Recording and evaluating motorcyclists' gaze behaviour in rural roads

Panagiotis Lemonakis[1] (presenter), Eleni Misokefalou[1], Myrofora Koroni[2], Nikolaos Eliou[1] (substitute presenter)
[1] Department of Civil Engineering, University of Thessaly, Volos, Greece
[2] International Hellenic University, Thessaloniki, Greece

Abstract

Over the last years, distracted driving constitutes a considerably increasing road safety problem with disastrous results and it possesses a leading position among the accidents causes. The road safety audit in the rural road environment during the last years includes apart from the car passengers' drivers, the motorcycle riders who also share the road network with other vehicle users like bus and truck drivers.

The present study deals with motorcycle riders' gaze behaviour due to out of the vehicle sources of distraction. The exterior factors, as the most significant sources of distraction, can be grouped in four categories: built roadway, situational entities, the natural environment, and the built environment. All these contribute to the setup of a very dangerous environment by increasing rider's distraction and inattention.

This research is based on a medium scale experimental procedure which took place in an urban and a suburban road sections in Western Greece. The distraction of the motorcyclist's attention is evaluated via a continuous recording of his gaze which acts as the main indicator regarding rider's performance with the use of special equipment under naturalistic riding conditions. The main objective of this paper is to identify and evaluate the main factors of distraction of motorcyclists' attention in rural road segments.

The results of this type of research procedures are very useful as a tool to encourage the adaptation of more precise regulations with regard to the road infrastructure, the placement of roadside elements, etc.

Keywords: Riding distraction, motorcyclists, naturalistic research, road safety

1 Introduction

Driver distraction is a phenomenon that can be easily recognized as a single or repeated visual reaction to certain sources located in the road environment. It is based on a mechanism that is activated and developed in a different way not only among drivers but also at the same person each time. The presence, the frequency of appearance, the duration of distraction are characterized of great variety depended on many factors.

Driver distraction may act in a positive or a negative way during the implementation of the driving task. A positive distraction may offer information to the driver that in the first sight may not be useful to the driving task but eventually may act as a catalyst for the safety. A characteristic example of the positive role of driver distraction is the attraction of the attention by a ball at the side of the road something that rings a bell for a child that may suddenly appear to catch that ball. At certain circumstances such as information signs distraction of attention plays a supportive role at the driving task.

Besides the positive effect on the driving task distraction of driver's attention has a negative form which captures the attention of the driver, binding mental workload, not allowing him/her to operate in a safe way especially in case of an unexpected event. In this case the driver himself as well as other road users become vulnerable and the results are critical for the safety.

Driver distraction has been under research the last decade and it is proved to be one of the main causes of accidents. Furthermore, driver distraction is high on the list of road fatal accidents.

While car drivers are the large majority of the road users, motorcycle drivers considered among the most vulnerable ones with significant participation in accidents. Road safety audit during the last years includes apart from the vehicles' drivers, the motorcycle ones who share the road network with other vehicle users like car, bus and truck drivers (Misokefalou et al., 2010). Scientific research has focused on vehicle drivers leaving a big gap of knowledge regarding the effects of distraction on other road users such as motorcyclists. The improvement of road networks demands to take into consideration all possible causes of accident. To this direction, the question of driver distraction for motorcycle users should be examined in all available aspects.

For this reason, the present study investigates the role of elements that permanently exist in the road environment and may affect the motorcyclists by attracting their attention creating a very dangerous condition due to the vulnerability of this category of road users. The main indicator to evaluate distraction is produced through continuous data recording of the driver's gaze with the use of a gaze tracker.

The present research tries to highlight possible sources of distraction that might have a negative effect on road safety, by analyzing the distraction of motorcyclists' attention both in a suburban and in an urban road network. The study focuses on out-of-the-vehicle factors, especially those that are not necessary for the execution of the driving task, having as its main objective to detect their impact on driver's safety.

A medium scale procedure was developed to serve the objectives of the research. A number of 21 motorcyclists participated in the study. An urban as well as a suburban road were selected for the execution of the measurements. The recording took place with the use of Gaze Intelligence gaze tracker equipment. The results of this procedure focus on the time that the driver's gaze remained on each of the road elements under research. The analysis is based on the total duration of the time that the motorcyclist was gazing at every selected element even if the gaze was interrupted and repeated. At this point it should be noted that the present research is part of a larger research project conducted by the University of Thessaly, Department of Civil Engineering. The first stage of the research included 11 of the 21 drivers and only the urban road environment was analyzed (Lemonakis et al, 2020).

The results of this type of research procedures are very useful as a tool to encourage the adaptation of more precise regulations with regard to the road infrastructure, the placement of roadside elements, etc.

1.1 Theoretical background

The most precise definition on distracted driving has been agreed in the in the first International Conference on Distracted Driving according to which: "*Distraction involves a diversion of attention from driving because the driver is temporarily focusing on an object, person, task, or event not related to driving, which reduces the driver's awareness, decision-making, and/or performance, leading to an increased risk of corrective actions, near-crashes, or crashes*" (Hedlund et al., 2005).

Distraction causes are divided into two major categories based on their location. Internal factors of distraction are those that are based into the vehicle while the external factors are based outside of the vehicle. The second category consists of four subcategories built roadway, situational entities, natural environment, and built environment (Horberry & Edquist, 2008). The fourth subcategory, related to road infrastructure and commercial land use, combined with high vehicle speeds that occur in motorways, might contributes to the creation of a very dangerous environment, by increasing driver distraction and inattention.

Scientists have tried to investigate the mechanism behind distraction bringing to the fore psychological tools such as Neisser theories, Gestalt theory etc. (Misokefalou, 2014). Lee and his research team (2009) in an attempt to describe the phenomenon present a multilevel procedure which includes various forms of distraction- visual, cognitive, biomechanical and auditory (Ranney et al., 2001). The various

sources of distraction and their impact on different drivers - both the source and the receiver of a message influence and are being influenced in a different way each time - as well as the technology innovations which demands a great amount of mental load make distraction of attention difficult to be managed.

Road advertisement plays an important role in road safety due to the distraction of attention that causes. At this point it is important to note that the main goal of advertisement is to capture driver's gaze in order to gain the attention and transmit the message. The time interval needed to transmit the message may be long enough to be dangerous for the road safety especially in case of changeable messages (Oveedo-Trespalacios et al., 2019) as the ability to respond properly in case of an event diminishes significantly. Many countries have established proper guidelines regarding the placement, the design or even the prohibition of roadside advertisement. On the other hand, the pressure that derives from the industry because of the strong financial impact of advertising is strong and creates problematic conditions (Herrstedt et al., 2013).

1.2 Frequency of driver distraction

Both international and domestic statistics prove the importance of distraction in road safety. Accident data from either fatal or serious accidents place distraction from a secondary task in a high position among accident causes. Virginia Tech Transportation Institute (VTTI) on behalf of NHTSA carried out a characteristic research "100- Car Naturalistic Driving Study" (Klauer et al., 2006). During the 100-Car Naturalistic Driving Study, driver involvement in secondary tasks contributed to over 22% of all crashes and near-crashes recorded during the study period (NHTSA, 2009). These secondary tasks, which can distract the driver from the primary task of driving (steering, accelerating, braking, speed choice, lane choice, maneuvering in traffic, navigation to destination, and scanning for hazards), are manifold and include such things as reading billboards, conversation with passenger(s), viewing the scenery, cell phone use and related conversation, use of other wireless communication devices, and note-taking, to name a few (Hedlund et al.,2006).

Domestic data confirm the above conclusions. Based on the results of the first semester of 2019 that the Greek Traffic Police announced, distraction caused a 6% of the fatal accidents (Greek Traffic Police, 2020). In addition, the accidents from an unknown cause that consist the 18.5% of all accidents or the 52.7% which are under investigation may also contain distraction related cases. External factors are proven to have great impact on road safety. Wallace (2003) confirms that 10% of the accidents have their roots in distraction because of external factors.

Particularly for advertising, many studies have identified them as a significant cause of traffic accidents (Stutts et al., 2001). The few studies that have been conducted regarding billboard effect on the driver task have demonstrated that drivers do look at and process roadside advertisements, and that fixations upon advertisements can be made at short headways or in other unsafe circumstances (Smiley et al., 2004). In Young et al. (2009) simulator study there is a tentative suggestion that more crashes occur when billboards are present. Conservative estimates collated from a review of several accident databases put external distractors responsible for up to 10% of all accidents (Wallace, 2003). University of Thessaly with a naturalistic research confirms the above mentioned (Misokefalou, 2014).

Statistics for motorcyclists' fatal accidents also raise concerns as 37.9% of fatal accidents in Greece are caused by distraction (Greek Traffic Police, 2020).

2 Methodology

2.1 Selection of the appropriate method

The most effective way for the researchers to detect driver's distraction is via the results that distraction produces. These effects are gaze declination from the driving task for a time interval considered as dangerous, loss of control, speed changes, exit from the lane lines and, finally, crashes.

An analysis that conducted from University of Thessaly compared all the available methods to study driver distraction in order to detect the most appropriate in terms of validity and reliability. The available methods can be grouped into the following categories (Misokefalou and Eliou, 2009):

- Studies based on elements of accidents.
- Experimental studies (simulator studies or studies in a test tracks).
- Observational-naturalistic studies (observation of determined point or use of special equipment vehicles).
- Questionnaires studies.
- Specific methods like Peripheral Detection Task and Visual Occlusion.

Not all of the above methods are applicable at all situations. In case that all means are available and the conditions permit it, the most suitable and effective method is an observational one that belongs in the naturalistic methods. These studies take place in the field with the use of gaze recording equipment to detect the cause of distraction as well as to provide data of frequency and duration of the glances on every potential source of visual distraction.

2.2 Design of the experiment

The participants who carried out the measurements were male riders because they constitute the typical rider gender. Their permanent residence was adjacent to the starting point of the experimental routes whereas they were all capable of manipulating the experimental motorcycle. Aiming to ensure the familiarity of the participants with the handling of the instrumented motorcycle and consequently eliminate the possibility of accident occurrence the riders were asked to drive the motorcycle until they felt confident and safe with its operation. They were all experienced riders who travel to the experimental route very frequently on their ordinary life. Therefore, the probability of an accident was very limited because they were familiar with the geometric features of the experimental route.

The recruitment of the participants was based on two crucial principals: The implementation of safety precautions against accidents and the selection of riders who represent a typical rider. Since young riders are over-represented in vehicular accident statistics the age of the subjects of the measurements ranged between 40 and 60 years old, having obtained their riding license for more than 5 years from the date of the experiment. Nevertheless, a valid driving license for more than 5 years' time was a demand from the insurance company of the motorcycle in order to cover any damages occurred during the measurements.

Eventually 10 and 11 male riders were selected for the suburban and the urban route respectively who drove the instrumented motorcycle throughout the experimental routes using special eye tracking glasses which constantly record their gaze (Figure 1). The participants were not aware of the objects of the measurements in order to drive as natural as possible and record unbiased data. The experiments took place between 04/05/2020 - 13/06/2020 and between 27/12/2019 – 30/12/2019 for the suburban and urban measurements respectively under good weather conditions.

Fig. 1. Eye tracking device of Gaze Intelligence

The eye tracking glasses that were used to record riders' visual behaviour were manufactured by Gaze Intelligence. On this equipment, two cameras are installed at the inner side of the glasses recording the

behaviour of the eyes whereas one camera is installed in the front capturing the external environment. Since the ambient lighting depends on a number of factors which can change ever during the experiments e.g. clouds, fog, time of the day, sunlight intensity, two pairs of Infra-Red Filtering spare lenses of different shading were also part of the main component aiming to smoothly stabilize the lighting levels around the cameras. That is particularly important because the maintenance of constant lighting levels is a basic prerequisite in order to record reliable data.

In order to ensure adequate space to fit the eye tracking glasses inside the helmet, a flip up one was used from which the side paddings were removed. Every rider, with the help of an assistant and after putting the proper pair lens and a nose rest on the main tracking component, wore the flip up helmet in open face mode allowing thus a convenient adaptation of the recording equipment beneath it (Figure 2). The rider was allowed to use the helmet as a full face or a jet helmet afterwards but he was not allowed to close the visor because that would affect the sunlight level in the camera lens and consequently the recorded data would not be reliable.

Fig. 1. Instrumented motorcycle and eye movement recording equipment

Through a USB portal the eye tracking device was connected to a notebook. The next steps was to run the software that supports the hardware and calibrate the system based on the three points mode at a distance of 3 meters ahead of the rider. The calibration procedure performed for each individual independently because it depends on the current lighting level and the physiology of rider's eyes. Finally the assistant pressed a button to start the recording of the measurement, closed the lit of the notebook and put it in a rucksack hanging at the back of the rider who then begun his individual measurement. At the ending point the rider took the notebook out of his rucksack and clicked on the stop recording button. By doing so the file of the measurement was saved on the notebook which was then uploaded on a second software program. Through the latter the uploaded raw file was converted to a video file format (i.e. *.avi) which integrated the outcome of the three cameras described above. The successive directions of eye movements are depicted with a coloured circle (Figure 3).

Fig. 3. Snapshot of output video file

The motorcycle that was used to carry out the field measurements was a sport touring motorcycle very much prevalent on the Greek rural roads. The technical specifications of the motorcycle allowed the riders to smoothly cope with the irregularities of a typical rural pavement which consists of scattered potholes, sedimentation parts, puddles etc. For safety reason it was equipped with ABS brakes rendering the specific motorcycle very friendly for rural and urban riding.

Lastly, the environment where the field measurements conducted is on the one hand for the suburban measurements part of a rural road which connects two mid-sized Greek cities and particularly the city of Arta and Preveza in Western Greece and on the other hand for the urban measurements part of the urban network in a mid-sized Greek city, the city of Arta. The coordinates of the starting (A) and ending (B) point of the suburban measurements were A: 39°09′51.63″N, 20°55′45.05″E and B: 38°59′41.20″N, 20°44′20.00″E respectively as depicted in the upper snapshot of Figure 4. The length of the experimental road sections were approximately 39.2 km for the suburban route and 4 km for the urban one, both gathering a great number of fixed and potential situational sources of riding distraction. The weather conditions were ideal for the needs of the experiments although in two occasions the measurements were postponed because of the rain.

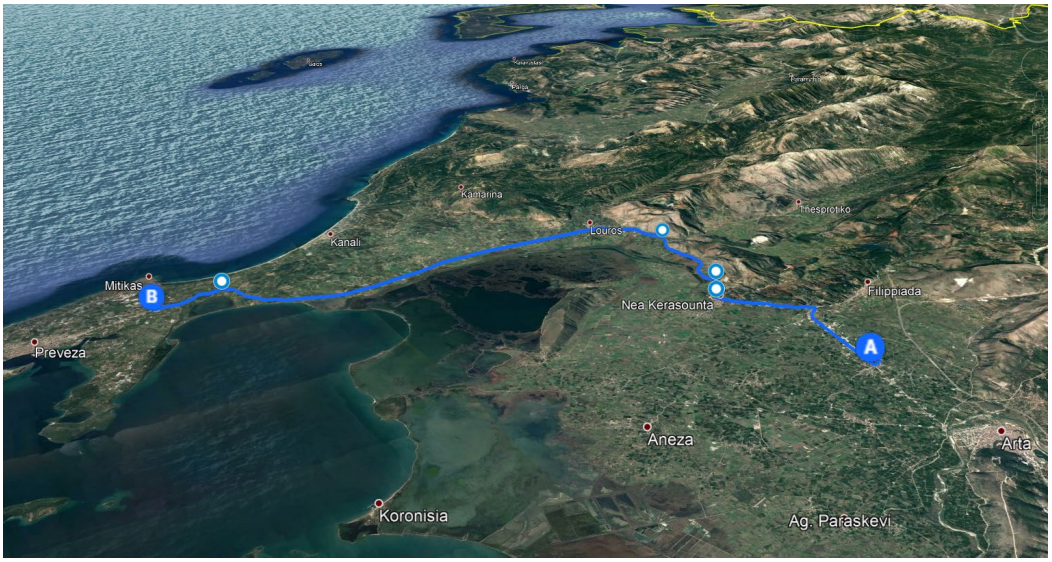

Fig. 4. Routes of the suburban (upper snapshot) and the urban (lower snapshot) experimental road sections

3 Results

3.1 Overview

Observing phenomena are the basis of every research that its goal is the production of representative and reliable conclusions. To this end, descriptive analysis is a very useful tool to identify trends and basic characteristics. For this study a total of 1482 records were collected and analyzed (804 from urban road environment and 678 from suburban road environment) from a total of 21 motorcyclists (11 riders at urban road environment and 10 at suburban road environment). Distraction time intervals were classified into four groups: 0 - 0.7 seconds, 0. 71 - 1.6 seconds, 1.61 - 2.0 seconds and anything more than 2 seconds (Misokefalou, 2014). The study focuses at driving distraction caused by specific visual stimuli for unsafe time intervals, greater than 0.7 seconds as this is considered to be the threshold for safe reaction times.

3.2 Analysis of significant distractions of attention per driver

The frequency of distraction per driver, for time intervals >0.7 sec, >1.6 sec and >2 sec is presented in Figure 5 and 6 for urban and suburban road environment respectively, while Figures 7 and 8 present the average time intervals for each of the previous mentioned cases.

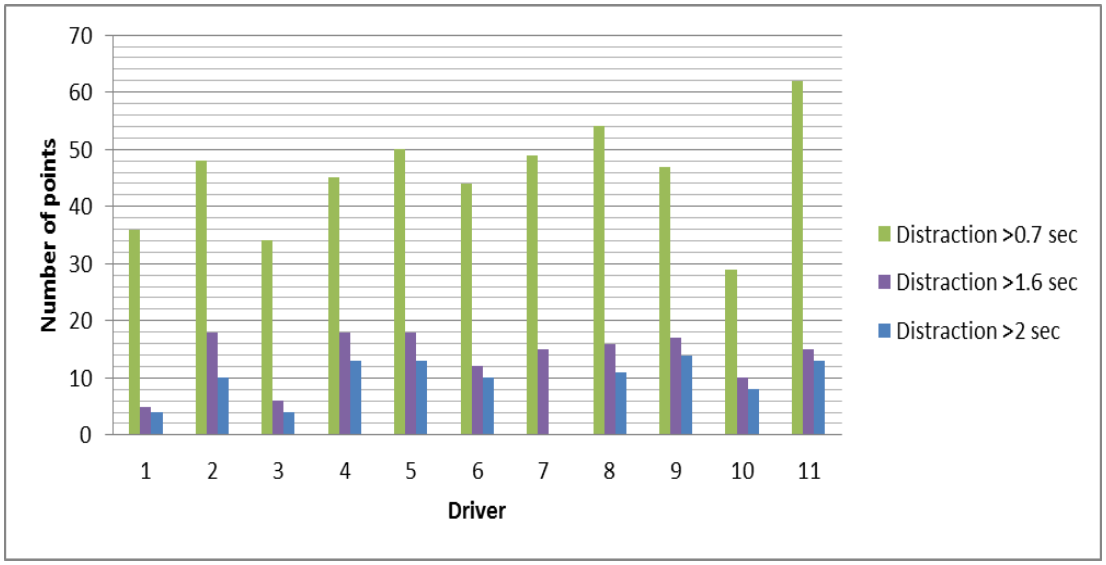

Fig. 5. Frequency of significant distractions per driver – Urban road environment (Lemonakis et al, 2020)

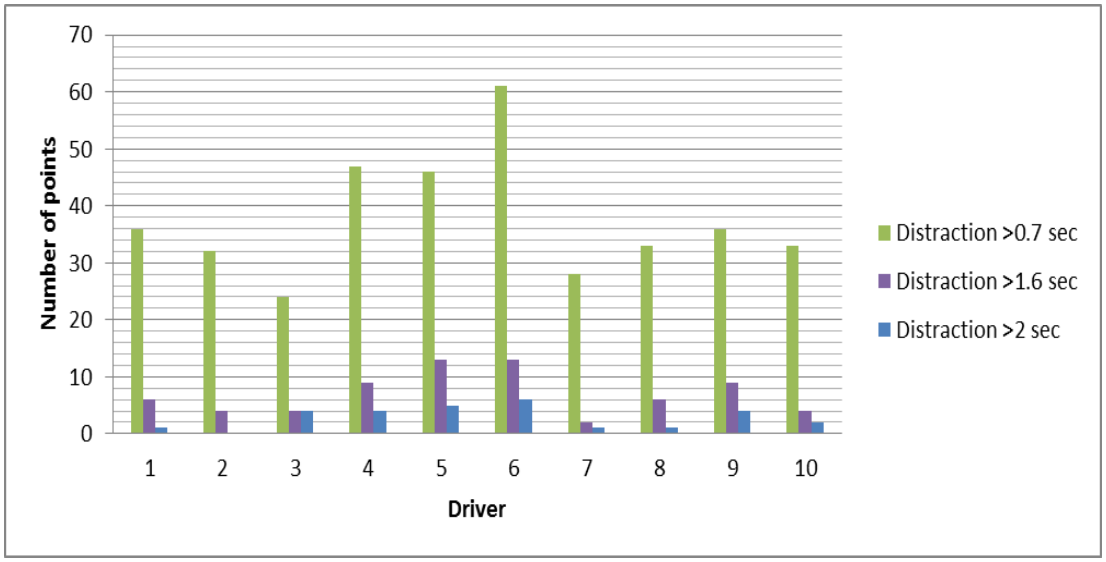

Fig. 6. Frequency of significant distractions per driver – Suburban road environment

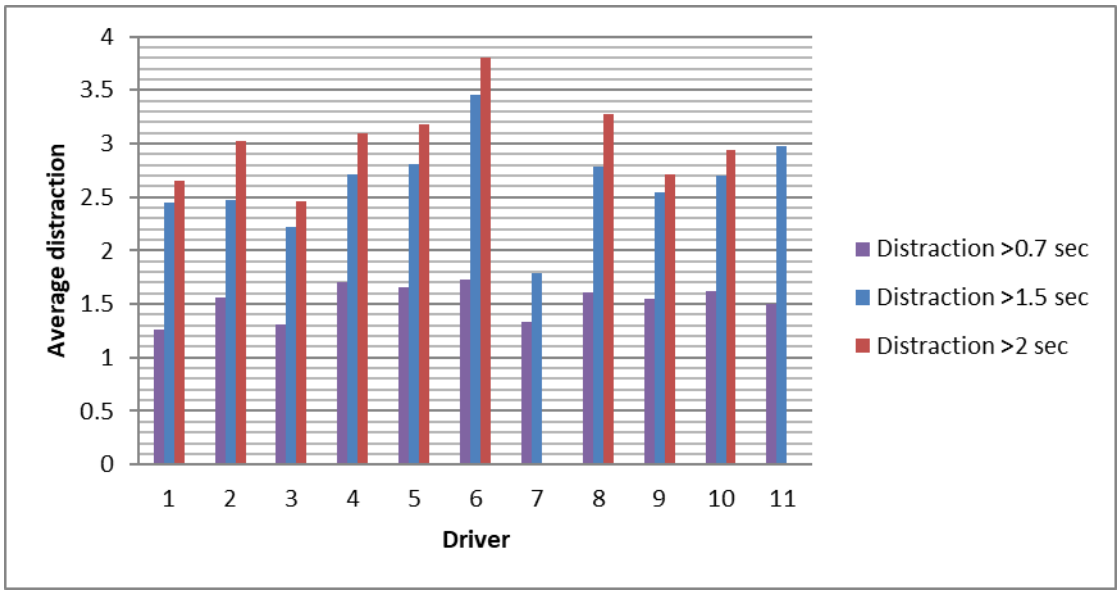

Fig. 7. Average time of significant distractions per driver – Urban road environment (Lemonakis et al, 2020)

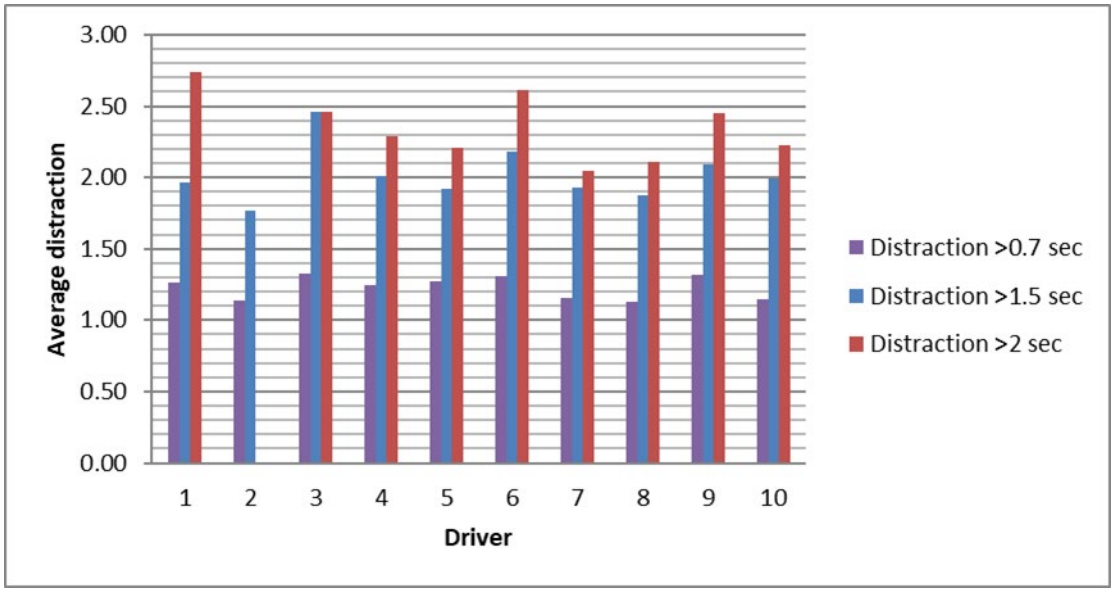

Fig. 8. Average time of significant distractions per driver – Suburban road environment

The study of the frequency of distraction cases shows that numerous road elements at the route attract driver's attention from the driving task for unsafe - in terms of road safety - time intervals. Except from the unrelated to the driving task elements, these results include road signs which are necessary to be seen. Consequently, the question arises regarding the time spent by the driver gazing at them. Another interesting observation is the fact that at the urban road environment there are a lot more drivers with average time of distraction that lasted more than 1.6 and 2 seconds than at suburban which produces lower average distraction times at the suburban road.

The analysis of the average time of distraction for each driver took into consideration only the distractions that lasted more than 0.7 seconds. The results showed that all drivers were distracted for unsafe periods of time. Every one of the participants were distracted on average for more than 1 second at the suburban road and more that 1.2 seconds at the urban road, enough time intervals to permit an accident to take place.

3.3 Analysis of significant distractions of attention per road element category

Figures 9 and 10 present the average time intervals of distraction per road element category, for time intervals >0.7, >1.6 sec and >2 sec. The selected categories are: 1. Road signs, 2: Advertising related signs, 3. Combination of road signs with non-related to driving causes of distraction, 4. Advertising signs with changeable message and 5: Other entities such as a gas station, a bus station etc. (Lemonakis et al, 2020). At this point it should be noted that category 4, signs with changeable message, doesn't exist at suburban environment at all.

Table 1 presents the participation rates of the above categories in the research.

Table 1**.** Participation rates per road element category

Category of distraction source	Urban	Suburban
1	16.17%	53.10%
2	68.78%	33.92%
3	7.46%	3.24%
4	3.48%	-
5	4.10%	9.73%

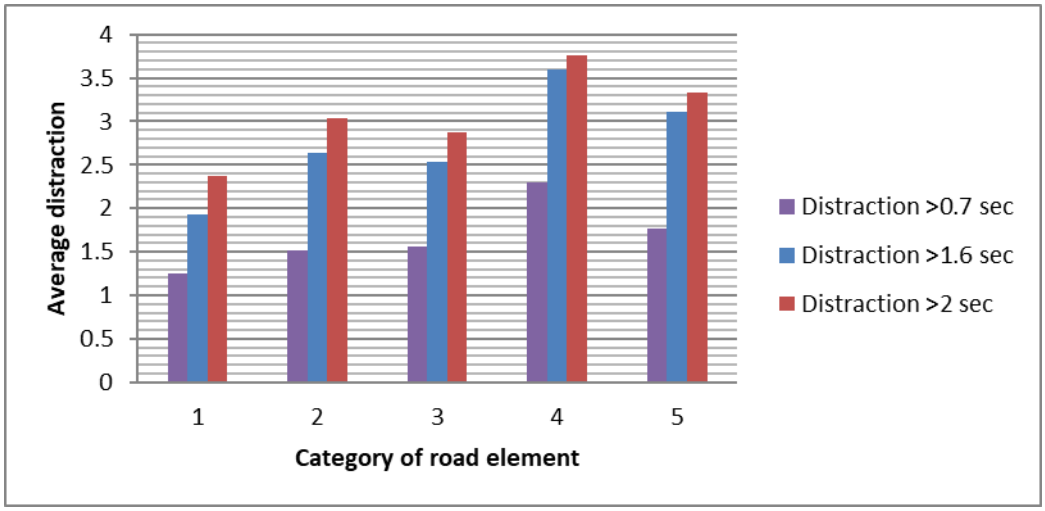

Fig. 9. Average time of significant distractions per road element category – Urban road environment (Lemonakis et al, 2020)

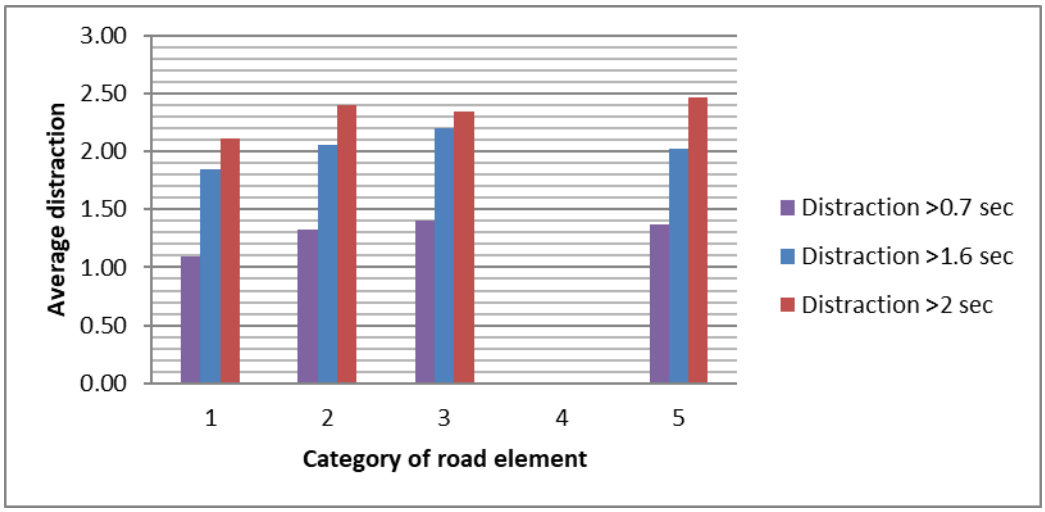

Fig. 10. Average time of significant distractions per road element category – Suburban road environment

From the analysis it is obvious that advertising (categories 2 and 4 cumulatively) possesses the leading position among distraction causes at urban roan environment. The lower distraction times at suburban road environments are obvious at this analysis as well.

Furthermore, signs with changeable messages also concentrate a great number of glances as well as the maximum average times of distraction at urban roads but the research cannot conclude for the suburban roads because of the lack of them at the selected route.

3.4 Analysis of significant distractions of attention per number of the elements

Analyzing the results of distraction based on the number of elements that distract driver's attention at the same time interesting results regarding proximity of road elements make their appearance. At 83% at urban and 78% at suburban environment of the cases there is a single element while at 17% and 22% of them respectively multiple elements that attract driver's attention exist. Figures 11 and 12 show that at both road environments a raise in distraction time appears in case of multi-elements distractors.

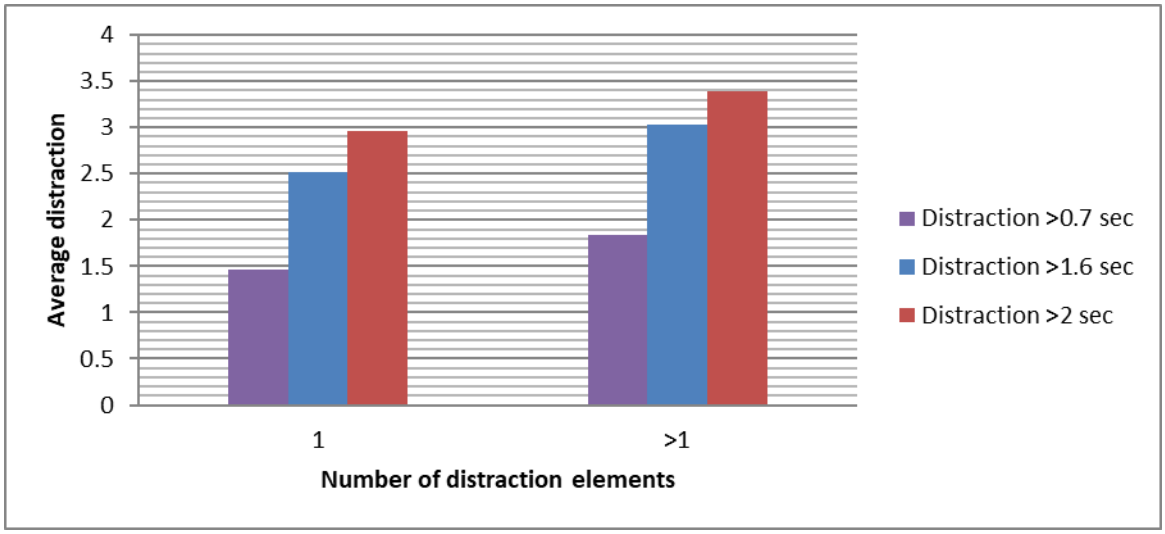

Fig. 11. Average time of significant distractions per number of elements – Urban road environment (Lemonakis et al, 2020)

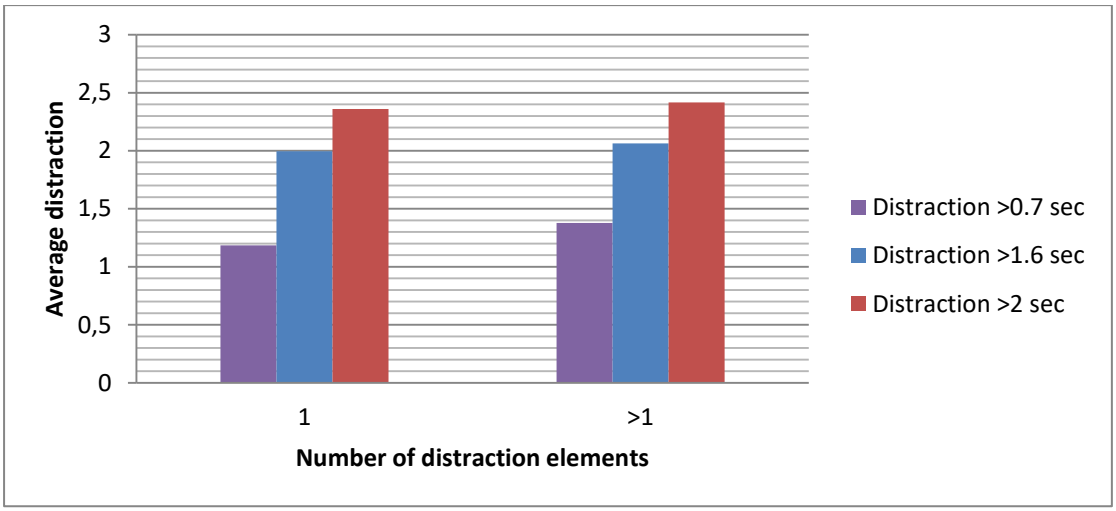

Fig. 12. Average time of significant distractions per number of elements – Suburban road environment

3.5 Analysis of significant non related to driving distractions

Table 2 presents a comparative analysis of frequency of appearance and average time for distractions caused by non related to the driving task causes and lasted for at least 0.7 seconds. This consists the 53% and 32% of all cases at urban and suburban environment respectively.

It is obvious that urban road environments are proved to be significantly more dangerous in terms of distraction duration. On the other hand, speeds at urban roads are lower thus the distance driven while distracted is shorter at this case.

Table 2. Frequency and average time of non-related to driving distractions

	Distraction >0.7 sec	Distraction >1sec	Distraction >2 sec
	Urban/Suburban	Urban/Suburban	Urban/Suburban
Frequency	429/219	130/58	95/27
Average time	1.58/1.34	2.74/2.07	3.12/2.40

Figures 13 and 14 present the average distractions from unrelated to the driving task elements and particularly to advertising signs which prevail in this type of sources of distraction. The analysis

highlights the critical role of advertising in road safety as well as the different driving behavior among the riders.

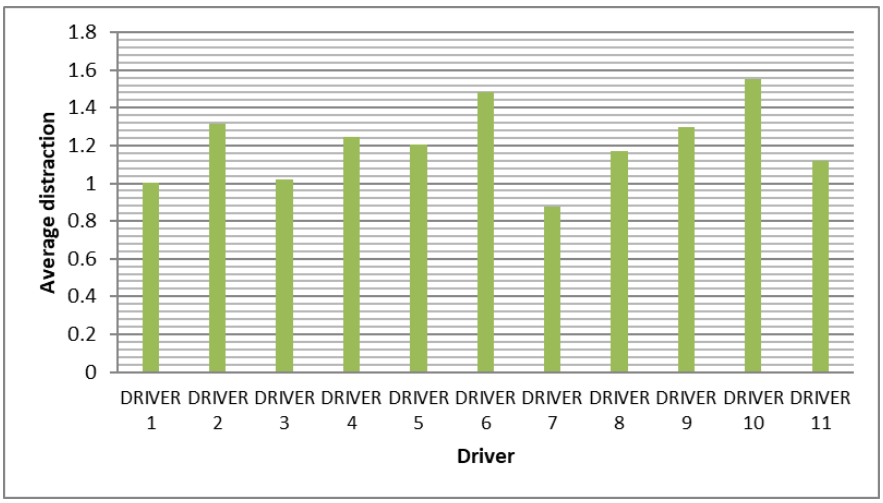

Fig. 13. Average time of non-related to driving distractions – Urban road environment (Lemonakis et al, 2020)

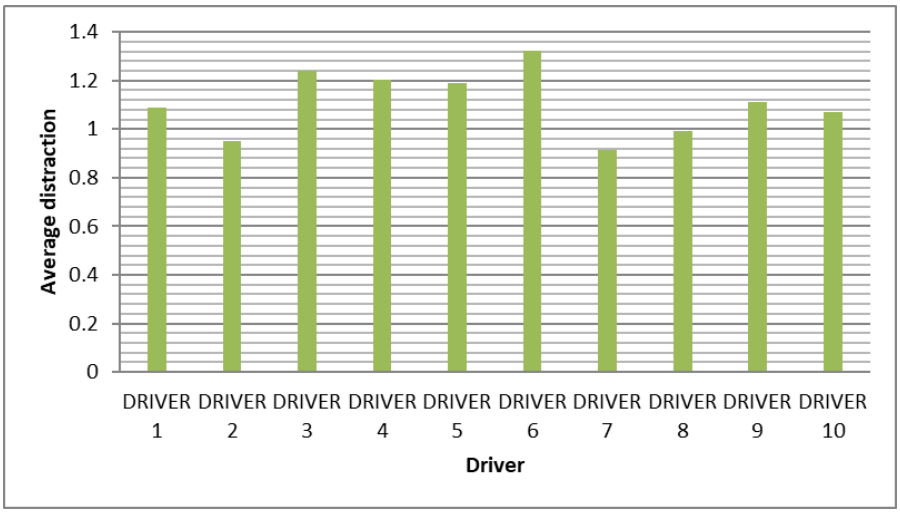

Fig. 14. Average time of non-related to driving distractions –Suburban road environment

4 Conclusions

Distraction of driver's attention during driving is a major road safety problem, which threatens not only the driver's safety but also the safety of other drivers and road users. The representation that motorcyclists have in road safety statistics and their vulnerability as road users arise the need for more targeted research on them.

The main objective of this research is to detect and highlight certain categories of elements in the visual field of the driver that threatens the safe execution of the driving task. The goal of the research is to identify and clarify the causes, the frequency of appearance and the special circumstances under which certain factors influence the distraction of attention of each driver, focusing on the role played by roadside advertising as a parameter of the distraction of the driver's attention.

The selection of a naturalistic method permits the continuous data recording, producing real time data. Thus, the results are reliable and valid to the maximum possible extent.

The research has certain restrictions that a future one might take into consideration. The absence of demographic data is the main reason why an inductive approach is not able to be performed. There is no possibility of controlling the conditions and create desirable driving scenarios. The environmental conditions, also, cannot be controlled and different environmental conditions prevail during the measurements. Finally, there is a difficulty in installing and calibrating the equipment. Attention should be paid in order to minimize the constraints that research inevitably has when planning and performing the experimental procedure.

The most generic conclusion of the analysis is that both at urban and suburban environment exist too many elements that attract the attention of the driver. Average distraction times differ among drivers but every one of them is being distracted for unsafe periods – more than 1 sec at suburban environments and more than 1.2 seconds for urban environments. These distractions last enough to create the circumstances for an accident to take place.

The fact that more than one elements existing at the place distract driver's attention for significantly longer periods raises concerns regarding the proximity of the elements.

Comparing the two road environments it is obvious that more distractions more than 1.6 and 2 seconds take place at urban environment. This is also confirmed from the analysis of the advertising related elements. On the other hand, at suburban roads the speed is higher which leads to shorter distances to be driven while distracted.

Focusing on the elements that are not necessary for the execution of the driving task urban road environment might be more dangerous in terms of road safety than the suburban. A more precise analysis has to take into consideration the speeds in order to conclude properly.

Advertising related elements and other unrelated to the driving task elements on the road attract driver's attention for time intervals greater than the ones derive from driving related elements. The fact that the average distraction times caused by non-related to the driving task elements varies among the drivers reveals the need for a more precise analysis which might take into consideration the personal characteristics of each driver.

Adverting related legislation exists but in many cases remains inapplicable. More work has to be made in that direction in order to prevent future accidents. To this end collaboration with experts and determination of the accident risk are necessary.

The present research may be used as a tool to improve road infrastructure and to eliminate road visual pollution aiming o the creation of a safer road environment, which will lead to less fatal and serious accidents.

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