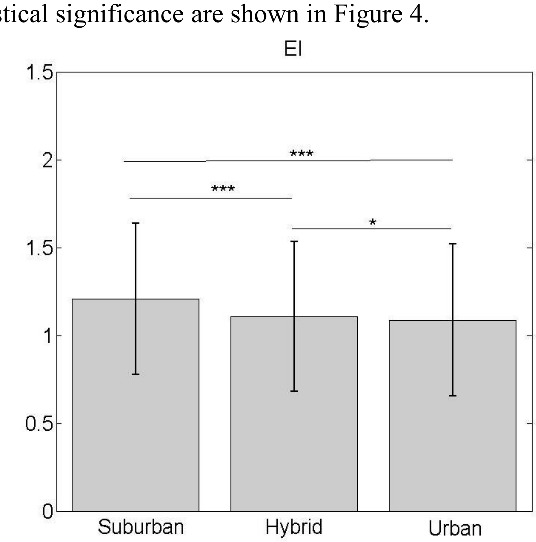

Fig.2: Mean value ± standard deviation for EI. Significant difference in shown between Suburban and Hybrid and between Suburban and Urban (***p<0.001, *p<0.05)

Distance from the central line (DCL): The numerical results show for 8 subjects a value lower than one in the *Suburban* scenario; the value, for the same subjects, increases when they drive in the *Hybrid* scenario. A value around one is shown for seven subjects in the *Urban* scenario. The values for each subject and for each scenario are shown in Figure 5. The statistical analysis does not outline significant differences with the exception of the comparison *Suburban/Urban* ($F(1, 8) = 6.86$, $p < 0.05$).

Mean, standard deviation and the statistical significance are shown in Figure 6.

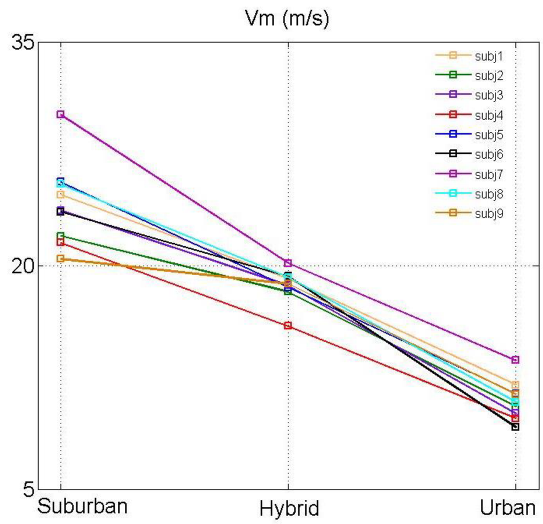

Fig.3: Mean velocity (Vm) for each subject and each scenarios.

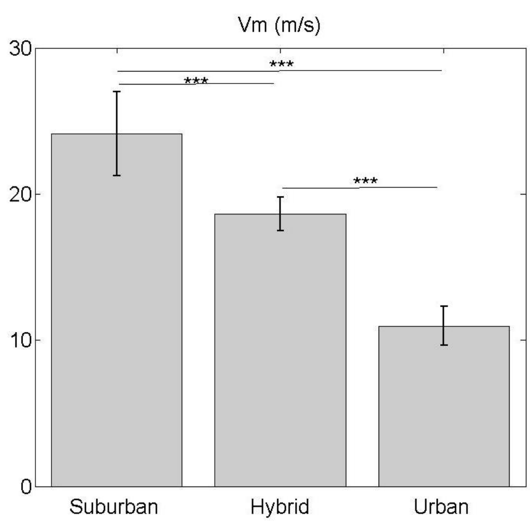

Fig.4: Mean value ± standard deviation for V_m. Significant difference is shown between Suburban and Hybrid , between Suburban and Urban and between Hybrid and Urban (***$p<0.001$)

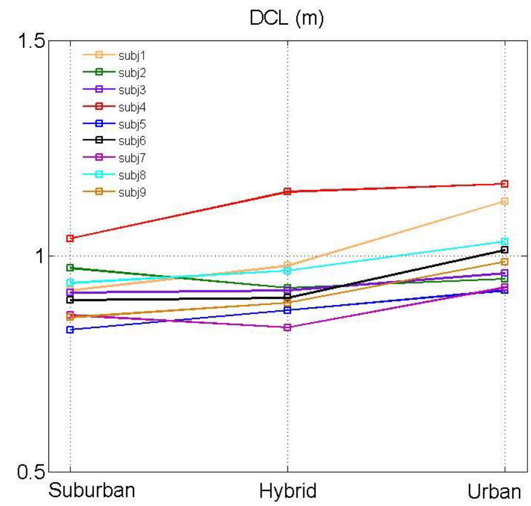

Fig.5: Distance from the central line (DCL) for each subject and each scenario.

IV. Discussion and conclusions

The aim of the present study was to assess the effect of the traffic flow on alertness, during simulated driving tasks, through the analysis of the EI and kinematics parameters.

The decrease of the EI, during driving in an urban scenario with respect to a suburban scenario, suggests that the level of alertness increases when the traffic conditions are more demanding. We can hypothesize that the presence of a large number of vehicles, pedestrians and urban elements determines a physiological effect on driver vigilance.

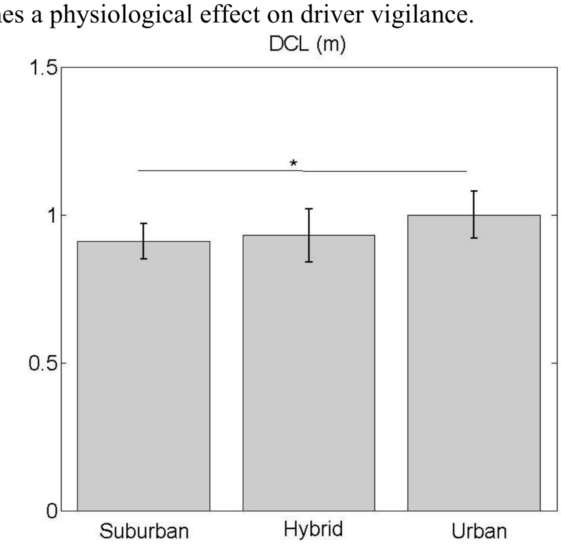

Fig.6 Mean value ± standard deviation for DLC. Significant difference in shown between Suburban and Urban and between Hybrid and Urban (**$p<0.01$, *$p<0.05$)

On the other hand, when comparing a hybrid scenario with an urban environment the values of EI suggest that the drivers maintain similar level of alertness in the two conditions. This result suggests that in a hybrid scenario, the alertness is more influenced by the elements characterizing the urban scenario than those of a suburban one.

The analysis of kinematic parameters shows that the mean velocity is greater in suburban traffic conditions than in urban and hybrid scenarios, as well as the distance by the central line. We can hypothesize that driving in a monotony suburban environment, characterized by few elements and low traffic, leads the drivers to increase velocity, and to drive away from the center of the road. The decrease of the velocity is instead associated with the capacity of the drivers to keep the vehicle on the center of the road.

Previous studies [21, 22] have shown that an unstable positioning with respect to the central line is often associated with a loss of vigilance and an increased percentage of crashes. Referring to this aspect, our results confirm the hypothesis: the global analysis suggests that high values of mean velocity (Suburban scenario) are associated with low alertness (increase of EI) resulting in a great risk of collision (high distance from the central line), while low values of mean velocity (Urban scenario) are associated with high alertness (decrease of EI) and positioning on the center of the road, so reducing the probability of collision.

We can conclude that the traffic flow influences the alertness of the drivers, determining variations in both physiological parameters and driving performance.

Future studies are needed to support and integrate our interpretation: among those we can outline the recording of the muscular activity (sEMG recording) to estimate muscular fatigue [23], the monitoring of the cardiac activity [24, 25] to study the effect of the traffic on heart rate and its variability and the administration of psychometric tests to study the level of arousal and/or sleepiness [26] during driving. Furthermore, the replication of the study in real traffic conditions could increase the comprehension of the phenomena.

References

1. Young K, Regan M, Hammer M. (2007) Driver distraction: A review of the literature. Distracted driving 379-405.
2. Atchley P, Dressel J. (2004) Conversation limits the functional field of view. Human Factors: The Journal of the Human Factors and Ergonomics Society 46(4): 664-673
3. Atchley P, Chan M, Gregersen S. (2014) A strategically timed verbal task improves performance and neurophysiological alertness during fatiguing drives. Human Factors: The Journal of the Human Factors and Ergonomics Society 56(3): 453-462.
4. McEvoy SP et al. (2005) Role of mobile phones in motor vehicle crashes resulting in hospital attendance: a case-crossover study. Bmj 331(7514): 428
5. Connor J et al. (2002) Driver sleepiness and risk of serious injury to car occupants: population based case control study. Bmj, 324(7346): 1125
6. Warm JS, Matthews G, Finomore VS., Jr . (2008) Vigilance, workload, and stress. In: Hancock PA, Szalma J, (editors). Performance under stress. 115–41Ashgate, Surrey, UK.
7. Hostens I, Ramon H. (2005) Assessment of muscle fatigue in low level monotonous task performance during car driving. Journal of electromyography and kinesiology 15(3): 266-274
8. Brown I D. (1994) Driver fatigue. Human Factors: The Journal of the Human Factors and Ergonomics Society 36(2): 298-314
9. Butler S, Glass A. (1987) Individual differences in the asymmetry of alpha activation. In *Individual Differences in Hemispheric Specialization.*103-120 Springer New York
10. Ray WJ, Cole HW. (1985) EEG activity during cognitive processing: influence of attentional factors. International Journal of Psychophysiology 3(1): 43-48
11. Veigel B, Sterman MB (1993, October). Topographic EEG correlates of good and poor performance in a signal recognition task. In Proceedings of the Human Factors and Ergonomics Society Annual Meeting 37(1): 147-151
12. Pope AT, Bogart EH, Bartolome DS. (1995) Biocybernetic system evaluates indices of operator engagement in automated task. Biological psychology 40(1): 187-195
13. Freeman FG, Mikulka PJ, Prinzel LJ, Scerbo MW. (1999) Evaluation of an adaptive automation system using three EEG indices with a visual tracking task. Biological psychology 50(1): 61-76
14. Atchley P, Chan M. (2011) Potential Benefits and Costs of Concurrent Task Engagement to Maintain Vigilance A Driving Simulator Investigation. Human Factors: The Journal of the Human Factors and Ergonomics Society 53(1): 3-12
15. Benedetto A, Benedetto C, De Blasiis M. R. (2004) A new effective approach to accidents prediction to improve roads'design and rehabilitation. Advances in Transportation Studies, 4:5-32.
16. Bella F. (2005) Validation of a driving simulator for work zone design. Transportation Research Record: Journal of the Transportation Research Board 1937:136-144
17. Bella F. (2008). Driving simulator for speed research on two-lane rural roads. Accident Analysis & Prevention, 40(3): 1078-1087
18. Calvi A, Benedetto A, De Blasiis M R. (2012) A driving simulator study of driver performance on deceleration lanes. Accident Analysis & Prevention 45:195-203
19. Delorme A, Makeig S. (2004) EEGLAB: an open source toolbox for analysis of single-trial EEG dynamics including independent component analysis. Journal of neuroscience methods 134(1): 9-21
20. Kamzanova AT, Kustubayeva AM, Matthews G. (2014) Use of EEG workload indices for diagnostic monitoring of vigilance decrement. Human Factors: The Journal of the Human Factors and Ergonomics Society 56(6):1136-1149
21. Ranney TA, Harbluk JL, Noy YI. (2005) Effects of voice technology on test track driving performance: Implications for driver distraction. Human Factors: The Journal of the Human Factors and Ergonomics Society 47(2): 439-454
22. Desmond P, Hancock P, Monette J. (1998) Fatigue and automation-induced impairments in simulated driving performance. Transportation Research Record: Journal of the Transportation Research Board 1628: 8-14
23. Conforto S et al. (2014) The Fatigue Vector: A New Bi-dimensional Parameter for Muscular Fatigue Analysis. In XIII Mediterranean Conference on Medical and Biological Engineering and Computing 2013 Springer International Publishing : 149-152
24. Censi F, Bibbo D, Conforto S. (2009) Heart rate variability analysis during bicycle ergometer exercise. In 4th European Conference of the International Federation for Medical and Biological Engineering-Springer Berlin Heidelberg : 47-50
25. Filho E et al. (2015). My heart is racing! Psychophysiological dynamics of skilled racecar drivers. Journal of Sports Sciences 33 (9): 945-959

26. Bertollo M et al. (2015). To Focus or Not to Focus: Is Attention on the Core Components of Action Beneficial for Cycling Performance? Sport Psychologist 29(2)

Author: Carmen D'Anna
Institute: Department of Engineering, University of Roma TRE
Street: Via Vito Volterra 62
City: 00146 Rome
Country: Italy
Email: carmen.danna@uniroma3.it