# Assessment of Drivers' Risk Levels Using a Virtual Reality Simulator

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**Abstract.** This study is part of a project aiming at analyzing driving behavior and the factors that most influence the generation of states of fatigue and distraction, which represent one of the main risk factors for road accidents. Both states are influenced by the possible condition of sleepiness linked to circadian rhythms. The global aim is to ascertain whether and how the mechanisms underlying the states of fatigue and distraction can be correlated with the variables describing the relationship between driver, road and vehicle. To this end, data related to driver physiological variables (EEG) and data on the scenario offered by the road, were recorded. Statistical differences between variables related to two different scenarios (Urban and Suburban) were calculated and also correlation between physiological and vehicles variables were enlightened. The first results are promising in terms of using physiological variables as risk indicators and improving the support offered by ITS systems.

**Keyword:** Driver's behavior · Human factor · Alertness · Risk levels · Driving simulator

## 1 Introduction

The states of fatigue and distraction represent one of the main risk factors for road accidents. Fatigue is defined as the impossibility or inability to continue an action to the best of one's physical and psychological faculties; on the other hand, we speak of distraction when attention is shifted from the activities necessary for the primary task (driving) towards antagonistic activities. Distraction can also occur without effort, and is induced by exogenous (visual, auditory or vibrotactile stimuli) and endogenous (cognitive distraction or 'being lost in thought') events [1, 2]. Both states are influenced by the possible condition of sleepiness linked to circadian rhythms [3].

The ability to perceive the driver's risk is referred to the ability to observe, comprehend and preview potential traffic risks and to make the right decisions to avoid or decrease the road accidents.

According to Kokubun et al. judgment errors refer to driver cognitive states in such a way that the perceived risk is lower than the actual one [4]. Moreover, driving experience contribute to a better ability to evaluate risky conditions. With respect to the expert

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drivers, inexperienced drivers had greater probability to cause accidents resulting from these causes. For this reason, Gregerson underlined that over 70% of driving errors were a result of an insufficient driving experience [5]. Fischer et al. indicated that mainly due to a lack of driving experience [6], novice drivers had greater probability to drive inappropriately with respect to their experienced counterparts.

However in-built road factors that require high levels of attention, and therefore increase risky condition, have not to be neglected. These are the boundary conditions, geometry [7, 8] of the road and the climate conditions. The weather conditions, such as fog, rain or snow, are associated with visibility as well as the friction of the road surface and further influence driving safety. Rahman and Lownes studied the impact of three weather conditions, no rain, light rain and moderate rain, on car-following behavior by using the time gap, following distance and vehicle speed as indicators [9].

The use of ITS, the operation of many of them is based on the evaluation of perceived risk [10], significantly contribute to the accident prevention. The use of techniques developed for driver assistance. Several studies for the evaluation of the perceived risk can be carried out through drivers data behavior through on intrusive instrumentation. In fact, in recent decades researchers made use of driving simulators to overcome this issue by studying driver behavior by collecting data on driver performance measures such as speed, braking behavior, acceleration pattern etc. These measures are indicators of driver's risk perception and therefore, by studying these measures it is possible identify the possible driving situations that can potentially lead to accidents, eventually road fatalities [11, 12].

The aim of the study is to compare different levels of driver's attention by a parameter of attention that is the Alertness Indicator (AI) extracted from the brain activity (EEG measurements), in two typical road conditions, that are urban and sub urban areas, both taking into account elements coherent with our country regulations, that is to say situation "always" expected by the driver.

## 2 Material and Method

### 2.1 Participants

The experiment was conducted on 10 healthy young males (age range 25–30 yrs), who volunteered in the study. None of them reported neuropathies at the peripheral level, or vestibular pathologies; they had normal visual acuity and no color blindness. All subjects had a valid driving license.

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.

### 2.2 Procedure

The entire experiment lasted approximately 40 min, preceded by 10 min of training for familiarization with the driving conditions and with the controls of the pedals and of the steering.

Each participant drove in the two different scenarios administered by a driving simulator. They were called Suburban and Urban, to recall the environment provided for the driving experience. The scenarios were presented to the driver by using a random order. To reduce possible fatigue effects, a period of rest (5 min) after each driving test was scheduled.

**Driving Simulator and Scenarios.** The research was carried out using the LassTRE (Laboratory of road safety of Roma TRE University) virtual reality driving simulator which is located at the Department of Engineering. This is a fixed base high fidelity driving simulator as shown in the Fig. 1.

The simulator is equipped with a driving simulation software called STISIM Drive®. The reliability of this driving simulator as a tool has been fully validated by several studies [13]. From the hardware point of view, the simulator is a real vehicle, a Toyota Auris, converted to a driving simulator by removing all unnecessary parts and integrating the vehicle with the components that can communicate with the workstation computer, equipped with the software STISIM Drive®.

The setup is also equipped with high-tech projectors which can project the simulation images in front of the car and sideways on a curved projection screen in such a way that it covers a visual angle of 180°.

Furthermore, there are sound speakers which are located in the hood of the car in order to emulate the acoustic environment at the best (resolution 1024 × 768 pixel; the refresh rate was 30–60 Hz depending on scene complexity and the traveling conditions of the vehicle).

A virtual driving environment representative of a standard two-way two-lane rural road was created using STISIM Drive® scenario definition language. The entire driving track was an undivided two-way two-lane rural road with lane width of 3.50 m and 1.25 m of hard shoulder width, both suburban scenario and urban one (Fig. 1).

The sub-urban scenario was implemented, characterized by houses and some road side vegetation. Urban environment, with a speed limit of 50 km/h, characterized by the same geometry elements than the suburban area and a significant urbanization: many houses, pedestrian crossing, bus stops, benches, pedestrians walking on sidewalks, etc.

**Fig. 1.** a. Driving simulator - b. Suburban scenario – c. Urban scenario.

**Electroencephalography Recording and Processing.** EEG Data Were Recorded Continuously During the Task Execution (Sampling Rate 100 Hz) Using Emotiv EPOC® Helmet (www.emotiv.com) (Fig. 2).

**Fig. 2.** EPOC® helmet and Spatial mapping of the electrodes on the scalp

The Raw EEG signals from 14 locations (AF3, F7, F3, FC5, T7, P7, O1, O2, P8, T8, FC6, F4, F8, AF4) were acquired during the driving tests. Data were stored for each virtual scenario session and for each participant and processed off-line using Matlab2019a. The EEG signals were processed following four steps:

1. All the EEG signals were filtered with a Band pass filtering (4th order - Butterworth filter, cut-off frequencies [3–48 Hz]) to remove excessive noise;
2. Independent Component Analysis (ICA) to remove bad channels, blinking and muscle artefacts;
3. estimation of the power spectral density (PSD) using Welch's method (by segmenting the signal with 1 s-long Hanning windows, overlapped by the 50%), for the extraction of the EEG power sub-bands: alfa (8–13 Hz), beta (13–30 Hz), and theta (4–8 Hz);
4. implementation of the Eq. 1 [14], combination of alpha, beta and theta power for the extraction of Alertness Indicator (AI):

$$\mathrm{AI} = \mathrm{beta}/(\mathrm{alpha} + \mathrm{theta}) \tag{1}$$

An increase of beta activity is directly related to the increase of alertness; an increase of alpha and beta activities reflects relax, low level of alertness and a decrease of information processing, therefore an increase of AI reflects an increase of alertness level.

### 2.3 Statistical Analysis

For each parameter descriptive statistics (mean and standard deviation) was calculated and one-way Anova test was done considering the scenario as a factor; also, linear correlation between AI and kinematics parameters (VM, DCL and TtC) was calculated. The level of significance was set to $p < 0.05$.

## 3 Results

The effect of the two different scenarios on alertness was studied both by comparing the AI indicator and the kinematics parameters in the two simulated driving tasks, and by assessing the correlation between the physiological index of alertness and the parameters of driving performance.

The statistical analysis showed significant differences for AI ($p < 0.05$), VM ($p < 0.01$), DLC ($p < 0.01$) and TtC ($p < 0.01$) between the scenarios. In particular, the results showed an increase of the level of alertness, of the distance from the central line, and a decrease of the mean velocity and of the Time to Collision while the participants performed the driving task in Urban scenario with respect to Suburban. Mean and standard deviation for all parameters is reported on Table 1.

**Table 1.** Mean and standard deviation for each parameter.

| | Suburban | p-value | Urban |
|---|---|---|---|
| AI | 0.92 ± 0.26 | <0.05 | 0.98 ± 0.27 |
| MV (m/s) | 24.11 ± 2.86 | <0.001 | 10.96 ± 1.33 |
| DLC (m) | 0.91 ± 0.06 | <0.001 | 1 ± 0.08 |
| TtC (s) | 0.82 ± 0.09 | <0.001 | 0.57 ± 0.12 |

Despite non-significance, that can be due to the low number of samples (only 10 subjects were tested), the linear correlation analysis showed indirect correlation between the alertness indicator and the kinematics parameters in both scenarios, except for the direct correlation between AI and MV and between AI and TtC in Urban scenario. The correlation values are reported on Table 2, scatter plot and regression line are reported on Fig. 3.

**Table 2.** Correlation values.

| | Suburban | Urban |
|---|---|---|
| AI vs MV | −0.40 | 0.16 |
| AI vs DLC | −0.36 | −0.2 |
| AI vs TtC (s) | −0.50 | 0.21 |

The 3D scatter plot shows the different driving performance and the relationship between the level of alertness in both scenarios (Fig. 4). In the graph each point represents one test, and it is drawn considering as its coordinates the values of TtC, MV and AI respectively. It aims at verifying if the points corresponding to urban (black) and suburban (red) occupy two different zones of the space in order to be classified.

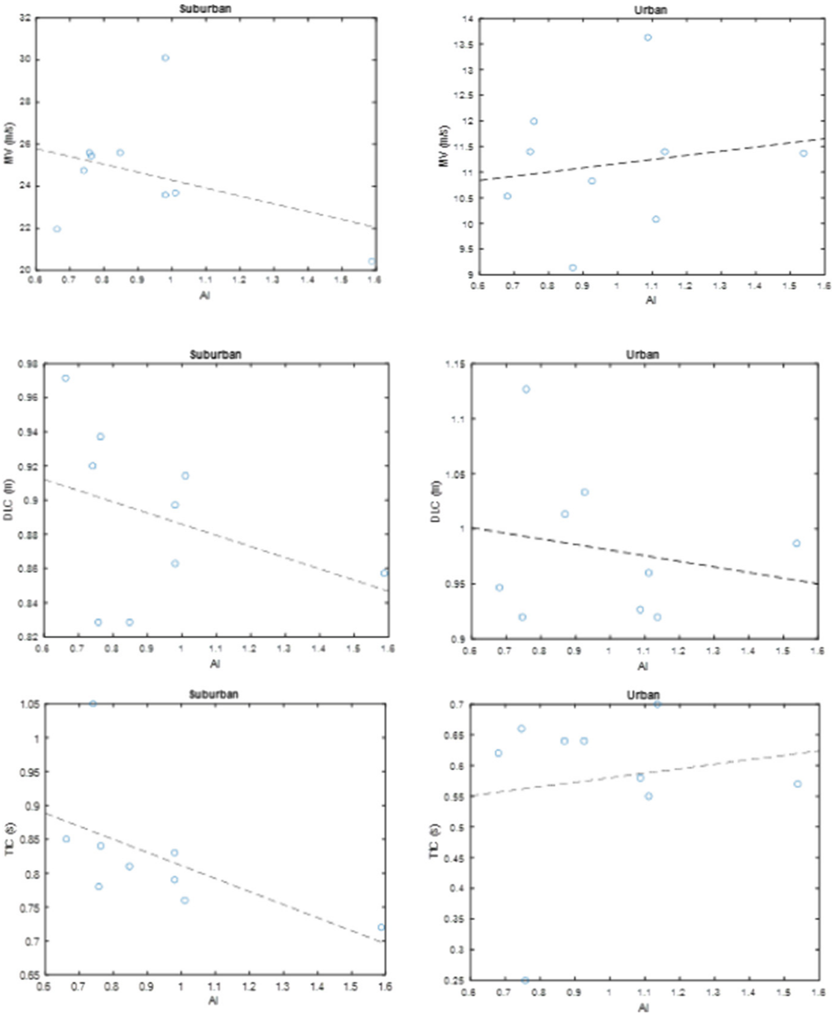

**Fig. 3.** Scatter plot and regression line in both scenarios for AI vs MV (top panel), AI vs DLC (central panel), AI vs TtC (bottom panel)

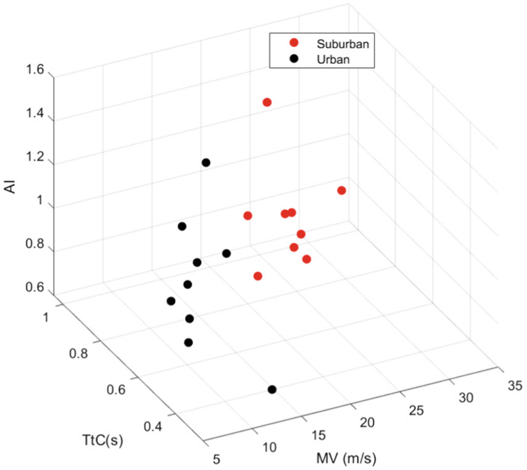

**Fig. 4.** Scatter plot 3D for both scenarios (black dots Urban; red dots Suburban) drawn using as 3D coordinates MV, TtC and AI. The different color dots lye on different parts of the space outlining a classification of the different scenarios

## 4 Discussion and Conclusion

The results obtained by the present study support the hypothesis that the traffic conditions influence the state of alertness while driving. In particular, the comparison between the two scenarios, Suburban and Urban, suggests that the level of alertness increases when the traffic conditions are more intense, pedestrian cross the road and vehicles are parked on the roadside. In the same way, the results highlight that in the urban context the drivers reduce the driving speed, as well the distance by the central line and the time to collisions, and consequently the probability of collision.

On the other hand, we can suppose that the low traffic condition, characterized by a uniform environment, leads to less attention to driving with loss of vigilance and higher probability of collision. These assumptions are supported by the correlation analysis: the indirect correlation between alertness indicator and kinematics parameters in Suburban scenario suggests a clear relationship between the state of alertness and the driving performance. In particular, the drivers showing a lower level of alertness drive at higher speeds, leading the vehicle further away from to the central line, and therefore have a shorter time to collision. Instead, in the Urban scenario, driver behavior appears more variable. In on one hand the indirect relationship between the alertness indicator and the distance by the central line suggest an influence of the state of alertness on driving performance, on the other the light direct correlation between the attention, the driving speed and the time do collision suggesting a heterogeneous driving style among the participants of the experiment in an urban and not very monotonous environment.

These preliminary results are promising, and they will be further investigated by enlarging the sample population. In fact, a more robust statistical assessment will allow the validation of the AI parameter as a risk indicator and will open future scenarios for the use of such approach in ITS systems also supported by new technologies simplifying the EEG measurements (e.g. dry electrodes and commercial low-cost helmet devices).

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