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Validation of an Eye-Tracking System for Use in Driving Simulator Research

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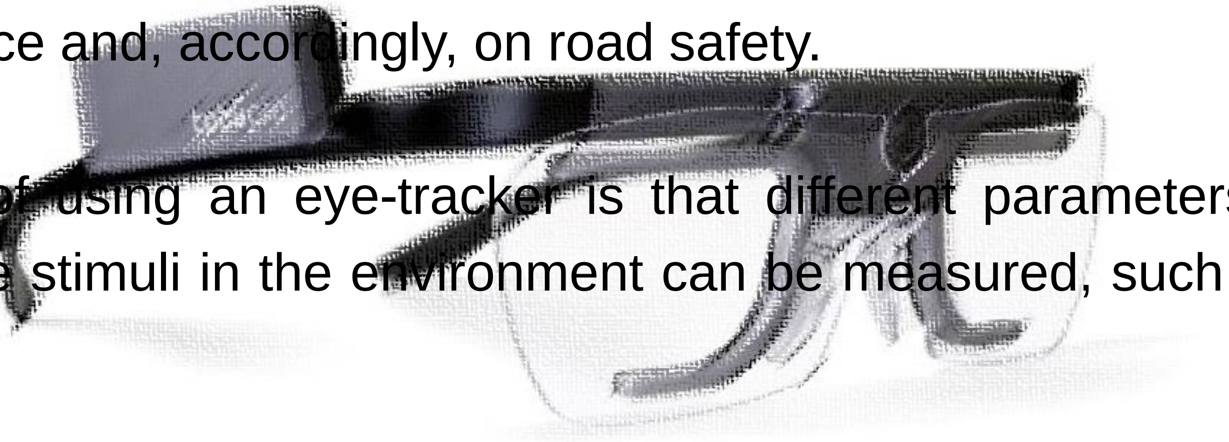
INTRODUCTION

- In the area of road engineering, the eye-tracking system has been used for **both on-field and driving simulation studies**.

- Eye-tracking tool allows researchers to investigate the **drivers' attention allocation** and their visual strategies as well as to understand whether and to what extent the road and roadside features can attract or distract the drivers' attention, with significant effects on their driving behaviour and performance and, accordingly, on road safety.



- The overall **advantage** of using an eye-tracker is that different parameters regarding eye movement towards visible stimuli in the environment can be measured, such as eye-fixations and saccades.

- Several studies have been developed by **combining the benefits of the eye-tracking system with driving simulators or real tests** on instrumented vehicles to simultaneously investigate driving behaviour and the potential sources of distraction

OBJECTIVES

The overall aim of this study is **to validate an eye-tracking system within the context of a virtual reality driving simulation environment** by considering a specific urban context application, the object of the investigated case study.

The validation of the system has been carried out by **a comparison between the eye movements** measured in **real driving** along a road section with those recorded in the same road environment reproduced in a **driving simulator**.

In addition, some key objectives are set out by the comparison between the driving simulation and the on-field study: validating the simulator for **speed measures specifically in a typical urban environment, while approaching and crossing an intersection**.

This study is aimed at providing a significant contribution in the field of **using the eye-tracking system within the context of both real driving and virtual reality driving simulation**.

METHOD

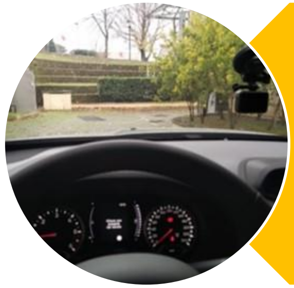
The experiments were carried out using the equipment system composed by:

Eye-tracking system

- a pair of glasses with a full HD wide-angle scene camera on the front of the glasses and two eye cameras per eye
- the glasses are equipped with a gyro and an accelerometer
- the outcomes of the eye-tracking system are related to the blinking behaviour, first fixations in terms of distance and duration, and static or dynamic Areas Of Interest (AOI) in order to select part of the driver's view

Driving simulator

- fixed based driving simulator placed in a full-cab Toyota Auris
- three projectors assure a wide image with a 180° field of view on a curved screen located in front of the vehicle
- road environmental sounds, such as the actual engine as well as those of the other vehicles, are



Instrumented vehicle

equipped with:

- a GPS for the evaluation of driving performance during actual driving tests
- a high-resolution camera for recording the driver's front view

METHOD – THE CASE STUDY

Urban intersection located in Rome:

- road cross-section: 18.00 m
- one lane in each driving direction (each lane was about 4.00m)
- both-side sidewalks of about 5.00m
- speed limit 30km/h
- entire route 4500m

The intersection was perfectly reproduced in the driving simulation environment.
All the vehicles that interact with the drivers at the intersection, both in the on-field and simulated environment, were controlled by the experimenters.

Field survey:

- the interfered vehicle was driven by an assistant experimenter.
- a series of elements and features were included in the simulated scenario, such as boundary conditions, markings and vertical signs, vegetation, buildings, green areas, and other vehicles.

METHOD – EVENTS FOR THE CASE STUDY

Two road events:

- Static: the presence of a speed limit sign
- Dynamic: the presence of a pedestrian who crossed the road

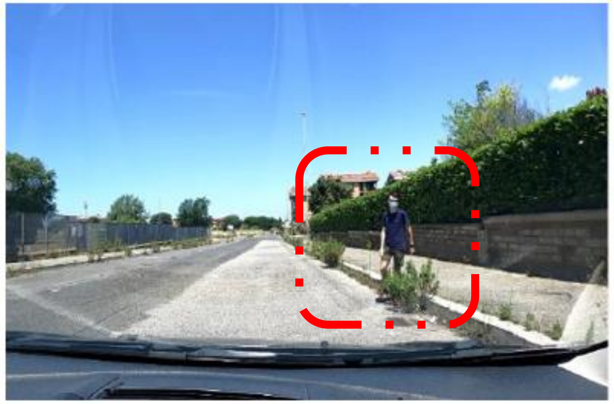
Pedestrian crossing event:

- the pedestrian out of the markings in the driver's view at a longitudinal distance of 300m and a lateral distance of 7.5 m
- when the driver was 100 meters from the pedestrian, he/she started crossing down the road at a speed of about 3.6 km/h

Real-environment setting

Virtual scenario

SPEED LIMIT SIGN



Real-environment setting

Virtual scenario

CROSSING PEDESTRIAN

Method – Sample of Drivers and Procedure

Originally the sample of participants consisted of 22 drivers (15 men and 7 women) with a mean age of 31.9 years, with at least 3 years of licensed driving experience and no familiar with the test site.

During the real tests:

- eight participants were excluded from the analysis due to technical issues related to the equipment and other issues.
- no drivers were identified as outliers and excluded from the analysis after the application of the Chauvenet criterion to the speed data

The final sample included 14 drivers (9 m and 5 f), with an average age of 27.7 years (SD = 9.3).

During the driving simulation tests:

- four participants experienced symptoms related to simulation sickness and were excluded from the further analysis
- no outliers were identified by the application of the Chauvenet criterion to the speed data reported.

The final sample included 18 drivers (12 m and 6 f) with an average age of 30.3 years (SD = 10.1).

METHOD – SAMPLE OF DRIVERS AND PROCEDURE

PROCEDURE

Both driving tests (field and simulation survey) lasted approximately 50 minutes, with the order being randomized between participants to avoid bias in the results due to the sequence of the drives.

In the simulation test, the participants first drove a training scenario to familiarize themselves with the driving simulator.

In addition, the participants had to fill out two questionnaires: the first, before the training, to provide basic information such as socio-demographic background, age, and driving experience; and the second, after completing the tests, to sign an informed consent form and provide any additional information on simulation sickness to investigate the driver’s discomfort during the test and gain insight into the experience of simulated driving.

DATA COLLECTION (drivers’ speed profiles from 50 meters before the intersection)

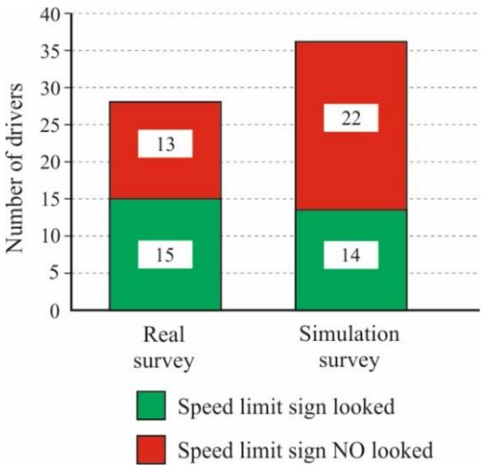
Eye movement data, such as distance and duration of the first fixation, and driving speed profiles at the approach to the events were collected, analyzed, and compared between the two drives.

The first fixation (the first pause of the eye movement in a specific area of the visual field) has been investigated in terms of duration and distance.

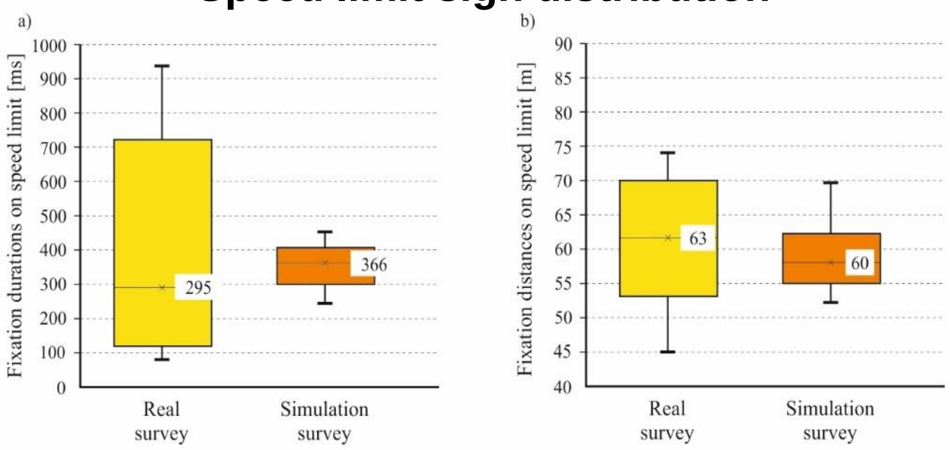
Two dynamic AOI were designed to enclose drivers’ views around the speed limit sign and the pedestrian and to monitor the eye movement parameters in these areas.

RESULTS – SPEED LIMIT OBSERVATION

The number of drivers who looked at the speed limit sign in the real and simulated surveys



Speed limit sign distribution



Fixation durations Fixation distances

STATISTICAL ANALYSIS

	Average [ms]	Standard deviation	Number of observations	Outliers	Normality		t-test		
					W	P	DOF	t	p
Real survey	295	336	15	0%	0.867	5%	27	0.77	44%
Simulation survey	366	71	14	0%	0.962	80%			

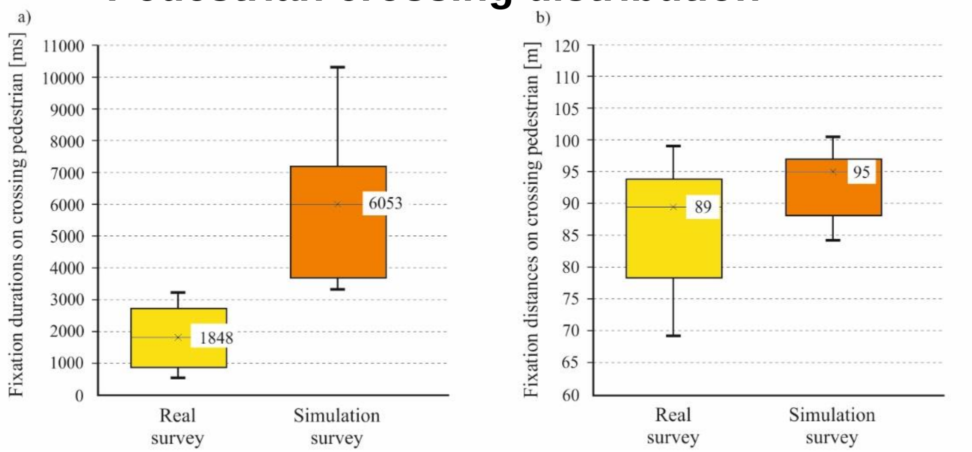
Results of the statistical analysis of the fixation duration on the speed limit sign

Results of the statistical analysis of the fixation distance on the speed limit sign

	Average [m]	Standard deviation	Number of observations	Outliers	Normality		t-test		
					W	P	DOF	t	p
Real survey	63	10.3	15	0%	0.939	40%	27	0.51	62%
Simulation survey	60	7.3	14	0%	0.942	50%			

RESULTS – PEDESTRIAN CROSSING ANALYSIS

Pedestrian crossing distribution



Fixation durations

Fixation distances

STATISTICAL ANALYSIS

	Average [m]	Standard deviation	Number of observations	Outliers	Normality		t-test		
					W	P	DOF	t	p
Real survey	89	14.1	12	14%	0.868	8%	27	1.89	10%
Simulation survey	95	5.1	17	6%	0.927	30%			

Results of the statistical analysis of the fixation distance on the speed limit sign

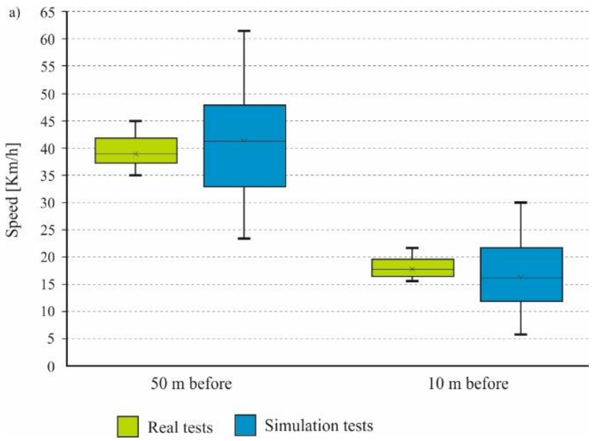
Results of the statistical analysis of the fixation duration on the speed limit sign

	Average [ms]	Standard deviation	Number of observations	Outliers	Normality		t test		
					W	P	DOF	t	p
Real survey	1848	948.8	13	7%	0.941	50%	29	7.52	0%
Simulation survey	6053	2261.3	18	0%	0.976	90%			

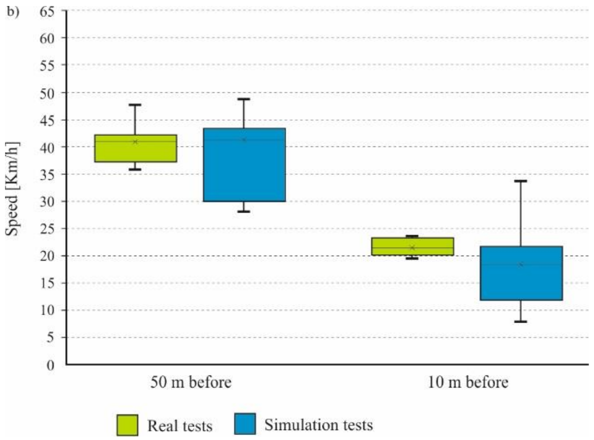
RESULTS – SPEED ANALYSIS

Pedestrian crossing distribution

Manoeuvre 1



Manoeuvre 3



	Survey	Average [ms]	Standard deviation	Number of observations	Outliers	Normality		t test		
						W	P	DOF	t	p
-50m	Real	39	3	26	4%	0.965	50%	60	1.04	31%
	Simulation	41	10	36	0%	0.975	60%			
-10m	Real	19	2	19	7%	0.963	80%	53	1.81	8%
	Simulation	16	7	36	0%	0.936	6%			

Results of the statistical analysis of speed data (Manoeuvre 1)

	Survey	Average [ms]	Standard deviation	Number of observations	Outliers	Normality		t test		
						W	P	DOF	t	p
-50m	Real	40	3.6	13	7%	0.934	40%	29	1.66	11%
	Simulation	37	7.2	18	0%	0.904	8%			
-10m	Real	21	0.6	10	29%	0.956	70%	26	1.31	21%
	Simulation	18	6.7	18	0%	0.962	60%			

Results of the statistical analysis of speed data (Manoeuvre 3)

CONCLUSIONS AND FUTURE RESEARCH

Eye movements have been measured and compared in real driving along a road section with those recorded in the same road environment reproduced in a driving simulator. Drivers' behaviors and reactions in both driving contexts have been analyzed with respect to the presence of a speed limit sign and a crossing pedestrian. Furthermore, a speed analysis at the approach of an urban intersection was collected to compare the drivers' behaviors in real and simulation driving and achieve the set key objective, namely the validation of the simulator for speed measures specifically in typical urban environments.

Statistical findings show that, especially for static objects, the driver's response in real and simulated driving is the same in terms of fixation distance and duration.

With respect to speed, the findings confirm the validation of the simulator to investigate drivers' behaviour in terms of speed and also in approaching an intersection where critical manoeuvres, such as crossing and turning, are performed by the drivers.

- The sample of participants could be expanded to consider a greater sample size, by reducing technical issues and by including other age classes, both young and old drivers.
- The behaviour of drivers who have already experienced the use of the eye-tracking system in the driving simulation environment will be studied for other test cases.
- Different eye-movement indicators will be explored to describe more in depth the drivers' visual behaviour.

Thanks

for your attention

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