Analysis of interaction mechanisms between regular vehicles and autonomous vehicles for road safety purposes

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Abstract

This research aimed at providing an answer to the safety concerns that can be introduced by the partially automated vehicles (PAVs) in traffic. In fact, PAVs still require the human interventions and actions, even after the human disengagement from the driving task. This transition from disengagement to engagement combined with the management of all the other inputs from the driving environment can lead to high risky situations. For this reason, it was decided to use a driving simulator to analyse the driving behaviour. The aim of the experiment was to analyse the influence of ACC, secondary tasks and route familiarity on the driver behaviour.

From the different combinations of the two types of secondary tasks, i.e. reading a message on the phone and answering a question, and ACC system, 5 scenarios and 6 repetitions were derived.

The dependent variables analysed were speed, acceleration, deceleration, distance from the lead vehicle and lateral position. The independent variables considered were ACC system, presence of secondary tasks, phase repetition, sex of participants, self-reported attitude to perform secondary tasks during everyday driving.

The results of the statistical analysis for overall data showed that phase repetition led to an increase in the average deceleration value, a shift to the right of the axis of the lead vehicle, and a decrease in distance from the lead vehicle. The presence of the ACC system led to an increase in the average values of acceleration and distance from the lead vehicle and a reduction in the average value of speed and deceleration.

The presence of the secondary tasks caused a shift to the right of the lead vehicle axis, as the number of repetitions increases. The ACC system led to a reduction in speed variation and an increase in distance from the lead vehicle, thus to a safer condition. Analyses showed that the second secondary task, i.e. reading a message on the telephone, led to a greater variation in speed and a greater variation in distance from the lead vehicle. It follows that there was a difference in behaviour between the secondary tasks and that the second secondary task appeared to have worse effects on the driver, due to visual distraction.

Cover image: Driving simulator, Gustave Eiffel University

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03

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Doctorate in Risk And Environmental, Territorial And Building Development

03
2024

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Analisi dei meccanismi di interazione fra veicoli a guida autonoma e veicoli tradizionali per una valutazione della sicurezza stradale

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Al Magnifico Rettore
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ANALYSIS OF INTERACTION MECHANISMS BETWEEN REGULAR VEHICLES AND AUTONOMOUS VEHICLES FOR ROAD SAFETY PURPOSES

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EXTENDED ABSTRACT (eng)

In the context of an increasing number of surveys and campaigns pointing towards the immediate introduction of Connected and Autonomous Vehicles (CAVs) in the ordinary traffic, research might provide its contribution highlighting the benefits and the strength of these new vehicles, as well as the weaknesses and the potential issues deriving from their implementation.

The aim of this research is to give a contribution in this field, by investigating the safety-related aspects due to the introduction of CAVs in traffic. Since road safety is a wide area of investigation, especially if connected to the emerging technologies, it is necessary to focus on specific aspects and deeply investigate them. Considering that the available crash dataset in presence of CAVs are limited, current research highly relies on simulations of future scenarios, trying to capture the impact that CAVs can have on safety.

In particular, traffic simulations can reproduce wide road networks by investigating the microscopic interactions between vehicles. One peculiar disadvantage of this approach is that it strongly depends on the input parameters chosen. In fact, depending on the selected parameters, simulation outputs can drastically vary, sometimes leading to unrealistic scenarios. While traffic simulations can simulate the interactions (and then, conflicts) between vehicles, they cannot explain specific individual and interacting driving behaviours in all time instants.

This aspect can be explored relying on driving simulations, which can help in investigating specific driving behaviours in the traffic stream. Results from the simulations of given scenarios can then pave the ground for accurately calibrating traffic simulation parameters. This procedure can be particularly useful when CAVs should be simulated, in absence of real on-road tests.

This advantage provided by the driving simulator is the core of this study. In fact, this work uses driving simulation to study safety issues related to partially automated vehicles (PAVs) that still require human interventions and actions, and for this reason can lead to high risky situations.

In fact, despite PAVs can help drivers in easy driving tasks, they require that the driver will eventually take control of the vehicle. This transition from automation to human intervention represents a blind spot for safety: if the driver is distracted, he cannot manage to take-over and then potential crashes or dangerous situations can occur.

Considering the above reported background, driving simulation scenarios were designed and tested in this study. In detail, the main aspects investigated in this research are:

- the effect of Adaptive Cruise Control (ACC), to understand the influence that this technology for advanced driving (a typical example of ADAS) has on the kinematic parameters of the vehicle (speed, acceleration) and on its position (lateral position and distance from the lead vehicle);
- The effect of secondary tasks to be executed by the driver, to understand the responses and the readiness to take over by the eventually distracted driver;
- the effect of repeating the same driving tasks, in order to test the potential influence of familiarity with both the route and the driving tasks on the driving behaviour.

A sample of 37 drivers, aged between 21 and 34 years old was recruited to test the simulation scenarios. The tests were run after collecting questionnaires and acknowledging the testers on their duties during the experiments.

The scenario implemented in the driving simulator reproduced the geometric features of a tangent section belonging to one of the most crash-prone rural roads in the area of the Metropolitan City of Bari (MCB), namely the SP106 (a two-way two-lane rural

provincial road). Data about this road section were available thanks to another research project related to the same area (MCB, Italy), which revealed the particular dangerousness of two-way two-lane rural roads, among the other road types. In the same research project, safety assessments were conducted, by considering also future scenarios involving the gradual market penetration of CAVs.

Results from the driving simulation tests highlighted that, on average:

- the ACC led to raise the average values of acceleration and distance from the lead vehicle and a reduction in the average value of speed and deceleration;
- different typologies of secondary tasks led to different observed driving behaviours and, in particular, visual distraction secondary tasks appeared to have greater negative impacts on the driving parameters;
- drivers' familiarity with ACC system and with the route was associated to an increase in the average deceleration value, a decrease in distance from the lead vehicle and a reduction of variability in lateral position.

In conclusion, these results provide a contribution to understand potential issues related to the introduction of CAVs with partial driving automation, which still require human intervention. Results can be useful for researchers since they could be used to calibrate traffic simulation parameters related to CAVs.

key words

Driving simulations; ACC; Secondary Tasks; Route Familiarity; Driver behaviour.

EXTENDED ABSTRACT (ita)

Nel contesto di un numero crescente di indagini, campagne e spot che puntano all'introduzione immediata dei veicoli connessi e autonomi (CAVs) nel parco veicolare circolante, la ricerca scientifica potrebbe fornire il suo contributo evidenziando i vantaggi e i punti di forza di questi nuovi veicoli, nonché i punti deboli e i potenziali problemi derivanti da una loro errata implementazione.

L'obiettivo di questa ricerca è dare un contributo in questo campo, indagando gli aspetti legati alla sicurezza stradale dovuti all'introduzione dei CAVs nel parco veicolare circolante. Poiché la sicurezza stradale è un'ampia area di indagine, soprattutto se legata alle tecnologie emergenti, è necessario concentrarsi su aspetti specifici e studiarli a fondo. Considerando che gli attuali dataset disponibili sugli incidenti stradali avvenuti in presenza di CAVs sono limitati, poiché siamo ancora nella fase iniziale della loro implementazione, la ricerca prova ad ipotizzare l'impatto che i CAVs possono avere sulla sicurezza affidandosi alle simulazioni.

In particolare, le simulazioni di traffico possono riprodurre ampie reti stradali, studiando le interazioni tra i veicoli a livello microscopiche. Uno svantaggio di questo approccio è la forte dipendenza dai parametri di input scelti. Infatti, a seconda dei parametri selezionati, i risultati delle simulazioni possono variare drasticamente, portando talvolta a scenari irrealistici. Sebbene le simulazioni di traffico possano simulare le interazioni (e quindi i conflitti) tra i veicoli, non possono indagare il comportamento puntuale del veicolo e la sua interazione con gli altri veicoli sulla strada.

Questo aspetto può essere esplorato affidandosi alle simulazioni di guida, che possono aiutare a studiare comportamenti di guida specifici nel flusso del traffico. I risultati delle simulazioni di determinati scenari possono poi aprire la strada a una calibrazione accurata dei parametri utilizzati nelle simulazioni di traffico. Questa procedura può essere particolarmente utile quando si devono simulare i CAVs, in assenza di test reali su strada.

Il vantaggio offerto dal simulatore di guida è il fulcro di questo studio. Infatti, questo lavoro utilizza la simulazione di guida per studiare la sicurezza stradale in presenza di veicoli parzialmente autonomi (PAVs), che richiedono ancora interventi e azioni da parte dell'uomo e che, per questo motivo, possono portare a situazioni di elevato rischio.

Infatti, i PAVs possono solo aiutare i conducenti nei compiti di guida primari, ma richiedono il pronto intervento dell'uomo durante la guida. Questo passaggio dall'automazione all'intervento umano rappresenta un problema in termini di sicurezza, in quanto in caso di distrazione del conducente, egli non sarà in grado di prendere il controllo sulla tecnologia, causando potenziali incidenti o situazioni pericolose.

Considerando il contesto sopra descritto, in questo studio sono stati progettati e testati scenari di simulazione di guida. In dettaglio, i principali aspetti analizzati in questa ricerca sono:

- l'influenza dell'Adaptive Cruise Control (ACC), per capire gli effetti che questa tecnologia di guida avanzata (un tipico esempio di ADAS) ha sui parametri cinematici del veicolo (velocità, accelerazione) e sulla sua posizione (posizione laterale e distanza dal veicolo precedente);

- l'effetto dei compiti secondari che il conducente deve eseguire, per valutare la prontezza di intervento del conducente eventualmente distratto;

- l'effetto della ripetizione degli stessi compiti di guida, per verificare la potenziale influenza della familiarità con il percorso e i compiti di guida sul comportamento dell'utente.

Per testare gli scenari di simulazione è stato reclutato un campione di 37 conducenti di età compresa tra 21 e 34 anni. I test sono stati eseguiti dopo aver raccolto i questionari e aver istruito i tester sulla sperimentazione in corso.

Lo scenario implementato nel simulatore di guida riproduceva le caratteristiche geometriche di un tronco appartenente a una delle strade rurali più incidentate nella Città Metropolitana di Bari (CMB), ovvero la SP106 (una strada provinciale a due corsie a doppio senso di marcia). I dati relativi a questo tratto stradale sono disponibili grazie a un altro progetto di ricerca relativo alla stessa area (CMB, Italia), dal quale è emerso che le strade più pericolose sono risultate proprio le strade provinciali (SP) a due corsie e unica carreggiata. Nello stesso progetto di ricerca sono state condotte valutazioni sulla sicurezza stradale, considerando anche scenari futuri che prevedono la graduale penetrazione sul mercato dei CAVs.

I risultati dei test di simulazione di guida hanno evidenziato che, in media:

- l'ACC ha portato a un aumento dei valori medi di accelerazione e distanza dal veicolo precedente e a una riduzione dei valori medi di velocità e decelerazione;
- vi è una differenza di comportamento dell’utente nell’eseguire differenti attività secondarie durante la guida; le attività secondarie che implicano distrazioni visive, piuttosto che cognitive, hanno maggiori impatti negativi sul conducente;
- la familiarità del conducente con il sistema ACC e con il percorso è stata associata a un aumento del valore medio di decelerazione, a una diminuzione della distanza dal veicolo precedente e a una riduzione della variabilità della posizione laterale.

In conclusione, questi risultati forniscono un contributo alla comprensione dei potenziali problemi legati all'introduzione dei CAVs con parziale automazione della guida,

che richiedono ancora l'intervento umano. I risultati possono essere utili per ricerche future, in quanto potrebbero essere utilizzati per calibrare i parametri dei simulatori di traffico relativi ai CAVs.

key words

Simulazioni di guida; Sistemi di assistenza alla guida; Attività secondarie durante la guida; Familiarità del percorso; Comportamento dell’utente.

LIST OF ABBREVIATIONS

CAVs - Connected and Autonomous Vehicles

FAVs - Fully Automated Vehicles

PAVs - Partially Automated Vehicles

ADS - Automated Driving System

AVs - Autonomous vehicles

RVs - Regular vehicles

SAE - Society of Automotive Engineers

ACC - Adaptive Cruise Control

ADAS - Advanced Driver Assistance Systems

VDM - Vehicle Dynamic Model

DDT - Dynamic Driving Task

HMI - Human-Machine-Interface

FOV - Field of View

SDD - Sensory Display Device

SFG – Sensory Feedback Generation

SCP - Simulation computer processing

HMD - Head-mounted Display

MCA - Motion cueing algorithms

NDRTs - Non-Driving Related Tasks

TTC - Time To Collision

ST - Secondary tasks

INDEX/INDICE

CHAPTER 1
INTRODUCTION

In the immediate future, it is expected that the vehicle types circulating on roads will drastically change. Autonomous vehicles will increase in number, and they will replace regular vehicles. Nowadays, we can see their presence on the market. In the United States, the first completely autonomous riding service has been deployed (Sun et al., 2020): this highlighted some peculiar issues such as route planning in promiscuous traffic conditions (Ettinger et al., 2021).

Fully autonomous vehicles are not the only one taking the scene, since also Advanced Driver Assistance Systems (ADAS) equipped vehicles are drastically increasing[1], thanks to the novelties introduced by regulatory acts (i.e., by the UE Regulation 2019/2144).

In this optic, there is the urgent need to understand how these vehicles can interact with the existing ones. The implementation of innovative technologies undoubtedly brings new chances and improvements to the state-of-the-art. Therefore, these positive aspects might be discussed also in light of the possible negative effects that the new vehicle typologies can have on safety.

Several aspects related to partially automated vehicles (PAVs) can be investigated with specific regard to safety. One of the main concern of PAVs is the promiscuity in driving tasks given by the combination of ADAS and human driving. The ADAS help in driving tasks is only related to simple manoeuvres and tasks (e.g., lane centering, speed assistance, Adaptive Cruise Control). When the ADAS cannot manage the driv-

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[1] https://www.futuremarketinsights.com/reports/adas-market. Last access on 21st of September 2023; https://www.counterpointresearch.com/insights/adas-penetration-crosses-70-us-h1-2022-level-2-share-46-5/#:~:text=The%20share%20of%20Level%202,in%20the%20US%20by%202023. Last access on 21st of September 2023.

ing task, the immediate human intervention is required. However, the human driver can be distracted while he/she must take the control over the vehicle. This transitory phase, from ADAS disengagement to the human driver engagement, is a remarkable blind spot for safety. This specific aspect is investigated in this research, in which different variables that can alter the correct human driving performance in the take-over process, are analysed.

The investigated variables are: the presence of the ACC system, the secondary tasks and the route familiarity. The position on the carriageway and kinematic parameters were correlated to the driving response in both cases of active or inactive ACC system. Another considered aspect is the focus of the driver on the driving environment. The use of ACC might induce human driver to lose the focus, being involved in some secondary tasks, like chatting or calling, or turning on and off the radio. The proposed work tried also to highlight how a secondary task can affect the driving performance. This is achieved by comparing the same parameters, such as speed, acceleration, lateral position and distance from the lead vehicle, before and after the application of a secondary task. The last considered variable is the road familiarity. One driver can modify his driving attitude according to his/her acquired familiarity with the route. A familiar user tends to know the main features of the route and so to behave accordingly, sometimes switching from a cautious to an aggressive driving behaviour. Thus, the effects of familiarity on the driving performance were investigated as well.

A general introduction to the research topic was provided in this section (Chapter 1), which is further deepened in the following paragraphs. They provide a review of relevant literature research related to: CAVs (par. 1.1, with particular regard to the ACC system, which is used in this research); driving simulation (par. 1.2, given that the experimental work is based on driving simulations); the interaction between human factors and automation (par. 1.3, always focused on a safety perspective).

After, the description of the driving simulator used for the experimental work is provided in detail in the following Chapter 2. It includes all the relevant information related to the design and implementation of driving simulation scenarios, alongside with the methods used to run the tests.

Results from the performed simulation tests are then presented and discussed in Chapter 4.

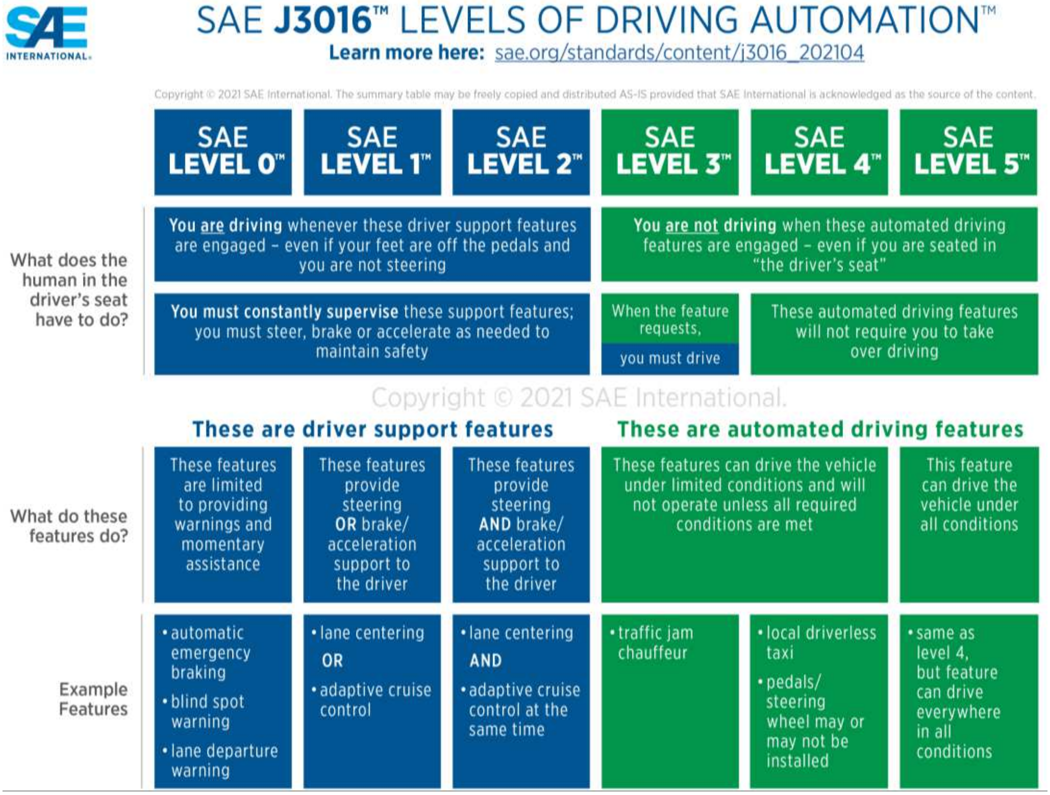
Finally, conclusions are drawn in the last Chapter (Chapter 5), which summarizes the key points and the contribution of the research to the state of the art, by highlighting also its limitations and future directions.

1.1 CONNECTED AND AUTONOMOUS VEHICLES

Connected and autonomous vehicles (CAVs) promise to change the transportation landscape with safer, faster, and more efficient mobility (Zeng et al., 2012). Autonomous vehicles (AVs) are already part of the current vehicle fleet, but it is possible to imagine that in the future new forms of AVs, such as shuttles and automated buses, will be the standard. These critical changes in the circulating vehicle fleet are occurring rapidly while the current road environment is not entirely ready to efficiently respond to the technological evolution (Zhou et al., 2019). So, while technology has the potential to drive progress in the field of autonomous vehicles, the government should support innovation through appropriate regulations, to brings cities and roads at the center of this change.

Nowadays, it is possible to see partially automated vehicles (PAVs), but in the future, thanks to technological innovation, fully automated vehicles (FAVs) will heavily penetrate in the market. Therefore, it is necessary to make a distinction between different levels of automation.

The Society of Automotive Engineers (SAE) identifies 6 levels of driving automation (see next Figure 1): level 0 corresponds to fully manual driving and level 5 corresponds to fully automated driving. This classification defines a target of performance for each level of automation. The distinction is useful to state and describe all the driving automation features that characterize the vehicle. The level of automation also refers to the three primary actors in driving: the (human) user, the driving automation system, and other vehicle systems and their components. Apart from the identification of the main actors, the driving performance is evaluated and assigned to each level also based on the dynamic driving tasks (DDTs), which are the real-time functions required to operate a vehicle. It is important to note that some active safety systems (levels 0-2), such as electronic stability control and automated emergency braking, and certain types of driver assistance systems, such as lane-keeping assistance, are excluded from the scope of the automation taxonomy because they merely provide momentary intervention during potentially hazardous situations, and the driver intervention is still crucial. On the other hand, full Automated Driving System (ADS) features belong to levels 3-5 since they perform the complete DDT, including crash avoidance capability.



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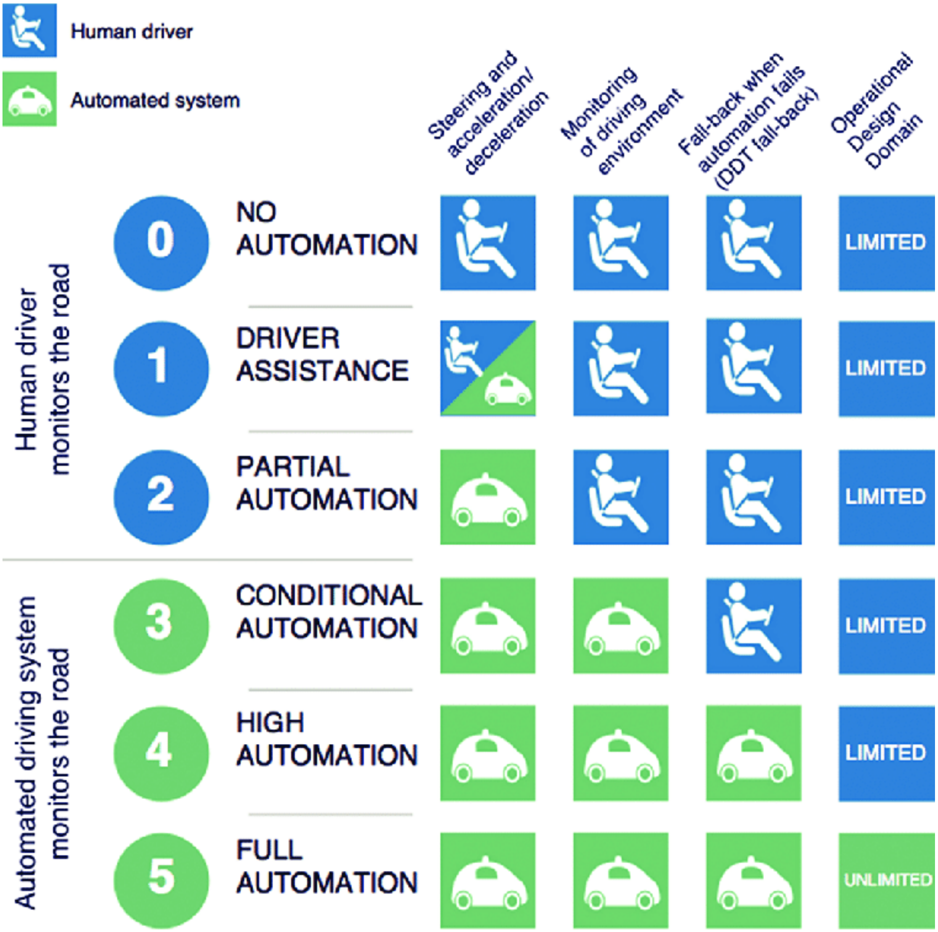
	SAE LEVEL 0™	SAE LEVEL 1™	SAE LEVEL 2™	SAE LEVEL 3™	SAE LEVEL 4™	SAE LEVEL 5™
What does the human in the driver's seat have to do?	**You are driving** whenever these driver support features are engaged – even if your feet are off the pedals and you are not steering			**You are not driving** when these automated driving features are engaged – even if you are seated in "the driver's seat"		
	You must constantly supervise these support features; you must steer, brake or accelerate as needed to maintain safety			When the feature requests, you must drive	These automated driving features will not require you to take over driving	
	These are driver support features			**These are automated driving features**		
What do these features do?	These features are limited to providing warnings and momentary assistance	These features provide steering **OR** brake/acceleration support to the driver	These features provide steering **AND** brake/acceleration support to the driver	These features can drive the vehicle under limited conditions and will not operate unless all required conditions are met		This feature can drive the vehicle under all conditions
Example Features	• automatic emergency braking • blind spot warning • lane departure warning	• lane centering **OR** • adaptive cruise control	• lane centering **AND** • adaptive cruise control at the same time	• traffic jam chauffeur	• local driverless taxi • pedals/steering wheel may or may not be installed	• same as level 4, but feature can drive everywhere in all conditions

Figure 1 – SAE Levels

Based on the previous Figure 1, it is possible to generate a rough distinction, which clusters the 6 AV SAE levels into just 3 categories. This macro-level distinction identifies (Calvert et al., 2016):

- Regular vehicles – RVs (SAE level 0-1);
- Partially automated vehicles - PAVs (SAE level 2-3);
- Fully automated vehicles - FAVs (SAE level 4-5).



🟦 Human driver

🟩 Automated system

			Steering and acceleration/ deceleration	Monitoring of driving environment	Fall-back when automation fails (DDT fall-back)	Operational Design Domain
Human driver monitors the road	0	NO AUTOMATION	🟦	🟦	🟦	LIMITED
	1	DRIVER ASSISTANCE	🟦/🟩	🟦	🟦	LIMITED
	2	PARTIAL AUTOMATION	🟩	🟦	🟦	LIMITED
Automated driving system monitors the road	3	CONDITIONAL AUTOMATION	🟩	🟩	🟦	LIMITED
	4	HIGH AUTOMATION	🟩	🟩	🟩	LIMITED
	5	FULL AUTOMATION	🟩	🟩	🟩	UNLIMITED

Figure 2 – Different level of automation (SAE J3016 levels of driving automation)

The SAE levels 0 and 1 can be considered as regular vehicles. The SAE levels 2 and 3 are characterized by partial automation since there is still the need for a human driver to take over the technology and act the main driving tasks. In these levels of automation, the presence of a regular human driver is crucial for safety. Regulations are in accordance with this aspect, assessing that the human driver is still responsible for what happens while driving. The human driver might be forced to drive in “hands-on-the-wheel conditions”.

The SAE levels 4 and 5 are characterized by full automation. Their reaction times and distances from lead vehicles (significantly lower than regular vehicles) can be equated to human drivers performing aggressive behaviour since they do not rely on the unpredictable human uncertainties.

Moreover, the main Advanced Driver Assistance Systems can be catalogued according to the Euro NCAP 2018[2] classification in three main categories:

- Lane control systems;
- Speed regulation systems;
- Systems that improve visibility.

Lane control systems alert the driver if the lane line is approaching or crossed without using the direction indicator (arrow). They are very useful for preventing sleep strokes and distractions often caused by infotainment systems and smartphones. The main variants of this system, available on vehicles on the market, are Lane Departure Warning (LWD) and Lane-Keeping Assist (LKA).

Speed regulation systems help the driver to adjust the speed of the vehicle according to environmental and traffic conditions. The main variants of this system, available on the vehicles on the market, are:

- Speed Alarm Systems or Intelligent Speed Assistance, for compliance with speed limits;
- Autonomous emergency braking systems, to avoid rear-end collisions;
- Speed regulation system according to the safety distance.

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[2] https://www.euroncap.com/en/car-safety/safety-campaigns/2018-automated-driving-tests/

The systems that improve visibility help the driver in those driving situations that are not entirely visible, due to particular traffic or road conditions. The main variants of this system, available on the vehicles on the market, are:

- Adaptive headlights, to increase visibility in corners;
- Blind corner warning systems, for visibility in overtaking manoeuvres;
- Parking assistance systems.

Nowadays, as above mentioned, most traveling vehicles are at least PAVs, equipped with ADAS to help drivers executing driving tasks. The impacts of ADAS have been widely tested in terms of driving behaviour (Viti et al., 2008) and traffic flow optimization (Shakel et al., 2010).

Bosurgi et al. (2023) highlighted the benefits generated by the implementation of ADAS in terms of road safety (i.e. warning message on the display), since they do not invalidate the driver performance in terms of longitudinal and transverse acceleration, speed, and steering angle. These positive effects have been demonstrated by Nodine et al. (2011): their results suggested that driving with ADAS improves driver behaviour and increases his/her safety, and that drivers perceive safety benefits. The influence of ADAS on the driver behaviour was different in rural, urban, and freeway driving scenarios. The drivers' behavioural response to different scenarios varied with lighting and weather conditions as well as with the age, gender, and ethnicity of the participant (Gouribhatla et al., 2022).

The implementation of ADAS can significantly reduce the traffic delay and conflicts in the medium and high penetration scenarios (Liu et al., 2017). The complete penetration of speed regulation systems in vehicle fleet would lead to 20% reduction in total travel time, 6–11% of safety improvements, through more cautious driving behaviour, and 5–16% reduction in fuel consumption, compared to a scenario with regular vehicles (Khondaker, et al., 2015). The benefits generated by the introduction of ADAS in the vehicle fleet are also environmental, as demonstrated by the lower spatial CO_2 emission rate (Wang et al., 2014).

This research will examine in detail the influence of speed regulation systems, such as the Adaptive Cruise Control, on driver behaviour. It is defined in the following sub-section.

1.1.1 ADAPTIVE CRUISE CONTROL

The Advanced Driver Assistance Systems are in charge of supporting the drivers in order to reduce the risks deriving from critical situations such as heavy traffic or queues. They analyse the surrounding environment throughout different sensors such as radars, cameras, Lidars, and ultrasound devices. Some of these devices can enable the ADAS to intervene independently on the driving controls (such as breaking and accelerating) in different travel directions. However, ADAS do not substitute human drivers, because they are programmed to intervene with some limitations. Therefore, ADAS only supports, but do not replace, a driver in performing the dynamic driving task.

Since June 2022, following the European Parliament decree ((EU) 2019/2144), the installation of some ADAS on all the new vehicles has become mandatory. In detail, the Automatic Emergency Braking, the Lane Keeping System, and the Adaptive Cruise Control have been declared as standard equipment on newly produced vehicles. The aim of these measures is to provide some useful sources and tools to help human drivers in managing the road environment, with the ultimate goal of reducing the number of victims due to human-driven road accidents.

As stated above, one of the systems considered mandatory on new vehicles is the Adaptive Cruise Control (ACC). For this reason, it is crucial to investigate its possible downsides. Thus, the focus of this research is the analysis of the mechanisms generated on human drivers by the Adaptive Cruise Control (ACC), with particular regard to safety.

The Adaptive Cruise Control (ACC) represents the evolution of Cruise Control; it allows to establish a given distance from the lead vehicle modulating the cruise speed according to the set spatial gap from the leader (Hajek et al., 2013). Piccinini et al. (2015) analysed a critical situation, that is a stationary vehicle stopped in the cruising lane of the highway, to compare the distance between the lead vehicle and the vehicle equipped with ACC, with the distance between the lead vehicle and a regular vehicle. The results showed a decrease in the distance between the lead vehicle and the vehicle equipped with ACC, due to a negative behavioural adaptation to the ACC system.

With the term "Adaptive" the main characteristic of the system is expressed, which can adapt the speed to traffic conditions, automatically accelerating or decelerating thanks to environmental information received from outside the vehicle through frontal Radar or Lidar sensors, appropriately weighted (Morando et al., 2016). The standard ACC can be activated at speeds between approximately 30 km/h and about 200 km/h. When the chosen distance falls below the safety threshold, the system automatically intervenes in the management of the engine and brakes to reduce the travel speed. When the road is again free of obstacles, the ACC returns the vehicle to the set cruising speed without the influence of other vehicles. In fact, the system records the environment in front of the vehicle so that, if the driver gets too close to the vehicle ahead, the system slightly decelerates to ensure compliance with the safety distance. This distance can also be adapted to the specific driver, and its behaviour. In this way, the travel is optimized by consider two following vehicles as a part of a platoon. Working like this, the ACC drastically decreases the chance of collisions/crashes. It has been calculated that, when combined with an anti-collision warning system, the ACC can reduce the number of sudden stops on motorways by 67% and rear-end collisions by 73% (Lin et al., 2009).

The ACC acts on the engine and limits emergency braking. It introduces two other important advantages: the reduction of emissions of harmful substances and of the road surface deterioration (Zhang et al., 2018). The ACC does not generate benefits only in terms of environmental impact, but also for the driving behaviour.

The first version of the commercial ACC system was presented in 2000 by Toyota and BMW, and was allowed only for motorway highway sections; the second version, presented in 2004, extended its use also to state roads. The future ACC generation will be different from the current one for more powerful analysis software that can drastically improve the ACC performance.

Nowadays, many drivers use the ACC while driving because of its comfortability, especially in rural roads (95% of the ACC use happen under this condition) and motorways (99% of the ACC use happen under this condition). These percentages fluctuate with the traffic conditions and tend to increase on roads with high-speed limits and in case of long journeys (De Winter et al, 2014); for this reason, Bahram et al. (2014) conducted a study about highly automated driving on highways, considering a penetration rate of up to 100%.

The ACC represents one of the ADAS useful to define a vehicle as belonging to SAE Level 1 or 2. In this context, it is important to provide a specific idea of the help given by ACC in case of a SAE Level 1. If the ACC is implemented on a Level 1 vehicle, it assists the driver by relieving the tasks related to the driving process. Thanks to the ACC, in this level of automation, the users should control the task of driving with the mind, having hands and feet free (Stanton et al., 2009). Although automated systems were originally designed to improve driver safety by reducing driver fatigue, stress and ultimately error, there is growing concern about the additional complexity provided to the driving task, due to the pressure on drivers to monitor both the environment and behaviour of vehicle sub-systems (Banks et al., 2014).

For this reason, this level of automation requires an active cooperation between the two actors: driver and ACC (Weyer et al., 2015). In fact, the system is not capable to act autonomously, thus the role of the driver is still essential: he/she can decide to activate the system or take control of the vehicle at any time, by pushing on the accelerator or braking pedal (Biassoni et al., 2016). The activation of the automatic emergency braking was found to be very effective, preventing 83% of rear-end crashes (Seacrist et al., 2020).

Despite the benefits introduced by the ACC, at this stage, its use is still causing new crash types. For instance, the system could miss the detection of the leading vehicle in curves, or not detect small vehicles, such as motorcycles, going too fast and neglecting the safety distance. It also presents problems for the identification of stationary vehicles, especially in urban contexts and low visibility due to rain and fog (Inagaki, 2003). An important issue is the clarity of information on the vehicle, because drivers need to be able to see what the automated system are doing and to redirect machine activities fluently in instances where they recognize the need to intervene (Christoffersen et al., 2002). Kaber et al. (2001) highlighted the need for discretion in designing transparent interfaces to facilitate human awareness of automated systems. Beller et al., (2013) showed that presenting uncertain information increases the time to collision in case of automation failure.

Nilsson (1996) has investigated the safety effects of ACC in critical traffic situations through a simulator study, which has involved twenty drivers. Only performance-based measures (braking behaviour) and subjective assessments (NASA-TLX score) have been used in order to evaluate the influence of ACC when the user has been stopped from a braking leading vehicle. The obtained results have shown that the ACC did not increase the difficulty of the driving task, but it increased the reaction times. This result was in opposition with Schakel et al. (2017), that have developed a naturalistic driving study consisting of eight drivers that have driven their car with ACC for five weeks. They have monitored only performance-based measures (spacing, headway, speed, acceleration, lane use, and the number of lane changes) and they have found lower reaction times in the ACC ON condition.

Under this umbrella, the study of the interaction between the ACC and the driver behaviour, also in terms of attention and readiness level (Vollrath et al., 2011) and mental workload, becomes fundamental. Several investigations are still needed to improve and assess the ACC safety.

1.2 DRIVING SIMULATION FOR FUTURE SCENARIOS

As stated in the previous Chapter, nowadays, it is possible to regularly see vehicles up to SAE Level 3 in the vehicle fleet. However, in the future, fully autonomous vehicles (FAVs) will constitute most of the vehicle fleet. Until that moment, it is quite difficult to get information about the interactions between FAVs and the other actors in the driving environment. This difficult task is also made more complex by regulations (D.M. 2018 SMART ROADS allegato A), since it does not provide for the circulation of FAVs. Thorough testing of FAVs is undoubtably important to properly prepare the ground for their introduction on roads. A way to obtain reliable results, preserving safety and bypassing complex procedures is to test the driving environment and traffic interactions by means of driving simulators (de Winter et al., 2019), in different driver health conditions (Iwata et al., 2021) and with specific details of the simulated environment (Wyne et al., 2019). In order to understand and analyse how autonomous vehicles will interface with regular vehicles, the road infrastructure, and other autonomous vehicles, it is necessary to use driving simulators. Through the use of driving simulation, it is possible to design a possible driving scenario characterised by a vehicle fleet consisting of autonomous vehicles.

Currently, several tests have been conducted for evaluating the ADAS performance by means of driving simulators, deepening different aspects: Aust et al. (2013) analysed the forward collision warning systems, Lee et al. (2002) delved into the rear-end collision avoidance systems, Bueno et al. (2014) studied the impact of different levels of mental workload associated with a non-driving task.

The importance of driving simulators stays in allowing several tests reproducing realistically the real-world environment but minimizing the risks. Realistic scenarios that reproduce driving behaviour according to the traffic flow theory has been developed for the first time in 1960 (Lauer, 1960). As the automation level increases and, therefore, as the number of automated vehicles rise, the question of how drivers behave in traffic flow becomes more and more important, in order to avoid possible issues in the transition from regular to autonomous control.

In 1965, the American Society of Mechanical Engineers published a report that described the development of a driving simulator in which drivers sat in a vehicle cab in front of a projection system that played back video recorded from a real scene (Fisher et al., 2012).

The evolution of these technologies has been motivated by achieving an acceptable representation of the driving environment and has been supported by the ever-increasing need of understanding the driver/vehicle behaviour.

Nowadays, driving simulators have been largely used to analyse driver behaviours and the consequent effects of technologies, devices, and road infrastructure, ranging from variable message signs (Comte et al., 2000), in-vehicle systems (Lin et al., 2009) as forward collision warning systems (Abe et al., 2005), and automated vehicles (Eriksson et al., 2017).

In fact, the implementation of a custom designed scenario in the driving simulator is a great peculiar advantage, which is used for the scope of this research.

1.3 HUMAN FACTORS, AUTOMATION AND ROAD SAFETY

The term “Human Factors” was introduced in 1930 with the growing use of man-machine systems in automation. This term is defined as the contribution of human to develop an error or failure in the machine function. As also mentioned before, the human factor plays a crucial role in road safety, since the critical reason for more than 90% of motorway road crashes is driver recognition, decision, and performance error (Singh 2015).

The road design engineer should not only consider physically imposed restrictions (i.e., curve radius, stopping distance), but also the driver behaviour while interacting with the road infrastructure, by anticipating the reactions of different road users. Some of these human-infrastructure interactions are related to the particular traffic condition; others are related to the human visual capacity, spatial perception and sense of orientation which are essential to detect obstacles, road signs and traffic lights.

The road transport system can be described through three key components: driver (human), vehicle and the road environment (Lenard et al., 2005). The study of the interactions between these components can be used to investigate the effect of each of these components on a traffic crash and to design assistant systems to increase road safety. These interactions can be listed as:

- the vehicle-road environment interaction: described in several technical guidelines used by road engineers for designing slopes, curve radii, etc. which are mostly calculated based on the vehicle dynamics and road surface properties;
- the driver-vehicle interaction (man-machine interface). Ergonomics aspects such as response time of drivers are taken into consideration;
- the driver-road environment interaction: this is the specific field where human factors should be considered. These interactions are not well described in existing technical guidelines. However, they are crucial for driving, such as in the estimation of speed and distance.

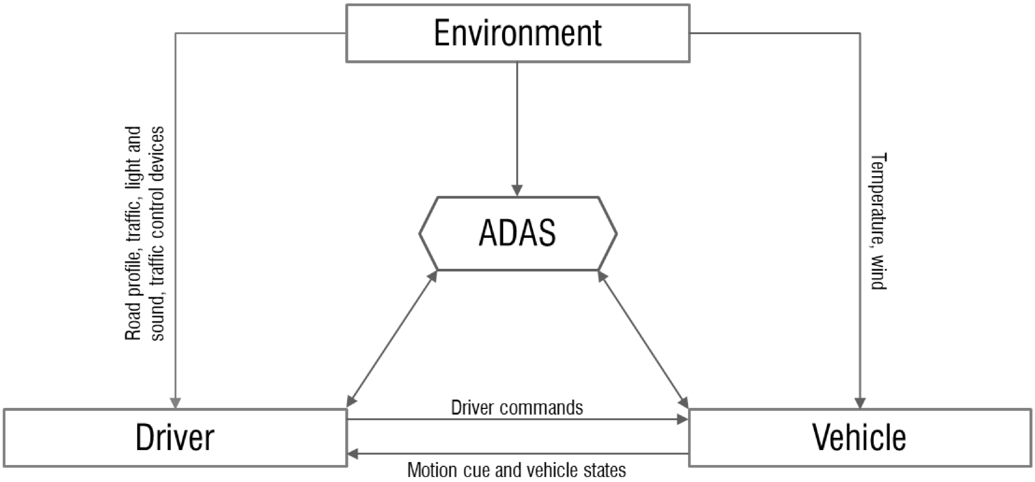


Figure 3 – Environment- Driver-Vehicle system

Road engineering standards should consider human behaviour, capabilities, and limitations since the road environment significantly affects the driver's choice of speed and position. For example, reducing the road width was found useful to reallocate drivers towards the centre of the road, which gives them a recovery area for steering errors (Mecheri et al, 2017). Drivers actively search for information to adapt their behaviour (speed and position) according to the road characteristics and perceived signals. During a trip, drivers should be able to quickly recognize the main function of the road signals.

As already mentioned, a crucial role is played by the interaction between human factors and ADAS (Maag et al., 2012). They should be:

- Usable - interaction with ADAS should be simple and easy to learn.
- Transferable - users should be able to easily adapt when shifting from the operation of one vehicle to another. This implies that interfaces and interaction processes should be roughly similar across different vehicle models.

- Consistent - in similar circumstances, a specific ADAS should perform in a consistent manner both in the interaction logic and in the vehicle behaviour.

- Supporting user role awareness - users should understand their roles and responsibilities. This implies that there should be a limited set of modes in a vehicle, i.e. a limited set of levels of automation and variety of automation functions within those levels, and that the immediate role of the user should be obvious.

- Foreseeability/predictability - users should be able to anticipate the system behaviour.

- Accessible - ADAS design should accommodate the full range of possible users.

- Equitable - other road users should not be disadvantaged in favor of ADAS users (and vice versa).

- Enhancing driving quality - automation should strengthen the joint capability of user and vehicle to achieve a specific effect (e.g., increase of traffic safety). This implies that automation must perform driving tasks competently and coordinate its activity with the human driver.

- Safe interaction with other road users - the ADAS interaction with other road users should be consistent and predictable and should not require other road users to have any special consideration for ADAS-driven vehicles.

- Accurate depiction of system capabilities - there should be no misleading names for ADAS functions and no exaggeration in the description of system capabilities or operation.

- Trust and acceptance - users should trust and accept ADAS to a degree that is consistent with its capabilities and limitations, and systems should be designed so as to earn appropriate acceptance and trust.

From all this, it is easy to deduce the importance that the human driver-ADAS relationship has in the current driving scenario and will have even more in future scenarios.

CHAPTER 2
DRIVING SIMULATOR

In the research field, driving simulators gained much consent because allow researchers to examine complex behaviours in a controlled environment that in other conditions might be not feasible, safe, or ethical (Calhoun et al., 2012). They represent a powerful tool for investigating the human driving behaviour and the consequent effects of technologies, devices, and road infrastructure, ranging from variable message signs, in-vehicle systems, and automated vehicles under safe conditions (Bobermin et al., 2021; Cheng et al., 2020). For this reason, driving simulators are considered a valuable and efficient alternative to test track evaluations (Fremont et al., 2020). Repeatability of test conditions, safety and cost-effectiveness of the tests are some of the leveraging factors that justify the use of driving simulators, whereas test tracks offer a very depleted and inflexible driving environment (Carsten et al., 2011). Driving simulators can also be used in comparison analysis to test existing road alternatives or new road configurations (Granda et al., 2011) or modifications (Huang et al., 2020). Therefore, the usefulness of driving simulators stays in the easiness of investigating the drivers' capability of understanding and reacting to road design and surrounding inputs. All these potentialities of driving simulators make them extremely suitable for road safety assessments.

This research work was the result of a collaboration with the University Gustave Eiffel (Paris); the technical descriptions of the simulator used in PICS-Laboratory derive from the manual "Procédure de démarrage Simulateur Lacet" (Ndiaye et Caro, 2014).

2.1 SIMULATOR'S VALIDITY

The analysis of driving simulator performance is based on the hypothesis that experimental behaviour that occurs during driving simulation could be compared with driving on real roads. Of course, this assumption must be verified by assessing the validity of the driving simulator itself.

The validity of simulators and their capability in replicating the real word scenario are variable depending on the research questions and driving tasks to simulate. In general, a distinction can be made between physical validity and behavioural validity (Mullen et al., 2011; Blaauw, 1982). The physical validity is the one related to the driving simulator capability of reproducing the real-world environment; thus, road design and layout. On the other side, the behavioural validity is the one assessed by the overlap between real-world driving behaviour on roads and driving behaviour in the simulated environment. This kind of validity is also strictly connected to the different configurations (Olstam et al., 2011) and algorithms of the simulator (Fisher et al., 2012).

Assuming that the behavioural validity can be hardly defined, a generic driving simulator may be validated by evaluating the differences between the characteristic parameters observed under real driving situations and the ones got in the simulated environment.

Blaauw (1982) also made a distinction between the absolute behavioural validity and the relative one. The former represents a numerical variation between the measurements during the simulations and during the real environment test tracks. The latter expresses the differences between simulation and real world driving as specific variations of the driving tasks that can potentially have the same impact on driving performance in both situations. This aspect is more useful for research purposes; hence the relative behavioural validity is considered as a priority. This concept is related to the driving simulators' data analysis which refers more to the effects of independent variables rather than to pure numerical measurements (Törnros, 1998).

It is possible to state that physical and behavioural validity (Klüver et al., 2016) are often assumed to be positively related (Ba et al., 2014).

Another classification of validity is the one presented by Malaterre et al. (2001):

- Physical, defined as the exact correspondence between the stimuli provided to the user;
- Experimental, seen as the plausibility of the simulated circumstances;
- Ethological, commonly known as the similarity of observed behaviour;
- Psychological, linked to the cognitive process.

Validation research have demonstrated that the simulator characteristics are dependent on the different uses of the simulator itself (Bellem et al., 2017).

2.2 VEHICLE DYNAMICS AND 2DOF MOTION PLATFORM IMPROVEMENT IN THE DRIVING SIMULATOR

The term "Driving Dynamic Task" (DDT) refers to “all real-time operations and tactical tasks necessary for operating a vehicle on the road, with the exception of trip planning and itinerary selection, which are strategic tasks” ((EU) 2022/1426). Operations like lateral vehicle motion control with the steering wheel, longitudinal vehicle motion control with the pedals, monitoring the driving environment through object and event detection, recognition, classification, and response planning (operational and tactical), executing object and event response, manoeuvre planning (tactical), and increasing conspicuity through lighting and signalling (tactical) are all taken into consideration by DDT (SAE J3063, 2015).

The Vehicle Dynamic Model (VDM) installed on the simulator oversees simulating in real-time all of the vehicle states required to the driver to perform dynamic driving tasks. Later, these data are shown on the dashboard (for example as speed and rpm), transmitted through a Human-Machine-Interface (HMI), or used as input for cueing systems that use visual, auditory, or motion cues. The engine, brake system, gear changing system, suspension, and even the driving assistance system or interior control are all factors that affect the vehicle dynamic model. Due to this, driving simulators are crucial research tools for automotive manufacturers to evaluate their vehicle designs and provide insightful data for enhancing the design of the transportation system.

However, the motion and the feedback of the vehicle to the input signal is providing information to the drivers so that they can adjust their control input in accordance with the performance of the vehicle. The visual cue is the major source of information for monitoring and event detection. The simulator mobility can improve the driver perception in the virtual environment, since the simulator moves in accordance with the visual cues. However, it is exceedingly expensive, if not impossible, to replicate the full-scale accelerations of the real vehicle. As a result, motion cueing techniques should be utilised to replicate the motion in driving simulators. The vehicle states from the vehicle dynamic model are used by the motion cueing algorithm, which makes calculations while taking into account the limitations of human vestibular perception.

The architecture of the simulator and the vehicle dynamic model utilised for the simulation are initially described in this paragraph.

The driver simulator can also be trained or programmed to simulate specific conditions of driving as the presence of ACC on the vehicle.

2.2.1 Driving Simulator Architecture

With regard to the brief introduction about the vehicle dynamic model and its importance in the driving tasks, it is possible to focus more on the simulations that can help in optimizing the HMI for easy driver responses, reducing the mental workload. The diagram depicted in Figure 4 shows how the simulators work, demonstrating how they exactly replicate the driver mental processes and behaviours that happen in real driving conditions. Figure 4 not only shows the correlation between each subsystem but also how drivers and their perceptions are at the centre of the driving process. Driver inputs are used to calculate the vehicle dynamics by the vehicle model, which is used by the feedback systems to provide the necessary cues to the driver. The scenario control uses the definitions of environment (terrain), and the vehicle dynamics to provide image and sound cues as outputs.

In simulators, multiple projectors are used to create a seamless image (processed and optimized before the projection) typically projected into different screens. This setting creates an immersive experience for the driver, that could feel the same emotions of driving in real conditions. The motion cueing can also enhance the feeling of immersion, considerably. Moreover, the motion cueing allows the examination of the dynamics of the vehicles, useful for the development of active systems. The motion cueing algorithm would collect the vehicle response and determine how to replicate the kinematics of that system, that can be transformed into actuator commands. Then the output produced by the motion system provides cueing to the human driver (Pieroni et al., 2016).

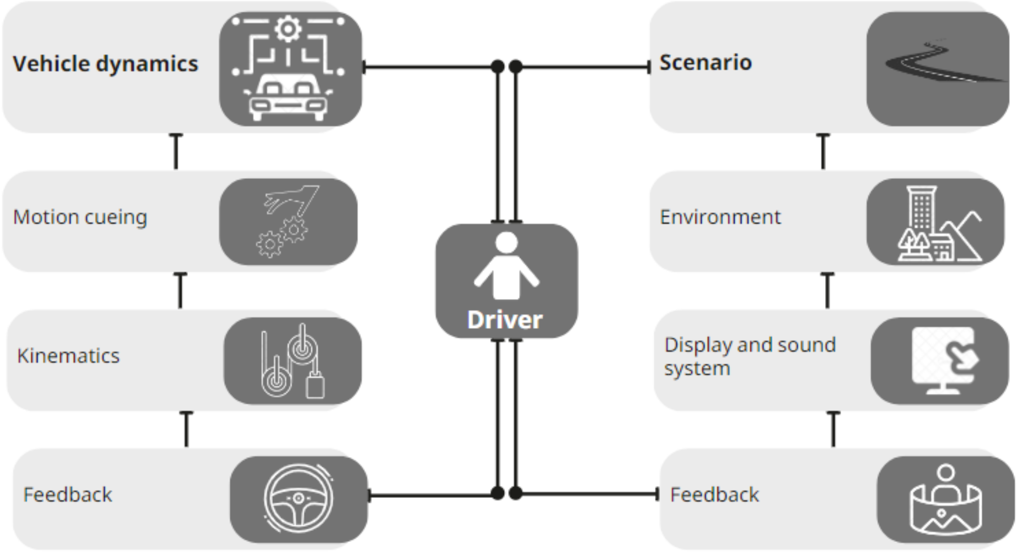


Figure 4 – Diagram of a driving simulator

The simulation purpose is to replicate the real driving and enable the participants to feel real driving in the virtual and multisensory environment in which they move by controlling an interface (Ghasemi et al., 2019; Ghasemi, 2020). Hence, to maximize the immersion and realism of the simulation, many elements are assembled with control devices (Ghasemi et al. 2020).

In general, a simulator can be seen as a device composed by different blocks representing simulation and human sensory systems and perception which interact to generate the illusion of reality (Simone et al., 2017) (Figure 5).

The simulation computer can calculate the vehicle motion with reference to the environment, driver control actions, aerodynamic and road surface inputs (Blaauw, 1982). In this way, it generates inputs for the sensory feedback generation (SFG) block. This one will produce sensory cueing commands or inputs to the sensory display device (SDD) block. As a result, the drive receives all these sensory cues information, responding to it and creating then control inputs that are fed back to the simulation computer processing (SCP). The head orientation must be added if a head-mounted display (HMD) is used on the simulator with virtual reality implementation (Pieroni et al., 2016).

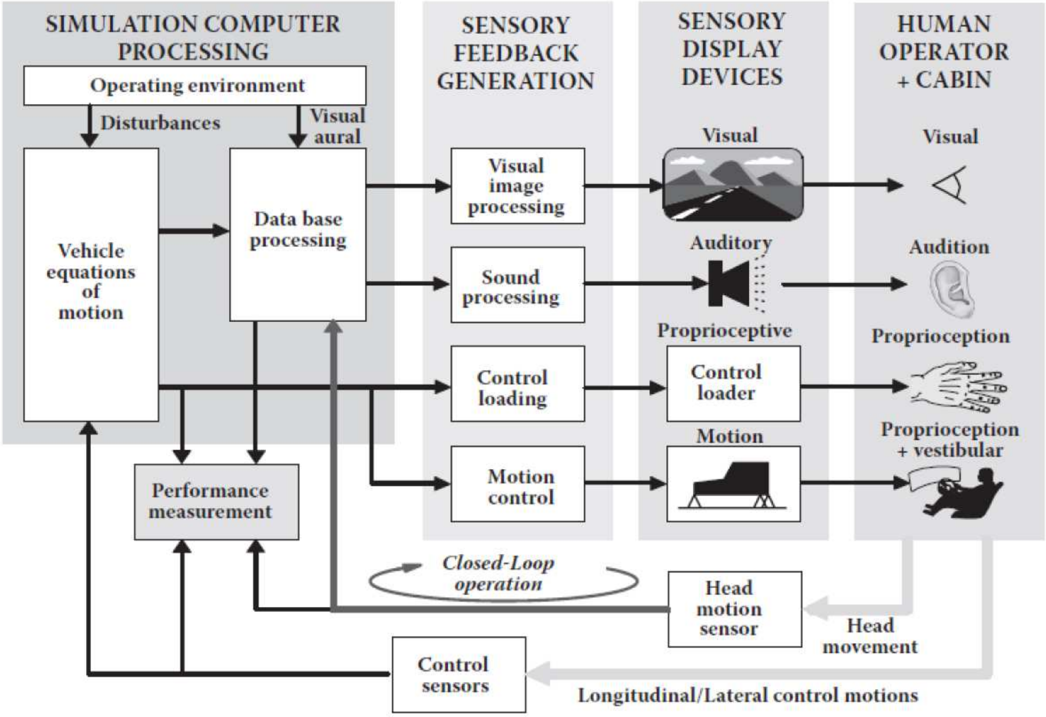


Figure 5 - Driving Simulator’s Components and their interactions (Ghasemi, 2020)

In general, as can be seen from Figure 5, the main elements of a driving simulator include:

- cueing systems;
    - visual
    - auditory
    - proprioceptive

  - motion

- vehicle dynamics;
- computers and electronics;
- cabs and controls;
- measurement algorithms;
- data processing and storage.

The components of the simulator and the connections among them are illustrated in Figure 6. The acquisition system is composed of an industrial microcontroller and has both analogic and digital input/output. This allows the control of the actuators in the desired position, speed or torque (used for the steering wheel force feedback).

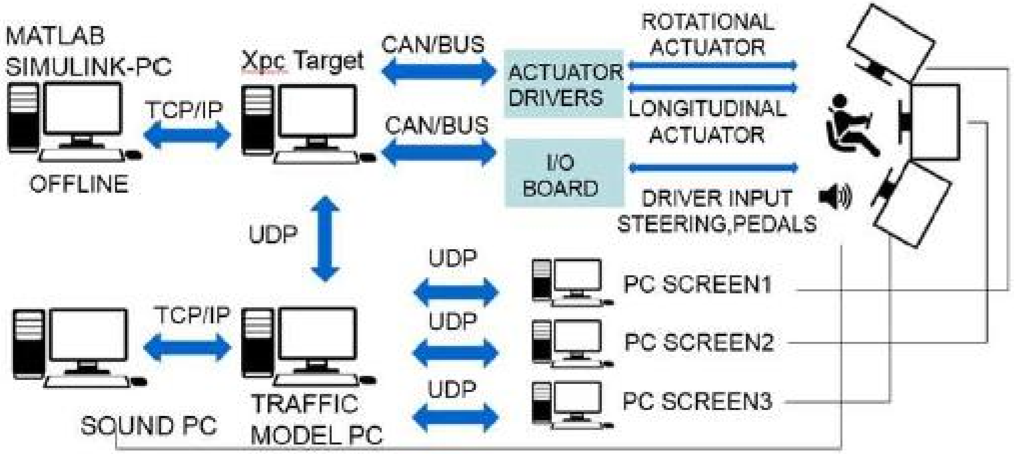


Figure 6 - Driving simulator architecture and connections (Ghasemi, 2020)

A bidirectional information exchange protocol is defined between this electronic board (I/O) and the PCs dedicated to dynamic simulation and traffic simulation. The communication is performed through CAN port between the electronic board and the XPC target. The driving simulator used in this research work is characterised by:

1. XPC Target: this PC is connected through a CAN interface directly to the I/O board. This board communicates to the MATLAB PC and the actuators. It is also linked through an Ethernet connection to the Traffic model PC.

2. MATLAB-Simulink PC: the Simulink interface is installed on the PC with the vehicle model and the real-time simulations are being controlled from the PC.

3. Sound cueing PC: the sound cues such as road-noise, engine, other traffic during the simulation is simulated using this PC which consists of a software managing the sound effects during the simulation. It works with a sound card mounted under the platform, while the speakers which are mounted in the motion cabin reproduce the sound;

4. Traffic Model PC (Dr2): this computer simulates the road environment, traffic and the driving scenario. The software ArchiSim2 is used for the programming of the traffic and allows different time, distance or speed criteria to be used for the simulation of the events.

5. Visual Rendering Unit: three Computers are connected directly with PC Dr2 and broadcasts. The pictures on three fixed screens visual cueing mounted on the cabin. The screens are 4K resolution and 100 Hz frequency (Figure 7) providing 180° of horizontal and 36° of vertical Field of View (FOV).

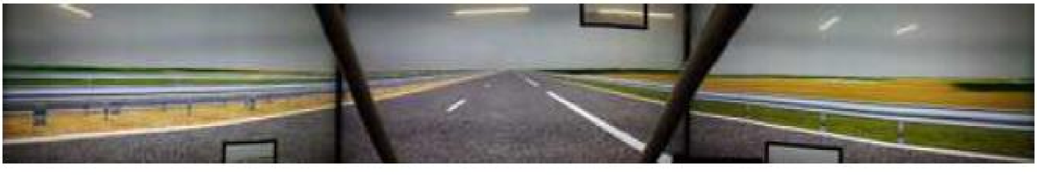


Figure 7 - Visual cueing unit (View from the driver seat) – Driving simulator PICS-L, Université Gustave Eiffel

2.2.2 Vehicle dynamic model (Matlab-Simulink)

The Vehicle Dynamic Model, responsible for calculating the response of the vehicle based on the driver control input, is implemented on the MATLAB-Simulink software and can be modified and controlled by the same interface software. The VDM shows the relationships between the different parts of the vehicle model in a graphical format. In this way, the various inputs can be traced graphically and the relationships between the inputs are in MATLAB script format. Each of the different models has sub-layers to make the simulation work and to show the outputs of the different parts of the model. As mentioned before, this model should represent vehicle motions and control conditions in response to driver control actions, road surface friction conditions and aerodynamic disturbances. All required vehicle feedback is computed in real-time for commanding the visual, motion and sound simulation systems. In addition to the vehicle model, the motion cueing algorithms and the commands to the actuators are also controlled and can be adjusted/modified in the MATLAB-Simulink model (Simone et al., 2017; Ghasemi et al., 2019).

The proposed VDM is nonlinear. The vehicle model allows the determination of the virtual vehicle states according to the driver’s control input. The vehicle dynamic model concerns the computation of the dynamics and the kinematics as a function of the driver input and the road characteristics. The model contains as main inputs the commands (Throttle, Clutch, Brake, Gear) which influence the longitudinal control of the vehicle; and the steering, which influences the lateral control input (Ghasemi et al., 2020).

The kinematic elements can greatly influence the vehicle dynamic behaviour. This is due to the existing interconnection between different parts of the vehicle. Due to the complexity of a complete vehicle, the model is limited to four interconnected subsystems: the chassis, the suspensions, the wheels and their interactions with the ground.

The vehicle characteristics used in this simulator belong to the Peugeot 406. The engine is simulated using the real engine dataset from the Peugeot 406 engine characteristics (engine torque curves, clutch pedal position, accelerating proportioning, etc.). After updating the vehicle state, the relevant resulting information is sent to the cabin dashboard and to the traffic model server. The platform is equipped with several sensors and electric boards in order to have information feedback on the control system states. The model computes the states of the vehicle with a frequency of 1000 Hz. The output of the vehicle model is necessary to send the location of the vehicle to the virtual environment (visual) and the longitudinal acceleration and yaw rate are also necessary to reproduce the cabin motion (Pieroni et al., 2016).

In this model, the vehicle is considered as one body with 6DOF (surge, sway, heave, roll, pitch and yaw). The engine part is modelled by a combined mechanical and behavioural approach based on the vehicle general characteristics (engine torque curves, clutch pedal position, throttle, etc.) (Ghasemi, 2020). Each of the blocks in the Simulink model governs a different part of the vehicle dynamics, as shown in Figure 8.

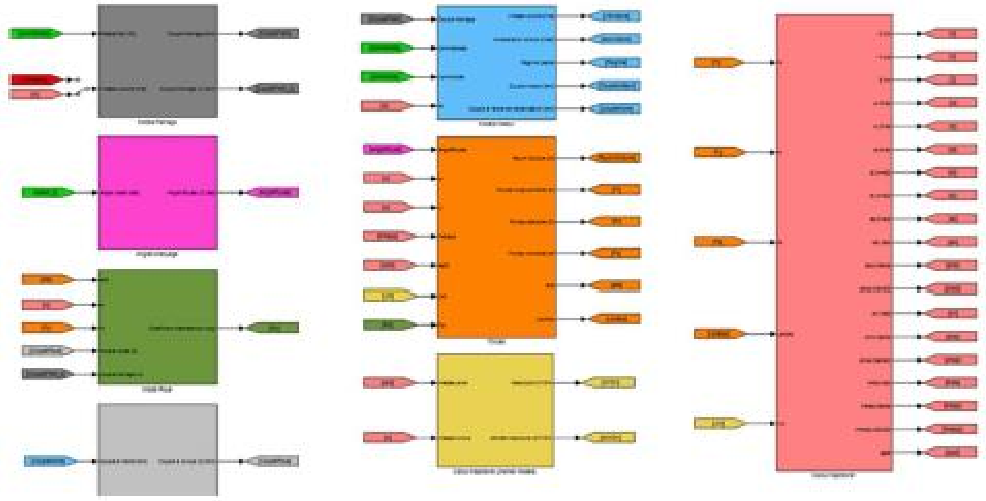


Figure 8 – Vehicle Model sub systems (Ghasemi, 2020)

2.2.3 Motion cueing platform

The motion cueing platform is composed of two separate structures. The longitudinal rail is located on the top of the rotating circular platform. The longitudinal upper structure can move linearly along the rail. A pulley-belts system is being used to move the cabin powering from a brushless servo motor (SMB 80). The lower structure provides yaw angle cabin rotation by using a circular platform in which the servomotor directly rotates the upper structure with wheel support in the front of the cabin. The vehicle motion simulation structure is shown in Figure 9.

Figure 9 – Simulator cabin and motion cueing platform - Driving simulator PICS-L, Université Gustave Eiffel

The participant in the cabin gives control input from the steering wheels and pedals to the vehicle dynamics model which generates the vehicle states. These states then will be used to mock the desired motion cues on the platform using the motion cueing algorithm. Two actuators generate the motion in the two degrees of freedom space of the cabin (yaw and longitudinal) using the desired platform states.

Motion cueing algorithms (MCA) render the physical motion of the simulated vehicle in real-time to provide a multi-sensory environment for the driver (Figure 10). The MCA goal is to: Keep the motion platform within the physical boundaries, stimulating the motion cue within the driver perception threshold and return the platform to its neutral position.

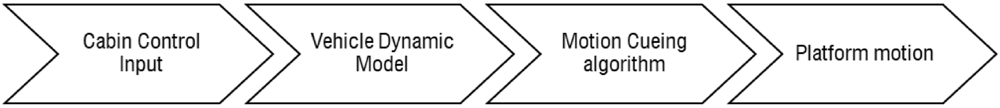


Figure 10 – Motion cueing algorithm implementation

2.2.4 Motion cueing algorithm

The classical algorithm was the first motion cueing algorithm for simulators, initially used in the 6DOF flight simulators at NASA Ames Research Centre. The first motion cueing algorithm only rendered the high-frequency domain, whereas the second version introduced the cueing of the low frequency domain through the tilt-coordination. Nonetheless, the physical limitations of these first hexapods were considerable, and because of that the maximal displacement was very poor and since all the motion had to be cued, the parametrization of the algorithm was highly conservative and made considering the worst-case scenario, penalizing the rest of motion cueing. Nowadays, technological progress and advance knowledge of this algorithm overcame these problems.

A non-linear scale factor was introduced and implemented for both surge and yaw motion (Pieroni et al., 2016). The non-linear scale factor is then obtained as expressed in Equation 1:

$$\mathrm{SF}_i(\mathrm{inp}_{max}, \mathrm{SF}_{min}, \mathrm{a}_i) = e^{(-x*a_i)} \qquad \text{(Eq. 1)}$$

Where:

- inp_{max} = Maximum input;
- SF_{min} = Minimum scale factor;
- a_i = Input Acceleration;
- x = Scale parameter and the scaled input SCInp (expressed in Equation 2).

$$\mathrm{SCI}_{inp} = \mathrm{SF}_i * \mathrm{a}_i \qquad \text{(Eq. 2)}$$

Where:

- a_i = Acceleration input at i-time;
- SF_i = Scale factor calculated for the input $a_{i.}$

In this way, fixing the maximum acceleration and the minimum scale factor to be applied to this acceleration, the procedure generates each time a new non-linear exponential equation to calculate the scale factor to be used for each input. For calculating the longitudinal acceleration input, considering acc_{max} = 0.8 g, being μ_{max} = 0.8 in the dynamic model; SF_{min} = 0.5. As a result, the exponential form to calculate the scale factor is expressed in Equation 3:

$$\mathrm{SF}_i = e^{(-0.0883*a_i)} \qquad \text{(Eq. 3)}$$

The classical algorithm is developed by the combination of the washout and tilt coordination algorithm. The filters separate the frequencies of the linear acceleration for the displacements and rates for the rotations in high-frequency components and low-frequency components. The classical algorithm cues a motion compatible with the limits of the platform, by treating those measurements. First, high-pass filter F_1 passes the high-frequency components of the scaled signal. These components represent the transitory component of the signal, namely the variation of acceleration. A typical representation of the filter through the transfer function of a second-order problem is represented by Equation 4:

$$Acc = \frac{s^2 \mathrm{k}_1}{s^2 + 2\xi_1 \omega_1^2}\ \mathrm{Acc.input} \qquad \text{(Eq. 4)}$$

Where:

- k_1 = Gain;
- ω_1 = Second-order system undamped natural frequency;
- ξ_1 = Damping ratio.

Figure 11 - Classical motion algorithm for translation motion

The first high pass filter F1 only collects the transitory acceleration. This signal is then double integrated for the acceleration of integrated once for the rate to obtain the position. A second high-pass filter F2 is then applied to this signal, which is called a washout filter. This filter allows the platform to bring back the cabin to its initial position after each transitory acceleration. It is by regulating the parameters of both filters which is possible to control the time needed to bring back the platform to its initial position, the amplitude of the signal and therefore also the space used by the platform.

When adjusting the MCA, it is important to define the parameters so that the perceived accelerations are not inconsistent with the rest of the motion, the so-called false cues. These reduce the quality of immersion and create a degradation of simulated vehicle control. This incoherence in motion perception can be removed by regulating the filters. In general, it is possible to distinguish three principal sources of false cues:

- Post-filter acceleration exceedance - after applying the high-pass filter to the simulated acceleration or rate, the filtered signal tends to follow the simulated signal in the transitory phase, whereas it vanishes when it comes to continuous accelerations. However, when the acceleration vanishes, an incoherent perception could be generated because of the motion conflicting with the rest of the simulation. Therefore, the overflow must be under the perceptive motion threshold of the vestibular system.

- Platform return to the neutral position - the washout filter purpose is to bring back the platform to its neutral position when continuous components of the input occur. However, the platform displacement to its neutral position might alter the perceptive coherence on the simulator. If the platform is moved in the opposite direction of the vehicle simulated motion with higher amplitude than the perceptive threshold of the vestibular system, a sensorial incoherence between visual perception and motion perception might occur.

- Sudden changes in input acceleration - this is a case typical of the longitudinal motion. Generally, in this driving situation, protracted braking is generated. In the stopping manoeuvre, the acceleration goes from zero to a negative value, while the filter allows the driver only to perceive the transitory component. In the continuous acceleration phase, the acceleration remains negative, and the driver does not perceive any inertial effect. However, at the end of braking, the vehicle simulated acceleration is characterised by a relevant jerk, going from negative to positive. The virtual world of the simulation displays a vehicle perfectly still, while the platform cues a negative acceleration. This situation might be perceived as incoherent and creates unpleasant feelings in the driver.

2.2.5 Driving simulator SimuLacet

The used driving simulator is the “SimuLacet” driving simulator, designed with a 2 DOF motion cueing platform to study the yaw motion vehicle control and simulator sickness in the virtual environment in Université Gustave Eiffel. The simulator designed as a two degree of freedom in motion platform. The cabin consists of a real car dashboard, steering wheel, clutch, brake, throttle pedal, gears change handle, hand break, blinking handle and a switch. The steering wheel feedback is integrated with the steering wheel. The cabin also provides information such as vehicle speed, engine round per minutes (rpm), fuel indicator and other vehicle states on the dashboard.

The image is provided to the driver in the cabin with three fixed screens in front of the seat. The visual system provides 4K resolution with a capacity of 100 Hz providing 180° of horizontal and 36° of vertical field of view for the participant in the simulator cabin. A rear-view mirror and two side-view mirrors implemented on each screen with a plastic frame isolating the screen from the front view. Visual rendering unit consists of three computers connected and broadcasts the images displayed on three mounted screens.

The sound cue is provided by a sound system with four speakers 30 W (50 Hz), reproducing the engine noise, wind sound, rolling noise and other traffic with the possibility to regulate the audio cue intensity.

The acquisition system is composed of an industrial input/output board with the bidirectional information exchange of 1000 Hz. This board is transferring data in real-time between the cabin and the computer in charge of the vehicle dynamics simulation (XPC Target). The XPC target PC also controls the actuators in the desired position and communicates the position of the vehicle to the visual rendering system. The Traffic simulation PC launches the visual scenario according to the position of the vehicle and simulates the road traffic using Archisim multi-actors traffic simulation model (Espié et al., 2007).

The vehicle model implemented in MATLAB SIMULINK is calculating the vehicle states in real-time using the input from the cabin (steering wheel, pedals) (Pieroni et al., 2016; Lobjois et al., 2016). The model first computes the torque of the engine based on Peugeot 406 from the sensor on throttle pedal percentage and the rotation frequency of the engine.

The gear shifting of the vehicle is implemented as a hybrid model that can be used with automatic or manual gear transmission mode. In this experiment, only automatic gear was used.

2.3 ADVANTAGES IN RESEARCH

One of the main advantages of relying on the driving simulator is that it can largely map human behaviour in real time, capturing how humans act in a driving environment, in terms of car following (Li et al., 2019; Sheu & Wu, 2015), lane changing (Hess et al., 2020), and gap acceptance (Li et al., 2020).

Secondly, driving simulators offer the opportunity to test different driving conditions in a controlled and safe environment. Some high-risk scenarios cannot be reproduced and tested in the real world. The driving simulator can test the risky scenarios without causing any risk of crash, such as distraction (Muttart et al., 2007; Navarro et al., 2017), adverse weather (Chang et al., 2019; Yan et al., 2014; Zhao et al., 2019), critical situation (Mcavoy et al., 2007), and fatigue driving (Meng et al., 2019). Third, the driving simulator can also provide a low-cost, high-efficiency, and repeatable environment for researchers to develop and test new interventions, such as the improvement of road auxiliaries (Hang et al., 2018; Ma & Yan, 2021) and new driver assistance technologies (Calvi et al., 2020; Zhang et al., 2021).

The limits of driving simulators should also be recognized. Firstly, driving simulators could cause motion sickness in participants (Almallah et al., 2021; Dużmańska et al., 2018); therefore, it is necessary to select drivers who can drive at the driving simulator regularly. In addition, the validation of driving simulators is important, mainly to ensure that data collected by driving simulator is comparable to the real world. Currently, many studies have verified the authenticity of driving simulators on both a subjective and an objective level (Bella, 2005; Bham et al., 2014; Hussain et al., 2019).

In this optic, various studies tried to verify some different aspects of driving and their reliability in driving simulators. For instance, Rossi et al. (2020) compared gap acceptance behaviours of drivers from both field observations and driving simulators and found that the mean critical gaps estimated in real conditions and in the virtual environment are not significantly different; thus, confirming the feasibility of using the simulator instead of real-world tests. Hussain et al. (2019) validated a fixed-base driving simulator comparing drivers' perceived speed to actual speed, and the results demonstrated the effectiveness of a fixed-base driving simulator in speed assessment. Therefore, the generally accepted relative validity of driving simulators suggests that they can be used as a valuable tool to assess driver behaviour, especially in risky situations.

Apart from the mentioned pros and cons of the driving simulators, the most outstanding advantages of driving simulators lies in the analysis of the human-environment-vehicle system interactions. The following are listed as the key benefits:

- Simulators are useful for testing dangerous situations (De Winter et al., 2011), since they give complete control over the simulated events in a safe environment, because they operate in virtual surroundings. As a result, it is possible to expose the participants to scenarios that could be challenging to study on a test track or the open road. They can also be used to investigate driver's fatigue, impairment and medical issues. Thus, specific phenomena can be studied avoiding the influence of dangerous factors (for example, degraded driving conditions, night or fog driving conditions with low visibility).

- Simulators enable to plan and control the events, as well as the capability to set up virtual scenarios that precisely match the requirements of a particular investigation (Dosovitskiy et al., 2017). It is possible to manage all the environmental agents and infrastructural components (traffic lights, state of road surface) to stress the driving behaviour. The simulated vehicles, as well as the driven one, can also be modified and controlled. Thus, it is possible to recreate the desired driving conditions setting the same starting conditions to make easy and reliable the analytical comparisons.

- Simulators recreate virtual environments by using technical data about the infrastructure (such as alignment and cross section). Infrastructure characteristics implemented in the simulator can be also not realistic and fictitious to test various possibilities. It might be a model of a future road project or a replica of an actual area. It would be possible to virtually add or modify road features for the evaluation, assessing the main features of the infrastructure (Bella, 2009).

- Simulators can record a variety of data, including traffic data, vehicle trajectory and states, driver feedback to the virtual environment, and parameters related to driving behaviour (steering wheel, pedals, gear change, etc.) during the simulation. Information can be gathered more often than with conventional road tests or inboard observatories, with the potential for fine data processing (Ricci et al., 2022).

- Driving simulations give the possibility to do low costs experiments (Caird et al., 2011). Even if the costs of manage the driving simulator system are high, the costs for modelling the scenario and the use of simulator are very low.

- Simulators do not create any difficulties in collecting data. Recording the data is extremely efficient because it is done automatically during the experiments (trajectory, local speed and acceleration, steering wheel rotation angle, pitch-ing angle, rolling angle, etc.) at time or space intervals of a fraction of a second or a fraction of a meter (Caird et al., 2011).

Summarizing all the expressed concepts, driving simulators can be considered the ideal tool for various applications and studies. The use of a simulator could be useful for evaluating sophisticated in-vehicle technologies, examining alternative signs, traffic signals, pavement markings, and route layouts (Ogata, 2010), as well as for understanding driver behaviour with subsequent interventions (electrical or industrial engineering). To test any potential distractions that new car technology can cause, automotive software engineers may find use for simulators.

2.4 CONSTRAINTS AND REQUIREMENTS

Even though driving simulators provide certain advantages over road tests, they also show some criticalities, especially residing in the requirements for road infrastructure reconstruction and for technological issues, and in the issues for behavioural analysis. The constraints of the driving simulators are listed as follows:

- The virtual environment strongly influences the reconstruction and perception of the infrastructure on driving simulators. For this reason, the investigation of an existing street or highway, requires topographic and geometric information, available by means of either a geospatial database, like Google Maps, or design software like AutoCAD. Road signs must be implemented as well, and their readability depends on the display resolution, though. This aspect can negatively influence participants that could not perceive and read the signals in the reconstructed environment as they saw in real world.

- The validity of simulators represents a fundamental requirement for a driving simulator to be an effective research tool. A generic driving simulator may be validated by evaluating the differences between the characteristic parameters observed under real driving situations and the ones got in the simulated environment.

- The simulated traffic and external agents must be realistic to increase the participants' sense of immersion in the simulation. The behaviour of the virtual road users must be sufficiently realistic to effectively simulate realistic driver choices.

- The computer graphics component of the driving simulation needs special consideration, since the visual aspect is the most important for a driving activity (Huang et al., 2004). The visual impact of some new systems to be tested, like pavement-embedded signals or road lights, could be adjusted and simulated by photometrically calibrated HDR rendering and presentation.

- Simulator can induce sickness, also known as kinetosis, into participants. It is a problem that should be considered when utilising simulators. A conflict between visual and somatosensory information is a prevalent theory for the cause of motion sickness. It is possible to investigate the effects of kinetosis on the driving experience through questionnaires (Brooks et al., 2010; Kennedy et al., 1993).

- There are significant differences between the level of distraction in the real environment and in the simulated one: in the real environment distraction is often caused by the use of mobile phones (Horrey and Wickens 2006; Spence and Ho 2008) and text messaging while driving (Hancock et al. 2003; Hosking et al. 2007); in the driving simulator this type of distraction is almost completely absent because the driver is absorbed by the new reality of the simulator.

CHAPTER 3
METHODOLOGY

This section illustrates the description of the real site considered for the reconstruction of the scenario in the driving simulator. The real site chosen for the analysis was the SP106, in the Metropolitan City of Bari, and represented one of the most widespread typologies of roads in that area and also one with the most accidents.

Once the road site was defined and then the scenario reconstructed in the driving simulator, the next step was to define the driving simulation scenarios. The aim of the driving simulations is to analyse the influence of ACC, secondary tasks and route familiarity on the driver behaviour. In order to analyse these three variables, 37 experiments were carried out, each consisting of 6 repetitions, for a total of 222 simulations.

Finally, the questionnaires submitted to the drivers were analysed, in order to investigate their driving attitude and the driving simulator experience.

3.1 INVESTIGATED SITE

In order to reconstruct a scenario suitable for the experiment conducted using the driving simulator, the first step was the identification of a real site with similar characteristics to those needed to carry out the experiment. The site selected for reconstruction in the driving simulator is the SP106, falling in the Gioia del Colle area, within the Metropolitan City of Bari, Italy (as in Figure 12). The real road site is an undivided two-way two-lane rural road. In the figure below, the selected site is highlighted in clear blue.

Figure 12 – Investigated site

The road layout consists of a succession of 13 straight section and 13 circular curves, detailed in the table below.

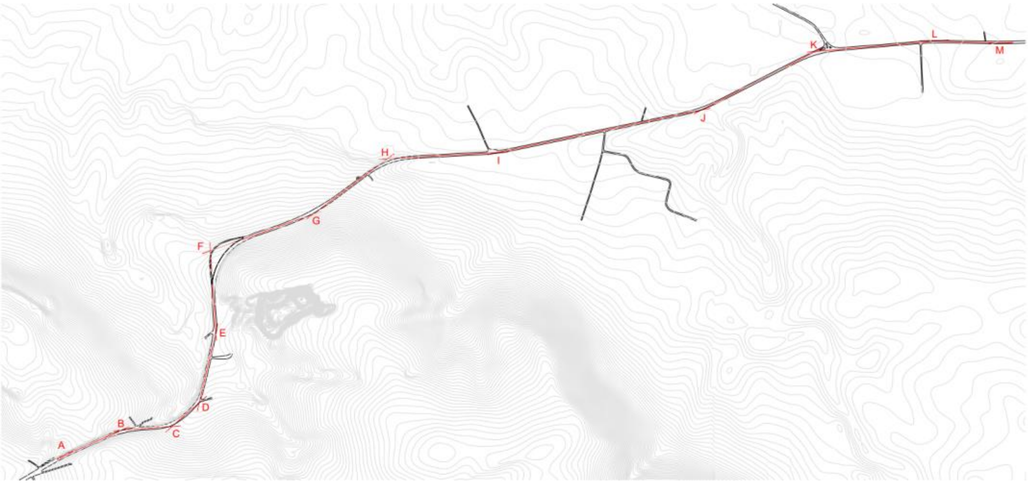


Figure 13 – Road layout reconstruction

Table 1 – Geometric characteristics

Planimetric element	Segment lenght [m]	Radii [m]	Angle in the centre [°]	Tangent angle [°]	Expansion [m]
Curve 1	-	744,62	5	33,99	67,60
Straight segment 1	109,82	-	-	-	-
Curve 2	-	395,80	20	68,66	135,97
Straight segment 2	48,37	-	-	-	-
Curve 3	-	169,35	37	57,25	110,41
Straight segment 3	25,53	-	-	-	-
Curve 4	-	118,41	35	37,35	73,08
Straight segment 4	175,60	-	-	-	-
Curve 5	-	254,54	17	37,82	75,09
Straight segment 5	94,06	-	-	-	-
Curve 6	-	197,90	74	149,30	255,81
Straight segment 6	24,30	-	-	-	-
Curve 7	-	659,13	32	99,68	197,86

Straight segment 7	130,46	-	-	-	-
Curve 8	-	294,58	34	88,99	172,84
Straight segment 8	230,40	-	-	-	-
Curve 9	-	794,82	9	59,46	118,70
Straight segment 9	585,07	-	-	-	-
Curve 10	-	505,62	15	68,70	136,58
Straight segment 10	295,73	-	-	-	-
Curve 11	-	385,04	22	76,31	150,66
Straight segment 11	241,83	-	-	-	-
Curve 12	-	1254,20	6	89,48	178,84
Straight segment 12	91,29	-	-	-	-
Curve 13	-	1550,38	3	45,00	89,98
Straight segment 13	131,89	-	-	-	-

The presence of just one major intersection, the absence of obstacles, and minor intersections were other crucial aspects which directed towards the choice of this road section (SP106). In fact, all these features potentially related to crash occurrence can also involve those vehicles equipped with ACC may have positive effects on the safety performance of this site.

Additional information regarding the site under investigation concerns the shoulder width, which is 1,25 m, and the main signs, i.e. the road markings, consisting of continuous lines indicating the two lanes on the road. The site under consideration has no vertical slopes.

A crash analysis of the site was then conducted. Crash data were related to Fatal+Injury crashes since 2015 to 2019 (ASSET-ISTAT dataset). On the other hand, traffic flow data were obtained through a previous monitoring phase of the entire road network belonging to the province. From the analysis of the crash dataset, the undivided two-way, two-lane rural roads seemed to be the most crash affected. This is due to the exceedance of driveways and minor intersections with low visibility present on tangent sections. For this reason, this type of road was chosen for the study.

However, among these roads, the dataset was filtered for crashes which involved at least two vehicles. This was justified by the fact that these types of crashes can be avoided by the implementation of ADAS, more than the single vehicle crashes (i.e., run-off-the-road). The crashes occurring on two-way, two-lane rural road involving two vehicles represent the 65% of the total recorded crashes.

Seventeen crashes occurred on this site, 53% of crashes are located at an intersection (29% signalized intersection, 12% unsignalized intersection, 12% junction); of the remaining 47%, 35% are located at a tangent section, 12% at a curve. With the aim of examining the conditions in which the crashes occurred, 41% of the crashes occurred as run-off-the-road. In case of crashes between travelling vehicles, 29% occurred as a result of head-on collision, 18% equally divided between angle, sideswipe, and rear-end collision. Crashes resulting from collisions with an obstacle were not negligible, accounting for the 12%.

The stone wall on the curb of the road is typical of the area, and it is easy to be reproduced in the simulator. Its dimension does not affect the driver visibility and its position on the side creates negligible effects to the drivers (as derived from a visual inspection of the site). As shown in Figure 14, other possible obstacles on the roadside are absent. All the trees are far from the lane margins. In this way, their impact to the driver is almost negligible. Under this umbrella, the trees could also be omitted in the driving simulator, also for another reason, that the screen cannot reproduce the entire area without limits. These trees could also fall outside the scenario possibly implementable on the simulator.

Lane and shoulder dimensions, as also blatantly shown from the figures below, are in line with prescriptions made by the Road Design regulation in Italy for this road category (Ministerial Decree 5th November 2001, n. 6792, Chapter 3).

The present area was visually inspected, and on-site investigations were performed to get all the geometric features and boundary conditions to be reproduced in the simulator. The inspections were made twice during the winter season of 2022, in two different moments. Moreover, traffic data (divided in light and heavy vehicle volumes) and the speeds (mean speed and operating speed) were measured by means of two traffic radar counters (Sierzega SR4). They were installed one per traffic direction and placed on the poles of the vertical signs for a time period of 7 days.

The data collection covered weekdays, weekends, days and nights for the two directions, in two different spots of the road. In this way, it was possible to cover different situations and gaining remarkable results to be used in the simulations. The traffic counters were placed according to the prescription of the manufacturer (Sierzega). The investigated sections by traffic counters were highlighted in Figures 14 and 15.

Figure 14 – Investigated site: Direction toward Gioia del Colle

Figure 15 – Investigated site: Direction toward Putignano

All the results obtained from traffic inspections made by the traffic counter are summarized in the tables below. The first of the traffic counters was positioned in the direction towards Putignano at the progressive kilometre 10+650, the second in the direction towards Gioia del Colle at the progressive kilometre 10+000, and the third on the SP 139 with which the SP 106 intersects.

This measurement was propaedeutic to get how the traffic is distributed over the road network and the rate of diversion into the intersecting road. This road is another undivided two-way two-lane rural road, SP 139. All these data were just useful for the recognition of the area in the optic of an accurate reproduction through the driving simulator.

Table 2 – Traffic surveys: SP106-Direction toward Gioia del Colle (the grey lines refer to the weekend)

January 2023	Detected daily traffic	Car	Heavy vehicle	%Car	V>50 km/h	%Veic. V>50km/h
20	888	888	0	100,0	414	46,6
21	1885	1885	0	100,0	981	52,0
22	1256	1256	0	100,0	632	50,3
23	2531	2531	0	100,0	1203	47,5
24	2629	2629	0	100,0	1191	45,3
25	1625	1625	0	100,0	511	31,4
26	1601	1601	0	100,0	485	30,3
27	828	827	1	99,9	353	42,6

Table 3 – Traffic surveys: SP106-Direction toward Putignano (the grey lines refer to the weekend)

January 2023	Detected daily traffic	Car	Heavy vehicle	% Car	V> 50 km/h	% V>50 km/h
20	886	884	2	99,8	784	88,5
21	2568	2558	10	99,6	2228	86,8
22	1525	1515	10	99,3	1239	81,2
23	2818	2818	0	100,0	2645	93,9
24	3003	3003	0	100,0	2830	94,2
25	2447	2443	4	99,8	2192	89,6
26	2458	2458	0	100,0	2192	89,2
27	1049	1048	1	99,9	1003	95,6

Table 4 – Traffic surveys: SP139 (the grey lines refer to the weekend)

January 2023	Detected daily traffic	Car	Heavy vehicle	% Car	V> 50 km/h	% V> 50 km/h
20	375	374	1	99,7	218	58,1
21	905	902	3	99,7	627	69,3
22	992	928	64	93,5	415	41,8
23	1277	1276	1	99,9	900	70,5
24	1252	1252	0	100,0	892	71,2
25	992	989	3	99,7	589	59,4
26	975	973	2	99,8	589	60,4
27	395	395	0	100,0	298	75,4

3.2 DRIVING SIMULATION

The driver behaviour was investigated while participants were asked to perform a dynamic driving task in the driving simulator. The used driving simulator is the "SimuLacet" driving simulator of the PICS-Laboratory of the Université Gustave Eiffel and it had already been used for other doctoral theses (Ghasemi, 2020; Acerra; 2023).

The simulation was carried out in a scenario characterised by an undivided two-way two-lane rural road, each lane 3.5 m wide, without curves or critical slopes. The 30 vehicles coming in the opposite direction were characterised by speeds of 80 km/h and a spatial headway between 100 m and 400 m.

Thirty-seven participants were selected in order to create a meaningful sample for the analysis and each of these was asked to repeat the driving simulation six times.

The six simulations differed from each other for the presence of the ACC and secondary tasks, creating 5 different scenarios. The first 4 simulations followed a fixed order, with the aim of investigating also the route familiarity effect; the last two were alternated in random order and involved the introduction of 3 Secondary tasks during the simulation. The fifth and sixth repetitions were alternated in random order to prevent results being influenced by the order of test presentation. This random variation was avoided during the first four tests, in which drivers should still acquire familiarity with the route.

Secondary tasks are of two types, namely reading a text message on the mobile phone and answering questions posed to the drivers. The questions to the driver (Point 1 and Point 3 of the Figure 16) were of a general nature, namely "What are you doing?", "Where do you come from?", "What would you like to do in the future?". The message sent to the driver mobile phone at instant 2 (Figure 16) was "Driving simulation". It was decided to alternate questions posed to the driver and the message sent to the driver mobile phone in order to avoid inducing familiarity with the type of secondary tasks.

The 5 proposed scenarios were:

- Scenario 0: ACC OFF - No secondary task;
- Scenario 1: ACC ON - No secondary task;
- Scenario 1s: ACC ON – Only a secondary task in the first section;
- Scenario 2: ACC ON – 3 secondary tasks;
- Scenario 3: ACC OFF – 3 secondary tasks.

The following table shows the pattern of repetition of the experiment. The acronyms DX and DY represent the example of the two drivers with alternate repetitions of scenarios 2 and 3.

Table 5 – Experiment outline

Driver	Number of repetition	Scenario	Description
DX	1	0	ACC OFF - No secondary task
	2	1S	ACC ON – Only a secondary task in the first section
	3	1	ACC ON - No secondary task
	4	1S	ACC ON – Only a secondary task in the first section
	5	2	ACC ON – 3 secondary tasks
	6	3	ACC OFF – 3 secondary tasks
DY	1	0	ACC OFF - No secondary task
	2	1S	ACC ON – Only a secondary task in the first section
	3	1	ACC ON - No secondary task
	4	1S	ACC ON – Only a secondary task in the first section
	5	3	ACC OFF – 3 secondary tasks
	6	2	ACC ON – 3 secondary tasks

Participants were instructed to follow the lead vehicle, thus following the lead vehicle acceleration and braking inputs. The behaviour of the lead vehicle is described as follows:

- Accelerating to 50 km/h in 5 s;

- Accelerating to 100 km/h in 15 s;
- Decelerating to 70 km/h in 5 s;
- Turning off lights and maintaining speed of 70 km/h for 5 s;
- Accelerating to 110 km/h in 15 s;
- Decelerating from 110 km/h to 80 km/h in 5 s;
- Turning off lights and accelerating to 90 km/h in 15 s;
- Decelerating from 90 km/h to 60 km/h in 3 s;
- Turning off lights and accelerating to 100 km/h in 15 s;
- Message: ACC ON;
- Decelerating to 70 km/h in 5 s;
- Turning off lights and maintaining speed of 70 km/h for 5 s;
- Accelerating to 110 km/h in 15 s;
- Decelerating from 110 km/h to 80 km/h in 5 s;
- Turning off lights and accelerating to 90 km/h in 15 s;
- Decelerating from 90 km/h to 60 km/h in 3 s;
- Turning off lights and accelerating to 100 km/h in 5 s;
- Message: END OF TEST.

The simulation was divided into two phases: in the first the ACC is always switched off and in the second the ACC is switched on for scenarios 1, 1s and 2. During the use of ACC, the driver should monitor the driving task. Therefore, the driver leaves the braking pedal but should monitor the road and keep the vehicle in a straight position in the same lane.

The simulations also differed for the presence of secondary tasks. Secondary tasks were implemented at the moments of the maximum recorded decelerations, i.e. at points 1, 2 and 3, shown in the diagram below.

In Point 1 there was a deceleration from 90 km/h to 60 km/h in 3s (deceleration rate of -2.78 m/s^2). In Point 2, there was a deceleration from 110 km/h to 80 km/h in 5s (deceleration rate of -2.22 m/s^2). In Point 3 there was a deceleration from 90 km/h to 60 km/h in 3s (deceleration rate of -2.78 m/s^2).

Point 4 represents the moment when the ACC ON message appears.

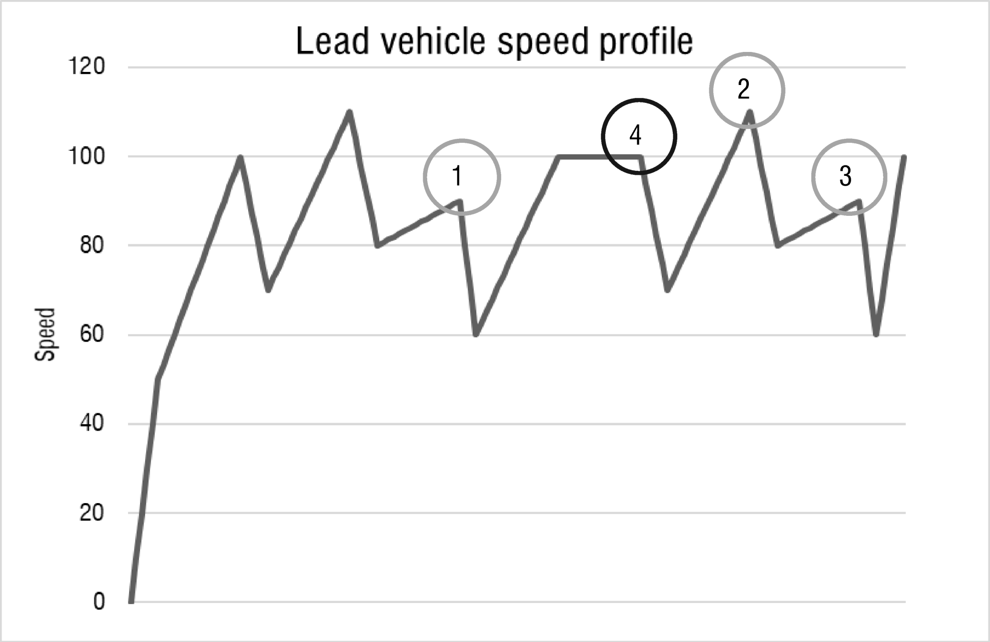


Figure 16 – Lead vehicle speed profile

The aim of the experiment is therefore to analyse the influence of ACC, secondary tasks and route familiarity on the driver behaviour.

3.2.1 Influence of ACC on Driver Behaviour

The Adaptive Cruise Control is one of the main technologies of Advanced Driver Assistance Systems, which tried to reproduce human driving through automatic speed regulation.

This technology allows for establishing a set distance from the lead vehicle, by modulating cruising speed and limiting sudden braking (Lin et al., 2008; Piccinini et al., 2015). The ACC, while maintaining the speed set by the driver, is also able to adapt it to traffic conditions, by accelerating or decelerating automatically. In fact, the system records the environment in front of the vehicle so that, if the driver gets too close to the lead vehicle, the system slightly decelerates to ensure compliance with the safety distance.

The influence of ACC on driver behaviour has been deepened by numerous research and most of them used a driving simulator.

The research programme "Technology Assessment Automatic Vehicle Guidance" (Hoedemaeker, 2000) demonstrated that driving behaviour with ACC leads to various benefits in terms of traffic efficiency. Driving with ACC reduces speed variability and initial individual differences in driving behaviour on motorways, which harmonizes traffic and increase traffic safety.

The distinction in driving style between high and low speed drivers was found to be important in the acceptance of ACC. Both driver groups like driving with an ACC, but for different reasons. High speed drivers like the comfort of the system, whereas low speed drivers like the system usefulness, crucial aspect in marketing strategies. In order to get both driver groups into ACC-cars they should be differently addressed.

One fundamental aspect to test in ACC-driving mode is the chance that ACC allows drivers switching between short and longer headways depending on their personal preferences and the current situation. However, when drivers choose to drive with a headway setting of more than 1.2s, the predicted gain in motorway capacity disappears (Ba et al., 2014). Thus, this situation could be possible prevented by future ACC that should prefer global average traffic flow benefits more than individual preferences. Increasing the driver comfort (more appealing to high-speed drivers) by means of ACC should mean a selectable headway switch ranging from 0.6 to 2.0 s. When the emphasis is on increasing motorway capacity, the ACC should have a fixed headway of 1.2s or less.

A key point of the headway choice is related to safety. In fact, higher speeds and smaller headways are precursors of crashes. The importance of speed as a contributory crash factor is well-known indeed.

Ohno (2001) tried to analyse the driver behaviours after the use of the ACC. This research compared behaviour of drivers in manual mode versus ACC mode and pointed out various advantages in the use of such system, as a longer headway and a smaller lateral deviation for drivers in ACC mode. The evaluation of adaptive cruise control in a driving simulator from a psychological perspective was also detected (Stanton et al., 2005). The ACC mode makes the driver perceive to lose vehicle control, reducing the level of trust in the vehicle, and the level of attention and awareness. Results showed that situation awareness and stress were reduced by the ACC.

Schleicher et al. (2011) conducted a study with a driving simulator, introducing as many secondary tasks as possible while driving. This research established that on both highways and motorways, drivers had about 5 to 10 km/h lower maximum speed in the ACC mode as compared to manual driving. Additionally, the percentage of time spent above the speed limit was substantially reduced by the ACC. It seemed that the conscious selection of speed with the ACC led to better compliance with regulations than in manual driving. Downsides of the ACC were found to be the longer time required to manage speeds at curves (about 5 seconds) and in low-visibility scenarios like under fog conditions.

Vollrath et al. (2011) have conducted a simulator study to evaluate the ACC influence on driving behaviour. They have selected a sample group of twenty-two participants that drove on a highway and on a motorway in two different conditions (with ACC ON and ACC OFF). Using only performance-based measures (maximum speed, driver reaction time), they have found that, in some instances, the ACC delayed driver reactions in critical situations, as a narrow curve or a fog bank.

Ciuffo et al. (2021) conducted a study involving 10 commercially available ACC-equipped vehicles. The test campaign has been executed in two different test-tracks of the ZalaZONE proving ground, in Hungary. Test results have been used to derive information about the properties of the different ACC systems, to study their string stability, to study the effect of ACC systems on traffic flow, and to draw inference about the possible implications on traffic safety. Results highlighted that ACC systems will introduce new safety risks when their penetration in the fleet increases. Therefore, results suggest that functional requirements to guarantee string stability and in general to not disrupt the normal traffic flow should be introduced both for ACC and for any automated system that will be implemented in the future.

On the other hand, a study conducted in China (Tan et al., 2021) showed that with a 100% market penetration rate of the ACC system, fatalities could be reduced by 5.48%, and injuries could be reduced by 4.91%. With a large increase in market penetration rate of ACC in the coming future, the reductions in the number of fatalities and severe injuries are significant and progressively increasing over time.

In different simulator studies, Stanton et al. (1997, 2000, 2005) have used performance-based measures to study the influence of ACC in terms of drivers' distraction. They have found that the use of ACC has decreased the driver's situation awareness and attentional resources. Cho et al. (2006), by using psychological measures (locus of control, trust, workload, stress, etc.), have explained that this decrease was due to the shift of their attention away from driving.

Based on the findings presented in this section, it is noted that ACC systems lead to changes in driver behaviour and awareness. Past studies showed contrasting results about the potential of ACC systems. These ambiguous outcomes will be verified in the present work of thesis. The ACC influence on driving behaviour and attitudes, as well as the influence of the ACC in performing secondary tasks and the deriving outcomes are crucial point of this research. As already stated, this research relied on the driving simulator.

3.2.2 Secondary tasks

Driving distraction has been underlined as a critical safety issue globally, with the World Health Organisation reporting distracted driving as a crucial problem contributing to tens of millions of crashes on roadways each year (World Health Organisation, 2018).

Driver distraction occurs due to the temporary shifting of attention from the task required for safe driving to the secondary task(s) unrelated to driving (World Health Organisation, 2018), and can engage drivers visually, auditorily, physically, and cognitively depending on the secondary task types.

Different in-vehicle or external sources can lead to driver distraction, such as conversing with passengers, eating/drinking and reaching for an object. Engagement with non-driving related tasks (NDRTs) while driving affect driving performance and safety, depending on the task type (Young et al., 2007). Vehicle control is affected by secondary tasks, as demonstrated by Harbluk et al. (2007): during the most difficult cognitive tasks there were more occurrences of hard braking.

Due to the rapid penetration of partially automated vehicles into the market, studying NDRT effects on partially automated driving becomes fundamental. Automation in vehicles is developing rapidly and brings many benefits such as improved traffic flow, increased road safety, and advantages to special populations such as younger and older drivers and mobility impaired drivers (Fisher et al., 2016). Automated vehicles have a potential to substantially reduce safety-critical events, primarily those usually attributed to human errors caused by driver inattention and distraction (Fagnant et al., 2015; Nasr et al., 2021).

Nevertheless, drivers under SAE Level 2 driving conditions are paradoxically relieved from some driving tasks allocated to the automated system. This reduction in the driving task demands, and possibly in cognitive workload imposed on drivers, results in a higher tendency to engage with non-driving related tasks (NDRT), higher frequency of interaction with NDRT, and a higher average duration of glancing away from the forward roadway compared to manual driving (Solís-Marcos et al., 2018).

Therefore, a crucial aspect that requires exploration is how drivers of partially automated vehicles distribute their attention between the forward roadway and performing NDRT (Naujoks et al., 2016) and how the fragmentation of attention affects their hazard perception performance. Naujoks et al. (2016) conducted a field study and found that under SAE level 2 driving conditions, drivers adjusted their level of engagement with NDRT to the traffic situation; as their vehicle speed increased, drivers focused their attention more on the forward roadway and less on the NDRT. This decrement in NDRT engagement due to traffic conditions can be considered situation-adaptive behaviour since it may reduce the perceived safety or increase the perceived workload during partially automated driving.

According to De Winter et al. (2014), drivers using adaptive cruise control (ACC) performed about 12% more in-vehicle visual tasks than in manual driving.

However, it is necessary to examine separately the visual distraction caused by secondary tasks, such as the reading of a text message on the telephone. Secondary tasks which require visual attention are especially known to interfere with driving. Studies on attention while driving with visual secondary task often focus on glances directed away from the driving scene to the secondary task.

In the literature, it is reported that during visual secondary tasks, the gaze repeatedly switches between the driving task and the secondary task (Sodhi et al. 2002). The number of glances directed at the secondary task depends on the type of secondary task: more complex and visually more demanding tasks require more views (Victor et al. 2005).

In an overview of different studies, Metz (2009) reported that the mean number of off-road glances for different types of visual secondary tasks ranges between 2.2 for reading displays in the vehicle and 13.8 for handling complex infotainment devices. The relating mean durations of single glances varies between 1.32 for reading in-vehicle displays and 1.31 for the infotainment devices.

In general, mean durations of single glances are less dependent of task demands than the number of off-road glances and normally endure for less than 2 s (Chan et al., 2010). Horrey et al. (2007) reported that mean glance duration is independent of task complexity; instead, more complex tasks are related to a higher proportion of very long off-road glances.

Besides the already mentioned influence of task complexity on gaze behavior, an influence of the driving situation is also described in the literature. For instance, Wierwille (1993) reported longer glances back to the road in more demanding driving situations (1.2s vs. 3.0s). At the same time, the probability that attention is directed to the in-vehicle display is reduced. In different studies by Tsimhoni et al., glances directed to the driving scene endured 60% longer in curved compared to straight road sections (Tsimhoni et al., 2001; Tsimhoni et al., 2004).

Noble et al. (2021) analysed a subset of driving data for 19 drivers to assess whether driver eye glance behavior and secondary task engagement were different when driver assistance systems were active compared to when they were available but inactive. The results of this study demonstrate that drivers spent more time looking away from the road while driving automation systems were active and that drivers were more likely to be observed browsing on their cell phones while using driving automation systems. Current driving automation features require human monitoring of automation, yet the drivers of these automation-equipped vehicles are inclined to engage in secondary tasks and take longer and more frequent glances away from the roadway.

3.2.3 Route familiarity

The issue of driver distraction can be closely linked to the drivers' route familiarity. High route familiarity can cause driving distraction and overconfident driving behaviours like speeding to reduce the travel time (Intini et al., 2018).

The term familiarity refers to the attitude that an individual adopts after repeated exposure to a relationship, a place, or a situation. These repeated actions induce learning and thus behavioural adaptation (Montoya et al., 2017). Hence, by applying these preliminary concepts, a route familiar driver is a driver who is travelling on a route well-known from long or close association, and the travelling on that specific route composed of different road elements has been the stimulus repeatedly experienced.

Route familiarity has been investigated using two main methods which are both consistent with the concept of repeated exposure (Intini et al., 2019): distance-based and frequency-based. In the first case, drivers are familiar with a route whenever their residence is in the same country or environment (Donaldson et al., 2006). In the second, the driver becomes familiar with a route by driving several times on it (Colonna et al., 2016), as in the case of the present study. In these studies, familiarity is achieved when drivers get to know the environmental features of the road, i.e., alignment, cross-section, road signs, and it also depends on driver interaction with other users along the same route.

Both familiarity and unfamiliarity with roads may have adverse effects on driving tasks. Over time, the task of driving that car becomes easier. At first glance, unfamiliar drivers may seem safer than familiar ones since their attentional capacity is strongly focused on collecting information related to the road environment and they should be less likely to be distracted and less prone to speeding and risk-taking behaviours (Intini et al., 2018).

The idea that route familiarity might promote a delay in hazard response is indirectly supported by evidence in the driving literature. There are two opposite theoretical predictions concerning the effect that route familiarity has on hazard avoidance. Familiarity might lead to the route being processed automatically and thus freeing up resources that could be used to process other stimuli in the environment, like potential hazards. From this, it follows that reaction time to avoid a hazardous stimulus should be faster in familiar than in unfamiliar route conditions. On the other hand, given the previous evidence linking automaticity and route familiarity to a reduced likelihood of successfully monitoring the environment (Charlton et al., 2011; Martens et al., 2007), one might predict the opposite pattern of results. For example, it could be that as the driver becomes familiar, the incidence of inattentional blindness might increase, and thus the driver would be less able to deal with the hazardous stimulus. In this case, it follows that reaction time to the hazardous stimulus should be slower in familiar than in unfamiliar routes.

Compared to novice drivers, drivers with extensive experience are less likely to check their mirrors and to follow a lead vehicle at an adequate distance (Duncan et al., 1991). These findings could be an indication that experienced drivers are less likely to successfully monitor the environment for hazards, thereby limiting the ability to respond promptly when needed. In addition, it has been shown that as one becomes familiar with a route, there is a decrease in the amount of time spent looking at peripheral items, and drivers are less likely to notice changes in the environment (Charlton et al., 2011). In fact, Martens and Fox (2007) demonstrated that route familiarity can promote a state of inattentional blindness, where drivers are less likely to notice a critical stimulus in the environment even when the driver fixates on that stimulus.

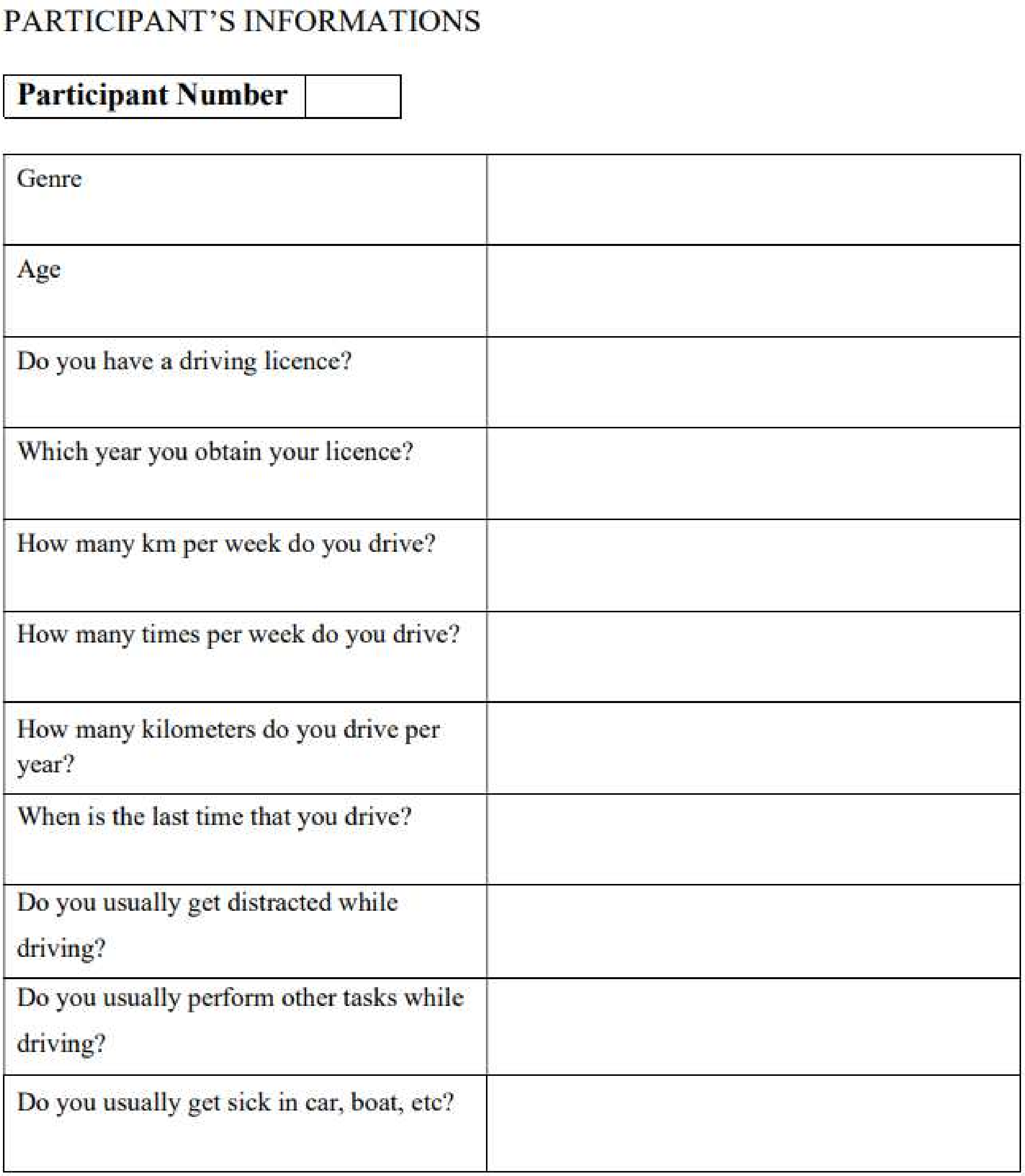
Martens and Fox (2007) explained that as familiarity with the route is increased, drivers may have been more likely to let their minds wander, thereby making it less likely for them to successfully process incoming sensory information – inattentional blindness – because the system is otherwise preoccupied. This possibility is supported by anecdotal evidence provided by Charlton and Starkey (2011) who noted that many participants found themselves starting to ‘daydream’ as they excessively practiced a route.

Based on these findings, it is reasonable to expect that when driving along a familiar route, drivers might take longer to notice an emergency event, and hence would be expected to take longer to respond than if they were driving along an unfamiliar route.

3.3 QUESTIONNAIRE

Drivers were asked to complete three different questionnaires: the first one was given to the participants before the driving simulation in order to find general information/attitudes; the other two questionnaires were given at the end of the simulation in order to investigate the driving experience.

The first test was composed of eleven questions, aimed at identifying the subject and the driver's self-assessment of his/her driving attitudes. In addition, there were two questions aimed to assess driver attitudes to perform other tasks while driving.



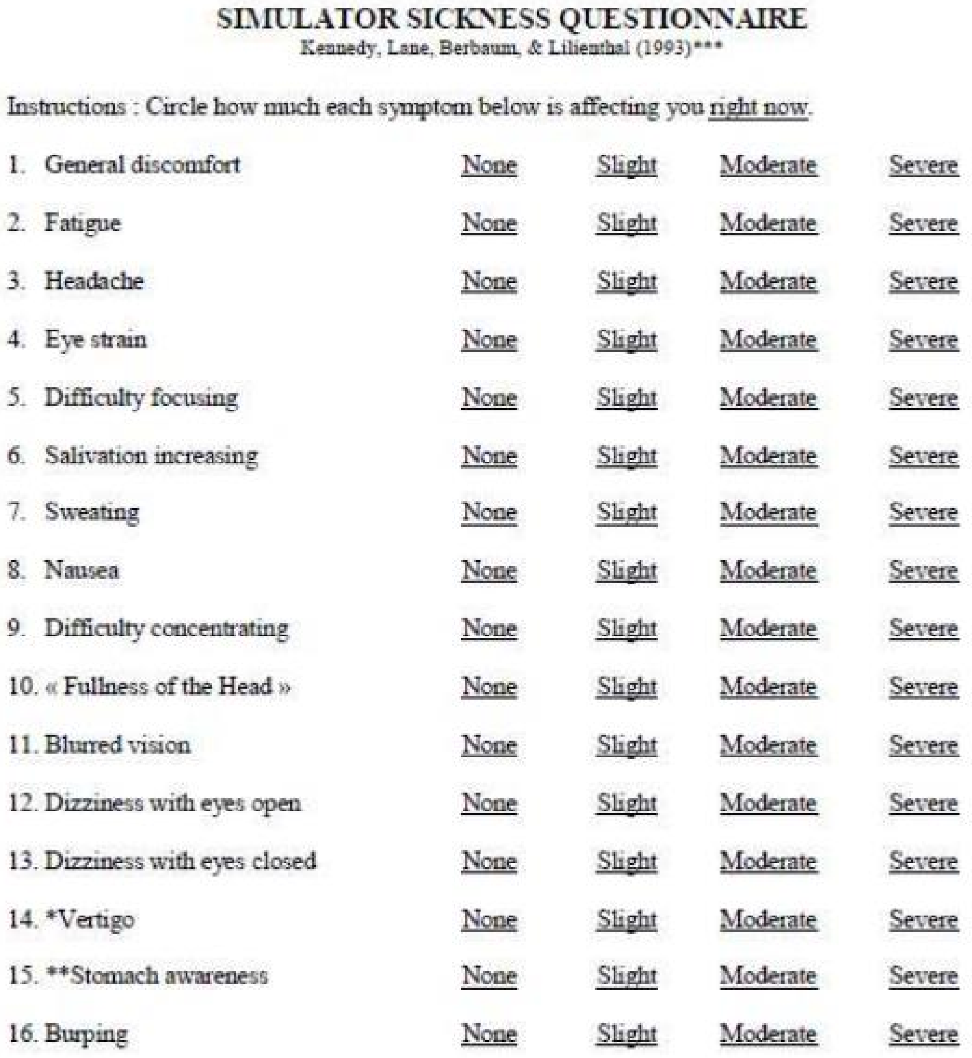
PARTICIPANT'S INFORMATIONS

Participant Number	

Genre	
Age	
Do you have a driving licence?	
Which year you obtain your licence?	
How many km per week do you drive?	
How many times per week do you drive?	
How many kilometers do you drive per year?	
When is the last time that you drive?	
Do you usually get distracted while driving?	
Do you usually perform other tasks while driving?	
Do you usually get sick in car, boat, etc?	

Figure 17 – First questionnaire

The second test was a simulator sickness questionnaire (Kennedy et al., 1993), aimed at investigating the symptoms affected the driver. The driver was asked to express how intense each of the sixteen eventually experienced symptoms was.



SIMULATOR SICKNESS QUESTIONNAIRE

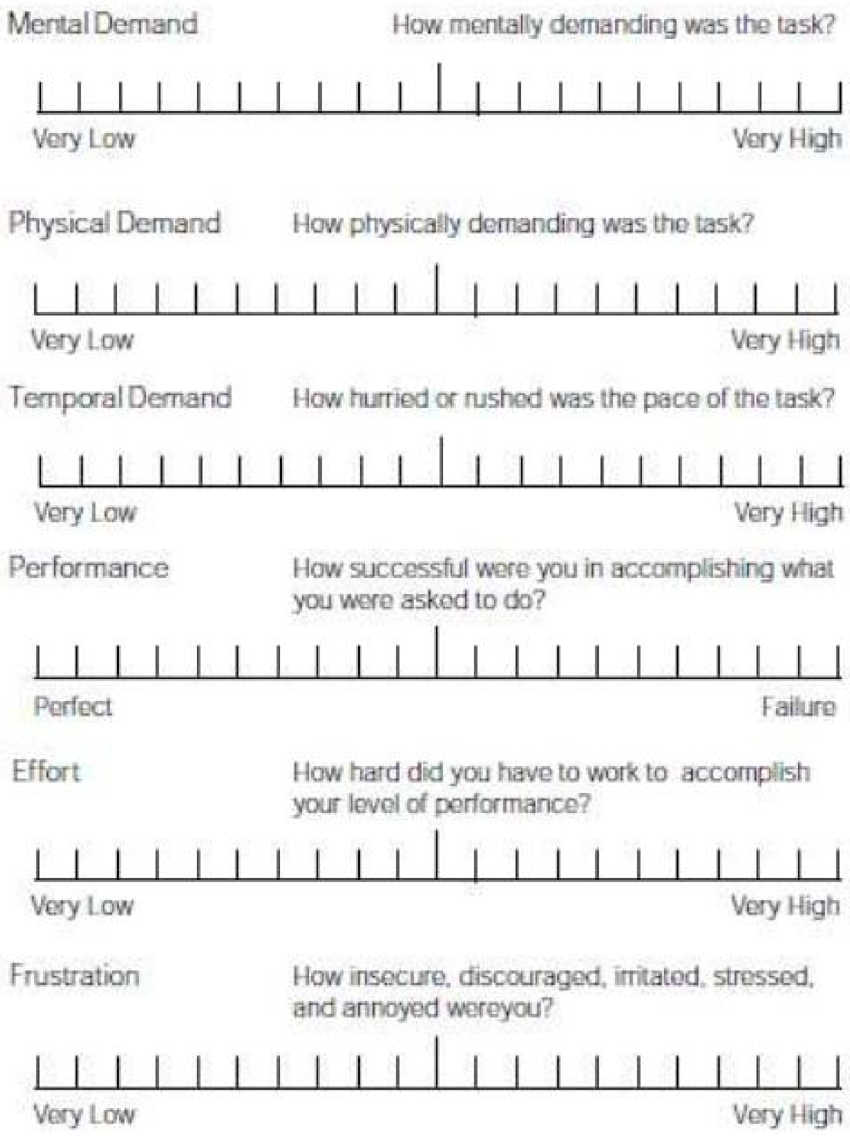
Kennedy, Lane, Berbaum, & Lilienthal (1993)***

Instructions : Circle how much each symptom below is affecting you right now.

1. General discomfort	None	Slight	Moderate	Severe
2. Fatigue	None	Slight	Moderate	Severe
3. Headache	None	Slight	Moderate	Severe
4. Eye strain	None	Slight	Moderate	Severe
5. Difficulty focusing	None	Slight	Moderate	Severe
6. Salivation increasing	None	Slight	Moderate	Severe
7. Sweating	None	Slight	Moderate	Severe
8. Nausea	None	Slight	Moderate	Severe
9. Difficulty concentrating	None	Slight	Moderate	Severe
10. « Fullness of the Head »	None	Slight	Moderate	Severe
11. Blurred vision	None	Slight	Moderate	Severe
12. Dizziness with eyes open	None	Slight	Moderate	Severe
13. Dizziness with eyes closed	None	Slight	Moderate	Severe
14. *Vertigo	None	Slight	Moderate	Severe
15. **Stomach awareness	None	Slight	Moderate	Severe
16. Burping	None	Slight	Moderate	Severe

Figure 18 – Second questionnaire

The third test was the NASA-TLX questionnaire, that consists of 6 questions investigating the driving experience with the ACC system.



Mental Demand How mentally demanding was the task?

Very Low Very High

Physical Demand How physically demanding was the task?

Very Low Very High

Temporal Demand How hurried or rushed was the pace of the task?

Very Low Very High

Performance How successful were you in accomplishing what you were asked to do?

Perfect Failure

Effort How hard did you have to work to accomplish your level of performance?

Very Low Very High

Frustration How insecure, discouraged, irritated, stressed, and annoyed wereyou?

Very Low Very High

Figure 19 – Third questionnaire

3.3.1 Questionnaires results

The experiment involved 37 participants, of whom 19 were men and 18 women. All drivers had a driving licence; the 19% of them had the driving licence for 5 years and the 16% for 8 years and 4 years.

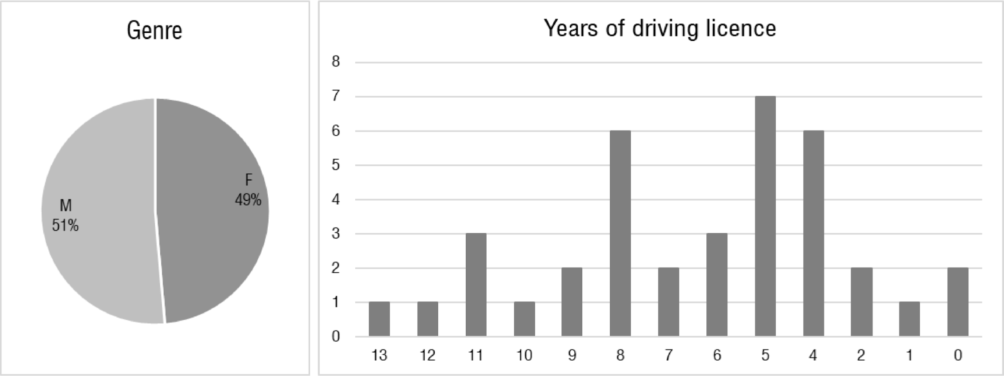


Figure 20 – Characterisation of the sample

The participants in 59.5% of cases drive between 1 and 500 km per week and in the 75.7% of cases between 1 and 5 times per week.

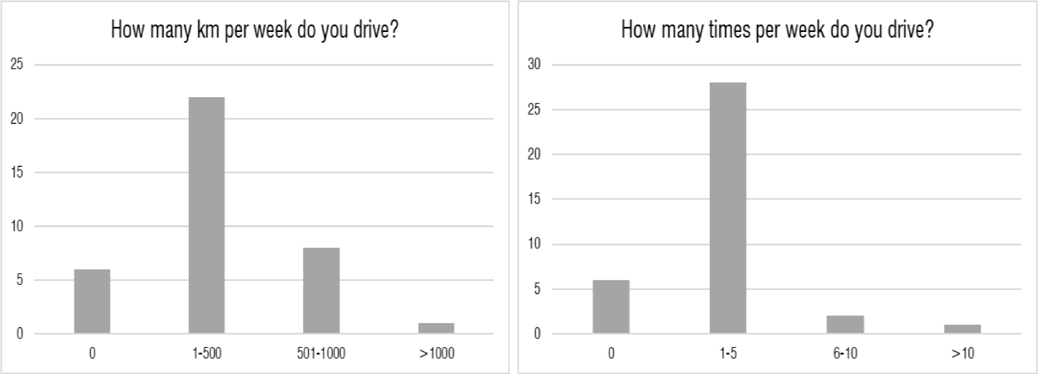


Figure 21 – Driving attitude

The first questionnaire also investigated the attitude of drivers to perform secondary tasks while driving. The analysis showed that 72% of them do not get distracted while driving and that only 27% of them usually perform other tasks while driving.

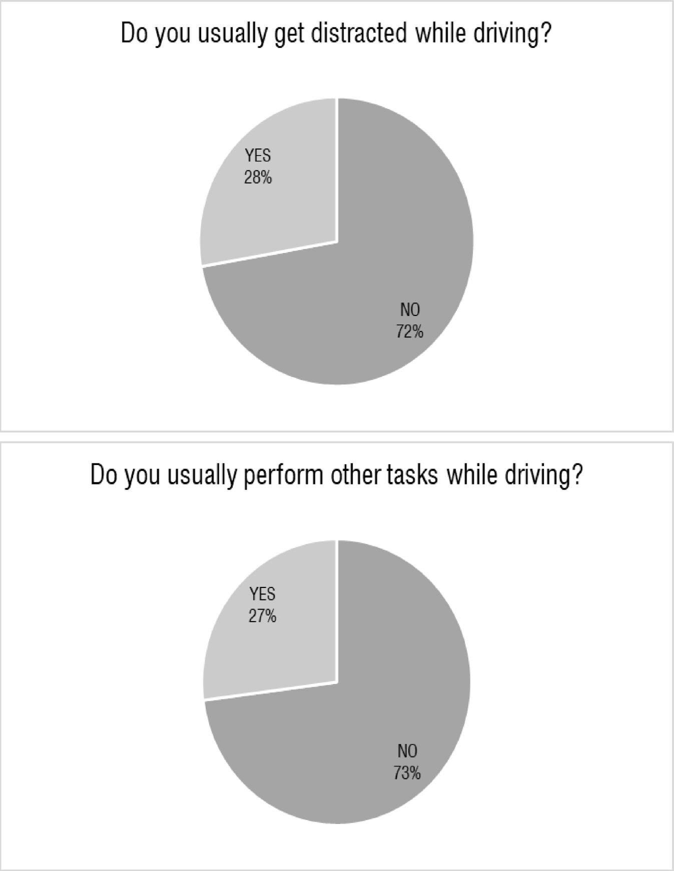


Figure 22 – Questions about secondary tasks during the driving

The second questionnaire was aimed at investigating the symptoms affecting the driver after the simulation. The drivers' answers showed no particular symptoms, with the exception of overload, difficulty of concentrating and focusing, eye strain, fatigue and general distraction with slight intensity.

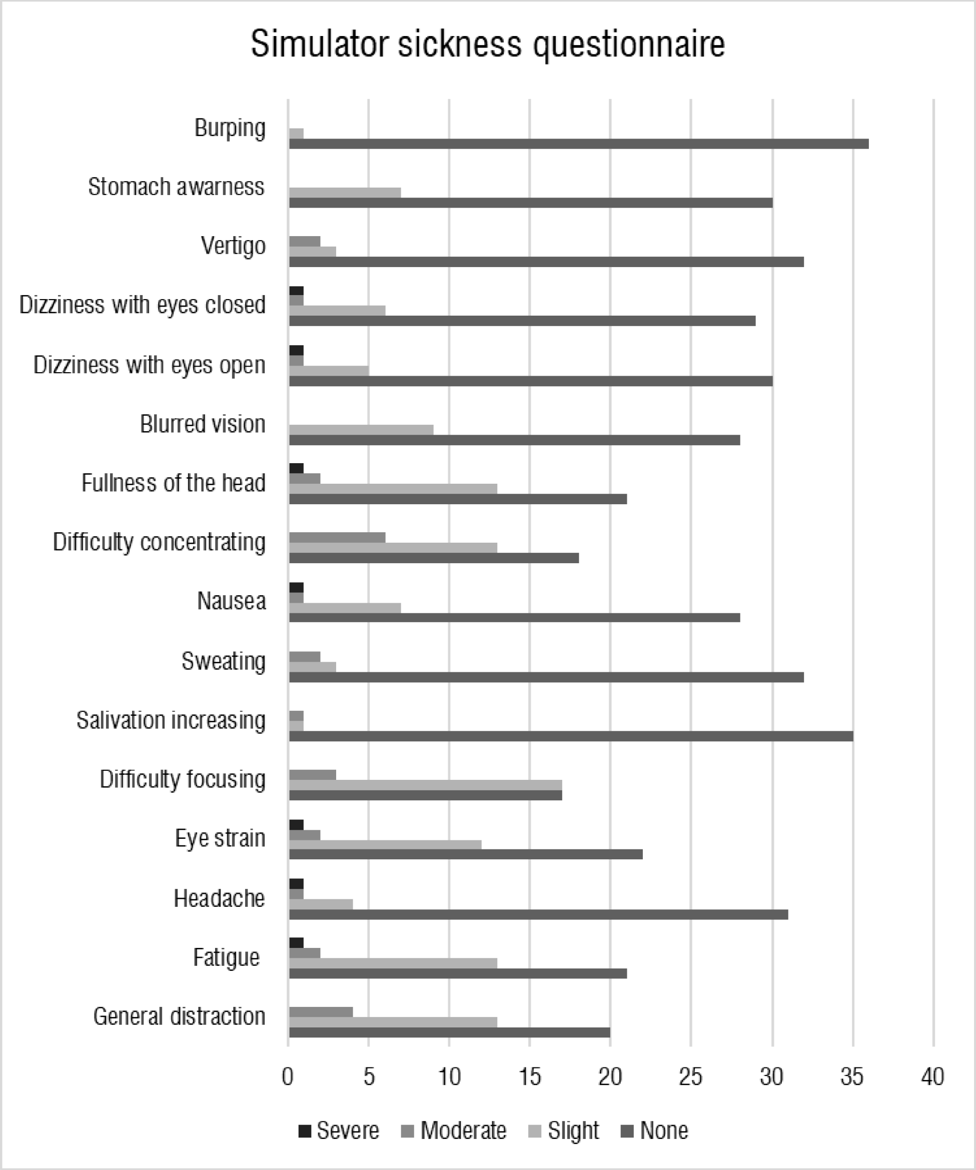


Figure 23 – Simulator sickness questionnaire

Then, data were aggregated in an overall binary indicator, called 'Global sickness'. In particular, a value of 1 was given to this indicator if at least one of the above reported symptoms (with the exception of the indicator ‘General distraction’) was declared by the drivers. Aggregated data showed that 32% of drivers experienced at least one of the symptoms (‘Global sickness’ indicator equal to 1).

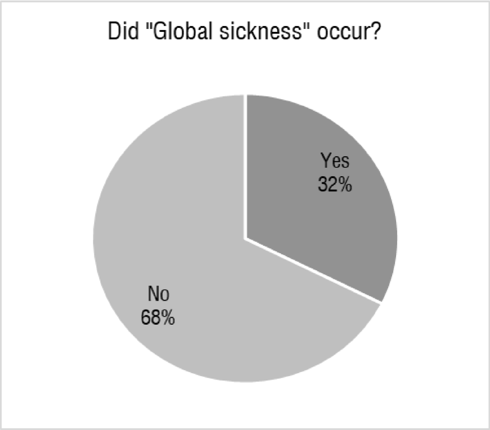


Figure 24 – Global sickness indicator

Bimberg et al. (2020) used another indicator, called “Total sickness”. The Pensacola Motion Sickness Questionnaire asked participants to provide subjective severity ratings of 16 symptoms on a scale from 0 (no perception) to 3 (severe perception) after the exposure. The ratings for the individual symptoms are grouped into three non-mutually exclusive categories representing symptoms for nausea (N), oculomotor disturbance (O), and disorientation (D). The score of each category is defined as the sum of its symptom scores multiplied by a constant scaling factor. Moreover, a total simulator sickness score (TS) combining the three sub-scales can be computed in a similar way. In general, higher scores on each scale indicate stronger perceptions of the underlying sickness symptoms and are therefore undesired.

However, the Pensacola Motion Sickness Questionnaire has different indicators and provides only three severity ratings, while the simulator sickness questionnaire used in this study includes four severity rating. For this reason, it was decided to use the previously calculated "Global sickness" indicator in the subsequent statistical analyses.

Another question was focused on the general perception of having been distracted during the test. 11% of drivers reported to having experienced “General distraction” while driving.

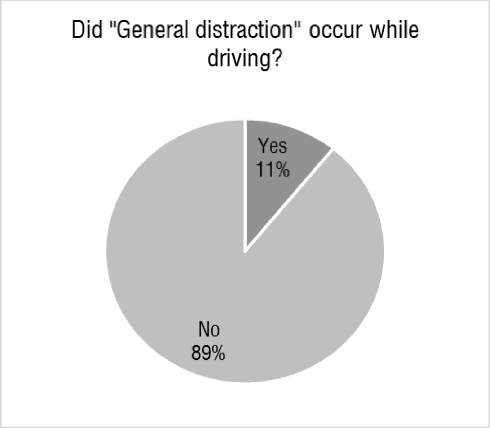


Figure 25 – General distraction indicator

The mean results from the first and second questionnaires submitted to the participants are summarized in Table 6.

Table 6 – Mean results from the questionnaires

Question	**Mean**	**St. dev.**	**Min**	**Max**	**Percentage**
First questionnaire (before the test)					
Sex	-	-	-	-	Male: 51 %, Female: 49%
Age	26,38	4,08	21	34	-
Weekly kilometres driven	399,31	433,72	0	2000	-

Weekly driving frequency	3,03	2,56	0	12	-
Years of driving licence	6,22	3,24	0	13	-
Usual distraction while driving	-	-	-	-	Yes: 28%, No:72%
Usual involvement in secondary task while driving	-	-	-	-	Yes: 27%, No:73%
Second questionnaire (after the test)					
Global sickness indicator	-	-	-	-	Yes: 32%, No: 68%
General distraction	-	-	-	-	Yes: 11%, No: 89%

The NASA-TLX questionnaire showed that participants found the mental demand significant, while the physical demand and their sense of frustration and effort was considered very low.

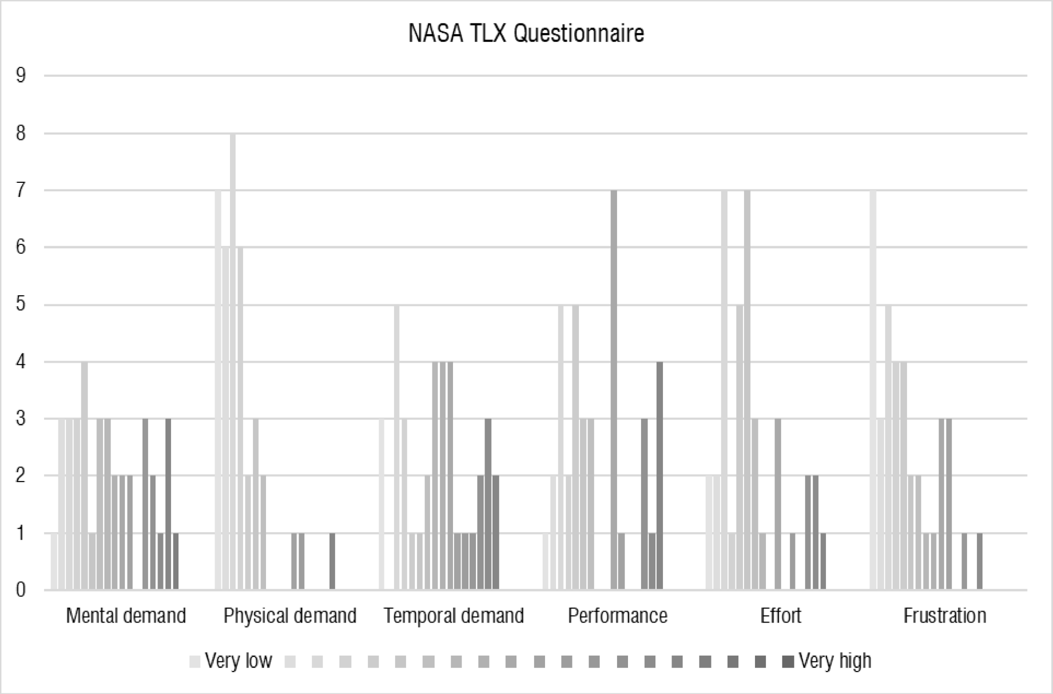


Figure 26 – NASA TLX questionnaire

CHAPTER 4
RESULTS

In the next paragraphs, the results obtained from this study are shown. The first part was related to the data processing of the driving simulator outputs. Then the descriptive statistics of data from overall tests and the descriptive statistics related to secondary tasks were presented.

After that, the statistical analyses were run, with the aim of finding a relationship between the dependent variables (speed, acceleration, deceleration, lateral position, distance from the lead vehicle) and the independent variables (ACC system, phase repetition, secondary tasks, the attitude to perform secondary tasks during the driving, sex of participants).

4.1 DATA PROCESSING

The data analysis started by dividing the 222 simulations, i.e., 6 repetition for 37 experiments, in two phases. The subdivision of the simulation was motivated by the need to identify phases that replicate themselves identically, in which the influence of ACC, secondary tasks, and phase replication could be analysed.

In order to divide the simulation in two phases, the speed profile of the lead vehicle was analysed, as it maintains the same acceleration and deceleration phases regardless of the driver behaviour. The resulting division is illustrated in Figure 27:

- Phase I - from the beginning of the simulation to the fourth deceleration of the lead vehicle (in scenarios 1, 1s and 2 in this moment the ACC ON message appears).
- Phase II - from the fourth deceleration of the lead vehicle to the end of the simulation.

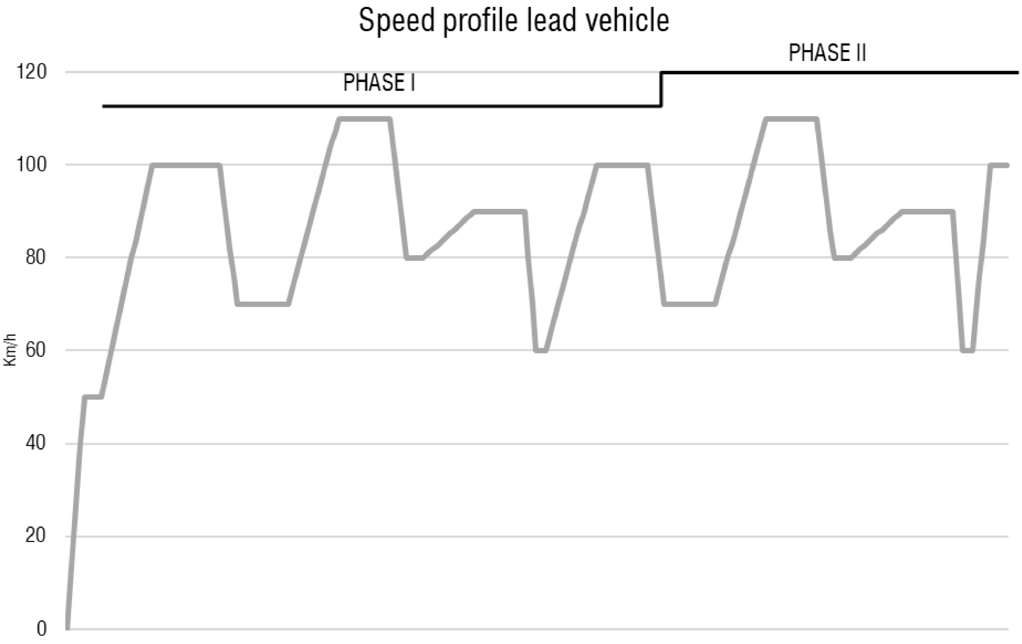


Figure 27 – Subdivision of the simulation into phases

The following characterisation of the scenarios was derived from the division into phases, thanks to which it was possible to analyse and compare phases.

Table 7 – Subdivision of scenarios into phases

Scenario	PHASE I	PHASE II
0	ACC OFF – NO SECONDARY TASKS	ACC OFF – NO SECONDARY TASKS
1	ACC OFF – NO SECONDARY TASKS	ACC ON – NO SECONDARY TASKS

1S	ACC OFF – 1 SECONDARY TASK	ACC ON – NO SECONDARY TASKS
2	ACC OFF – 1 SECONDARY TASK	ACC ON – 2 SECONDARY TASKS
3	ACC OFF – 1 SECONDARY TASK	ACC OFF – 2 SECONDARY TASKS

The driving simulator provides information about the behaviour of the lead vehicle and the test vehicle driven by participants as outputs. The variables analysed in this study were defined as follows:

- Speed (m/s): driver's speed recorded by the driving simulator.
- Acceleration (m/s^2): driver's acceleration obtained from consecutive speed values. The data for positive (Acceleration) and negative (Deceleration) acceleration values were analysed individually.
- Lateral position (mm): represents the lateral position along the lane where the axis position is conventionally located at 7000 mm. A lateral position value smaller than 7000 mm indicates a position to the left of the axis of the lead vehicle, a lateral position value greater than 7000 mm indicates a position to the right of the axis of the lead vehicle.
- Distance from the lead vehicle (m): difference in y-coordinate of the centres of gravity of driver and lead vehicle positions.

Data were aggregated and processed for intervals of 0.5 seconds. For the purposes of a macroscopic analysis aimed at analysing the driver behaviour, considering too small-time intervals would not have been meaningful. Considering the recorded speeds of the scenarios in the driving simulator, a value of 0.5 seconds was therefore chosen, which corresponds to the lowest Time To Collision (TTC) value tested for autonomous vehicles (Weijermars et al., 2021; Virdi et al., 2019).

In the 222 simulations, i.e., 6 simulations for 37 experiments, 3 overtaking maneuvers, 8 crashes and 2 technical problems (the driving simulator did not record the outputs of part of the first phase and the entire second phase of the simulation) occurred. Results showed that, after a crash or overtaking maneuvers, the boundary conditions changed considerably, affecting the quality and homogeneity of the test.

Due to the division of simulations into phases, it was possible to discard from the analysis the individual phase where overtaking maneuvers, crashes or technical problems occurred and not the entire simulation, in order to allow the replicability of the tests and to compare only results having the same boundary conditions.

The 3 overtaking maneuvers occurred in the following phases:

- Driver 1: Simulation 1- Phase I;
- Driver 2: Simulation 2 – Phases I and II;
- Driver 30: Simulation 1- Phase II.

The 8 crashes occurred in the following phases:

- Driver 3: Simulation 6 - Phase I;
- Driver 13: Simulation 6 - Phase I;
- Driver 33: Simulation 2 - Phase I;
- Driver 33: Simulation 4 - Phase I;
- Driver 33: Simulation 6 - Phase II;
- Driver 34: Simulation 1- Phase I;
- Driver 34: Simulation 2 - Phase I;

- Driver 34: Simulation 5 - Phase I.

The 2 technical problems occurred in the following simulation:

- Driver 21: Simulation 1;
- Driver 21: Simulation 2.

Experiments with 3 events to be omitted, i.e. D33 and D34, and with the whole simulation to be neglected due to technical problems, i.e. D21, were discarded.

With regard to data of the individual phases excluded from the analysis due to crashes (D3_S6_PI; D13_S6_PI; D33_S2_PI; D33_S4_PI; D33_S6_PII; D34_S1_PI; D34_S2_PI; D34_S5_PI) and overtaking maneuvers (D1_S1_PI; D2_S2_PI; D2_S2_PII; D30_S1_PII), they were replaced with the mean values of the corresponding scenario variables.

4.2 DATA PROCESSING RELATED TO SECONDARY TASKS

The same dependent variables were analysed considering the effects of secondary tasks on the driver behaviour.

The secondary tasks were of two types: secondary tasks 1 and 3 consisted of a question asked to the driver, while secondary task 2 involved reading a message sent to the driver's mobile phone.

The 4 variables (speed, acceleration, lateral position, distance from the lead vehicle) were firstly averaged over the 3 seconds preceding the moment of presentation of the 3 secondary tasks.

According to Italian road regulations (D.M. 5/11/2001), a delay τ was calculated to consider the time required for the driver to react to the secondary task. Equation 5 requires Speed (V) to be expressed in km/h.

$$\tau = 2{,}8 - 0{,}01 * V \qquad \text{(Eq. 5)}$$

The delay τ was calculated for each scenario and phase. In all cases, it can be ap-approximated to 2 seconds.

Table 8 – Calculated τ Reaction time

Scenario	Speed (m/s) PHASE I	Speed (m/s) PHASE II	Speed (km/h) PHASE I	Speed (km/h) PHASE II	τ PHASE I	τ PHASE II
0	23,43	23,9	84,3304	86,1111	1,9567	1,9389
1S	23,80	22,8	85,6655	82,1658	1,9433	1,9783
1	23,04	23,45	82,9591	84,4332	1,9704	1,9557
1S	22,95	23,4	82,6086	84,2040	1,9739	1,9580
3	23,41	22,8	84,2588	81,9237	1,9574	1,9808
2	23,17	24,0	83,4256	86,2424	1,9657	1,9376

The time used for the reaction time, equal to 2 seconds, was then excluded by the calculation of acceleration/deceleration. These two variables were calculated in the 3 seconds following the discharged reaction time.

In this case, during the investigated 3 seconds (“after” period) it was not necessary to separate positive accelerations from negative accelerations (decelerations). In fact, in most cases, accelerations were performed during the 3 seconds preceding the secondary task, while decelerations were detected during the 3 seconds following the secondary task.

4.3 DESCRIPTIVE STATISTICS

4.3.1 Descriptive statistics of data from overall tests

The mean values and standard deviations, obtained from each scenario and repetition for the two phases, were calculated for the dependent variables (speed, lateral position, distance from the lead vehicle, acceleration and deceleration).

Table 9 – Mean value and standard deviation of the variables for each scenario and repetition

Number of repetition	Scenario	PHASE I									
		Speed (m/s)		Lateral Position (mm)		Distance lead vehicle (m)		Acceleration (m/s^2)		Deceleration (m/s^2)	
		Average	St. Dev.	Average	St. Dev.	Average	St. Dev.	Average	St. Dev.	Average	St. Dev.
1	0	23,43	8,33	7026,04	305,31	103,43	55,69	0,57	0,28	-1,51	1,51
2	1S	23,80	8,04	7048,59	287,98	99,44	54,00	0,54	0,28	-1,29	1,45
3	1	23,04	8,28	7020,59	263,90	77,21	35,16	0,57	0,30	-1,43	1,56
4	1S	22,95	8,01	7074,17	261,33	80,50	36,45	0,61	0,31	-1,48	1,54
5	2	23,41	7,89	7074,90	283,87	80,40	35,44	0,57	0,30	-1,54	1,55
6	3	23,17	8,09	7099,54	279,42	84,47	40,11	0,58	0,32	-1,41	1,52

Number of repetition	Scenario	PHASE II									
		Speed (m/s)		Lateral Position (mm)		Distance lead vehicle (m)		Acceleration (m/s^2)		Deceleration (m/s^2)	
		Average	St. Dev.	Average	St. Dev.	Average	St. Dev.	Average	St. Dev.	Average	St. Dev.
1	0	23,92	3,85	6947,73	293,72	62,35	17,63	0,52	0,23	-1,79	1,59
2	1S	22,82	3,50	6997,67	390,52	105,54	36,14	0,63	0,12	-1,80	0,78

3	1	23,45	3,12	7005,11	277,93	75,64	21,59	0,59	0,11	-1,82	0,79
4	1S	23,39	3,25	7008,52	283,56	80,29	28,04	0,60	0,12	-1,84	0,82
5	2	22,76	3,41	7008,05	341,05	93,53	33,96	0,62	0,13	-1,86	0,91
6	3	23,96	4,06	6972,24	267,78	60,58	20,09	0,55	0,22	-1,87	1,50

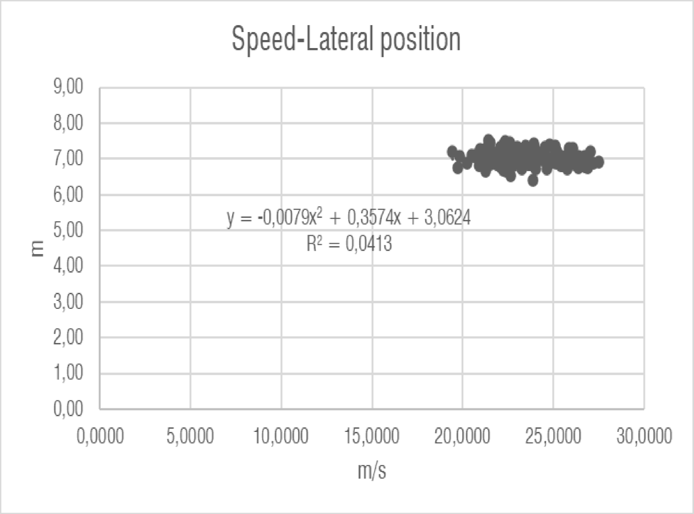
Possible relations between the dependent variable speed and the other dependent variables, i.e., acceleration, deceleration, distance from the lead vehicle and lateral position were qualitatively investigated, in order to check whether the dependent variables were correlated with each other.

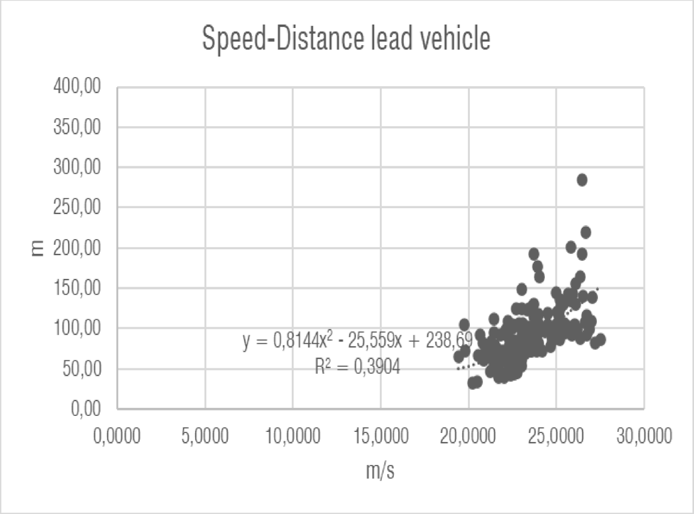
The variables x and y were linked by second-square polynomial regression through the Equation 6, in which the coefficients vary according to the specific case. This functional form was preferred above the other possible regression equations due to its superior goodnees-of-fit measured through the R^2 value.

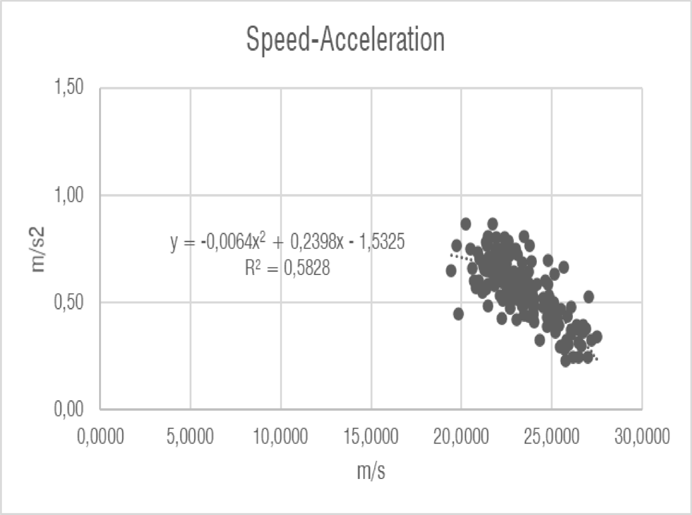
$$y = ax^2 + bx + c \qquad \text{(Eq. 6)}$$

For the first phase of the simulation, the graphs below show an evident correlation between speed and acceleration/deceleration, and data points are satisfactorily fit by the regression curve, as shown by the value of R^2 respectively equal to 0.583 for the acceleration and to 0.367 for the deceleration.

The graphs also show a moderate correlation between speed and distance from the lead vehicle, while speed and lateral position did not appear to be related.


Speed-Lateral position
9,00
8,00
7,00
6,00
5,00
4,00
3,00
2,00
1,00
0,00
m
0,0000
5,0000
10,0000
15,0000
20,0000
25,0000
30,0000
m/s
y = -0,0079x² + 0,3574x + 3,0624
R² = 0,0413


Speed-Distance lead vehicle
400,00
350,00
300,00
250,00
200,00
150,00
100,00
50,00
0,00
m
0,0000
5,0000
10,0000
15,0000
20,0000
25,0000
30,0000
m/s
y = 0,8144x² - 25,559x + 238,69
R² = 0,3904



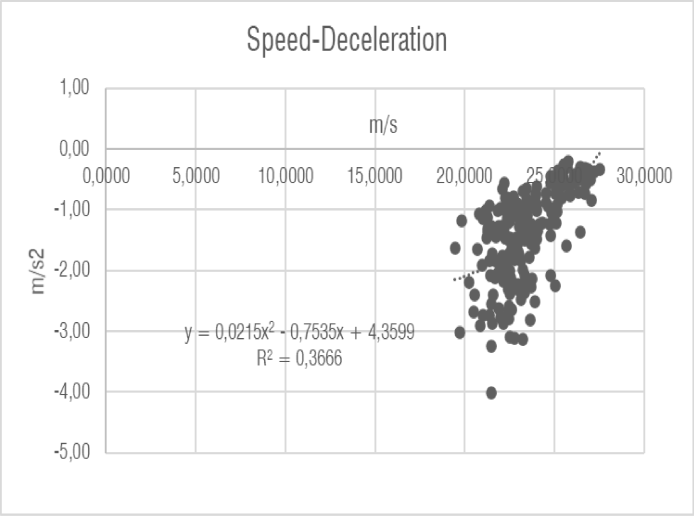
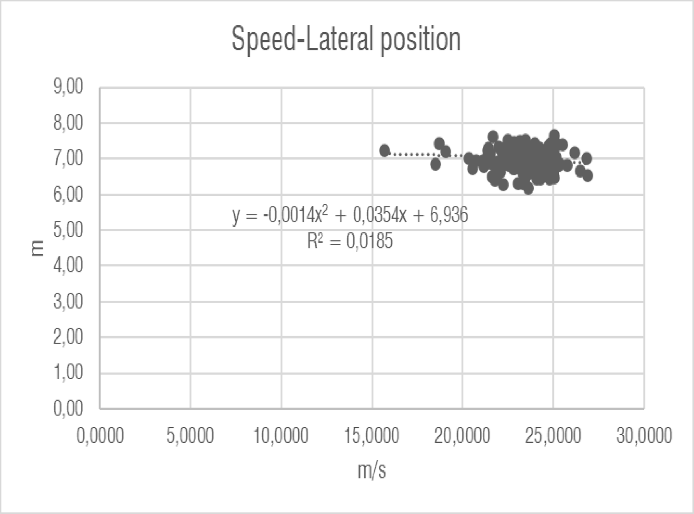
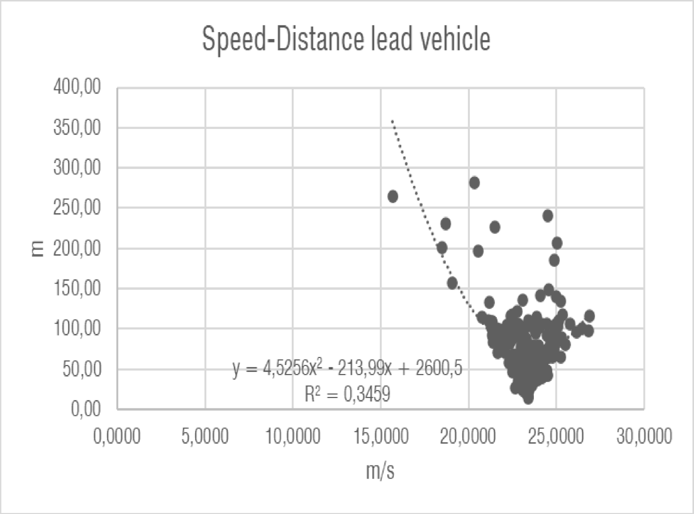
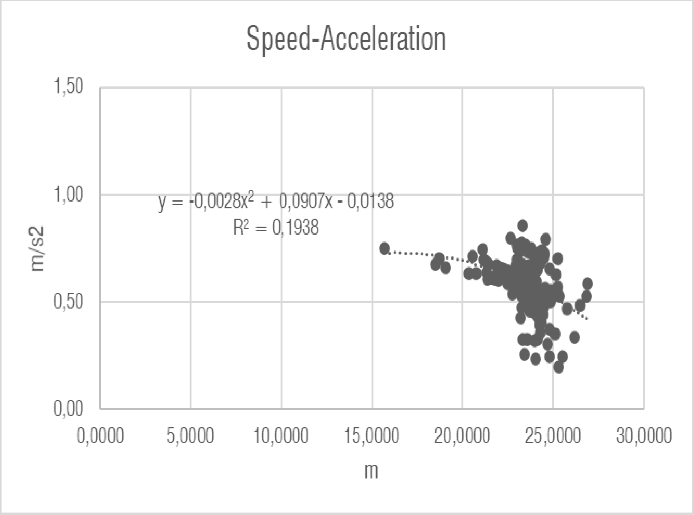


Figure 28 – Correlation of speed with the other variables for Phase I

For the second phase of the simulation, the graphs below show a moderate correlation between speed and distance from the lead vehicle, with a R^2 value equal to 0.3459. The other variables did not appear to be evidently correlated with speed.


Speed-Lateral position
9,00
8,00
7,00
6,00
5,00
4,00
3,00
2,00
1,00
0,00
m
y = -0,0014x^2 + 0,0354x + 6,936
R^2 = 0,0185
0,0000
5,0000
10,0000
15,0000
20,0000
25,0000
30,0000
m/s


Speed-Distance lead vehicle
400,00
350,00
300,00
250,00
200,00
150,00
100,00
50,00
0,00
m
y = 4,5256x^2 - 213,99x + 2600,5
R^2 = 0,3459
0,0000
5,0000
10,0000
15,0000
20,0000
25,0000
30,0000
m/s



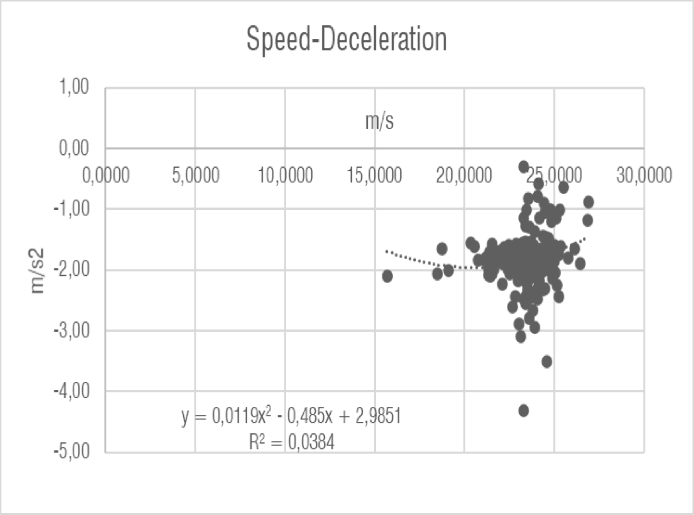


Figure 29 – Correlation of speed with the other variables for Phase II

Comparing the graphs concerning the correlations of the dependent variables for Phase I and Phase II, it could be seen that the correlation Speed-Distance from the lead vehicle was present in both Phase I and Phase II, as well as the fact that Speed and Lateral position were never related. The significant change from Phase I to Phase

II is the correlation between speed and acceleration/deceleration, which varies from strong to slight/absent.

Table 10 – Correlation between dependent variables: Overall data

	PHASE I	**PHASE II**
Speed – Lateral position	Not correlated	Not correlated
Speed - Acceleration	Correlated	Slightly correlated
Speed – Deceleration	Correlated	Not correlated
Speed – Distance from lead vehicle	Correlated	Correlated

In the experiment, independent variables were identified. The independent variables considered in the present study were:

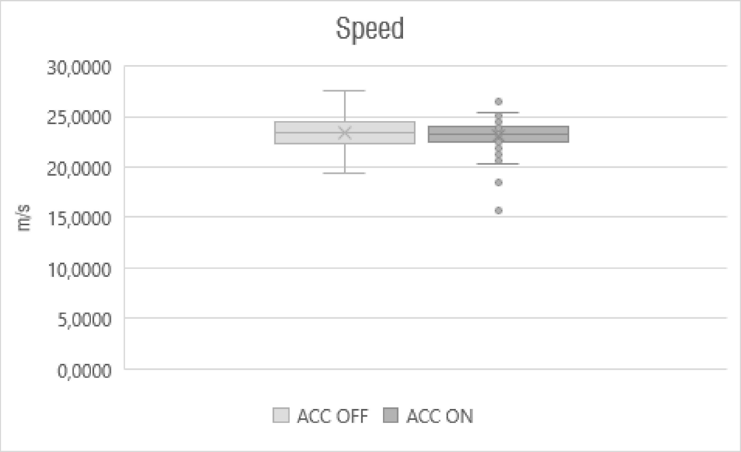
- ACC system;
- Presence of secondary tasks;
- Phase repetition;
- Sex of participants;
- Self-reported attitude to perform secondary tasks during everyday driving.

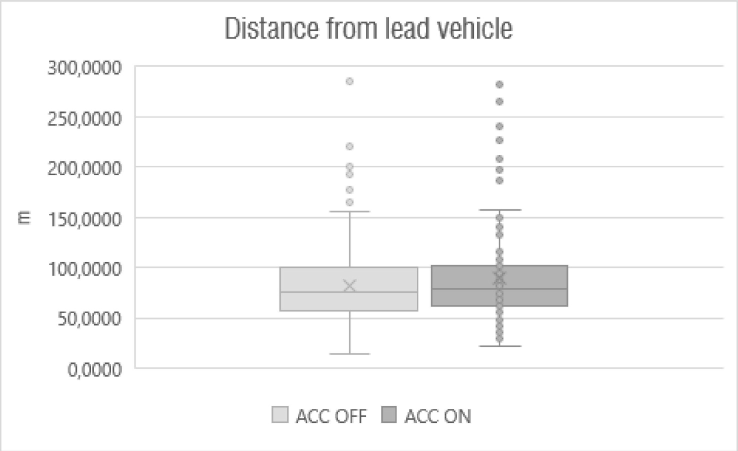
The variables "ACC system", "Presence of secondary tasks", "Phase repetition" were characteristics of the experiment, while “Sex” and “Attitude to perform secondary tasks during the driving” were derived from the processing of the answers to the questionnaires.

All the behaviours self-reported by drivers through the questionnaires submitted before the experiment were preliminary analysed by means of a correlation matrix (based on the Spearman rank method, given the presence of categorical variables). Variables different than sex and attitude to perform secondary tasks were removed from further analyses given the identified significant correlations (at a significance level $p < 0.05$).

The influence of the independent variables on the dependent variables was explored.

The ACC system had a strong influence on the acceleration and deceleration, as shown in the box plot below. The distance from the lead vehicle was affected by the ACC system, while the speed and the lateral position did not appear to be affected by the ACC system.





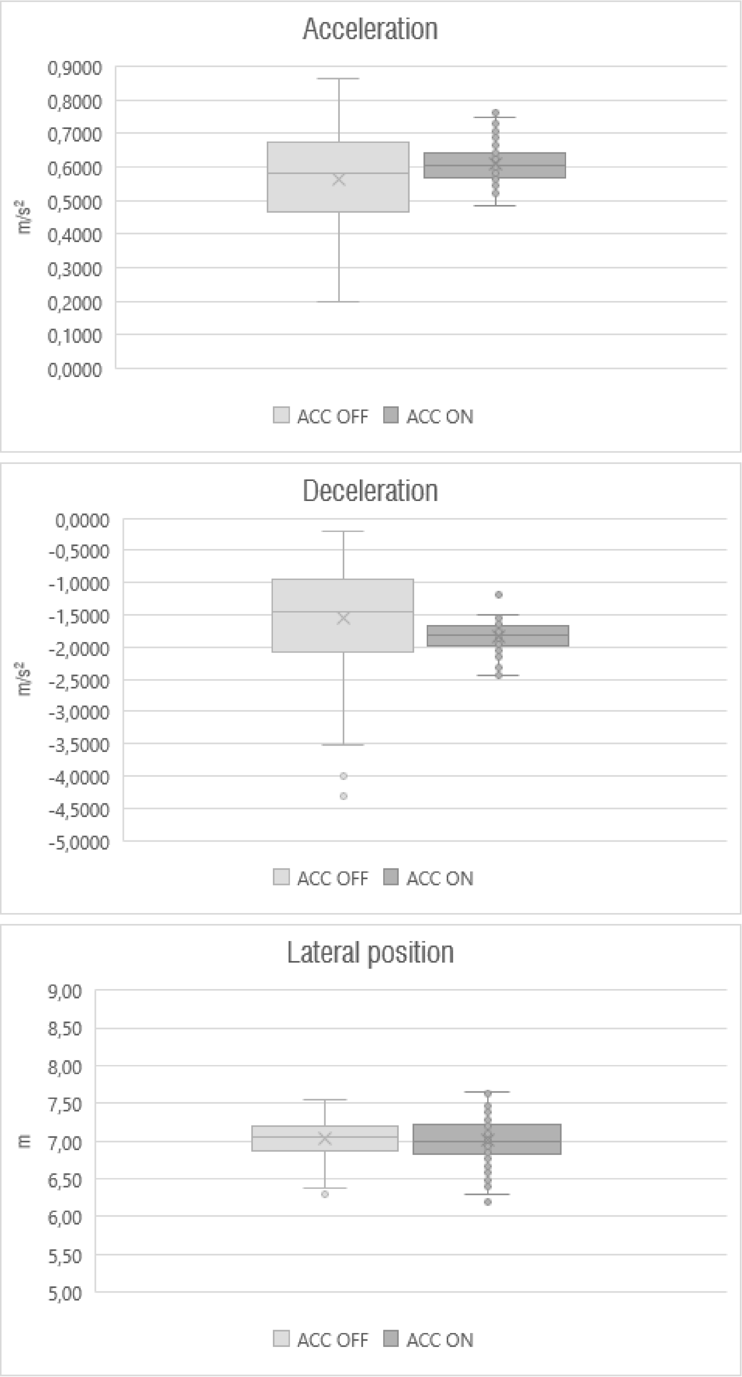
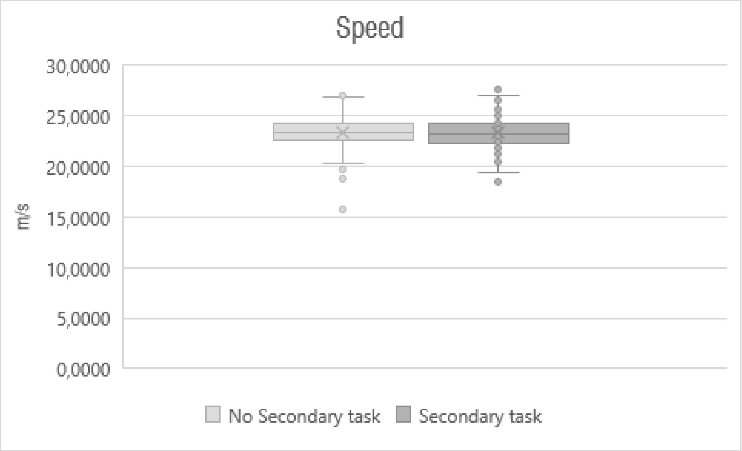
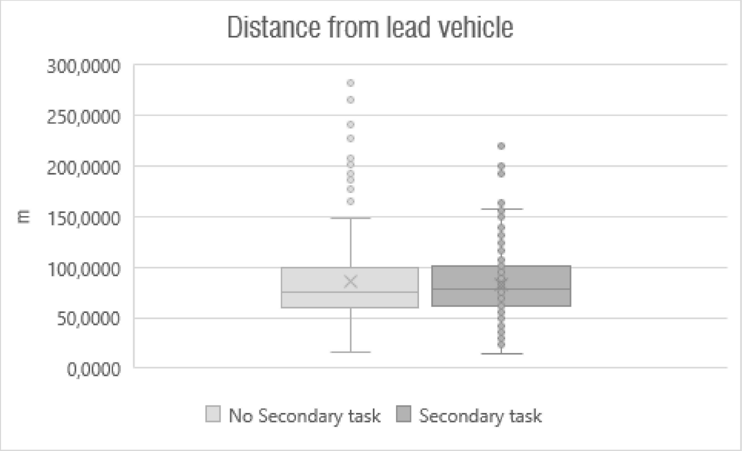


Figure 30 – Influence of ACC on dependent variables

The presence of secondary tasks had a slightly influence on the deceleration, as shown in the graphs below. The other variables, as speed, did not seem to be affected by the presence of secondary tasks and this may be attributable to the drivers' familiarity with performing non-driving related tasks, but also to the low incidence of the few seconds in which the secondary task is performed in relation to the entire phase duration. It is necessary to point out that, in this analysis, the influence of secondary tasks was sought on the average data, despite the fact that they are punctual events and had an effect for a few seconds in the various phases. For this reason, further analyses were carried out in the following paragraphs in order to investigate variation in the variables specifically related to secondary tasks.





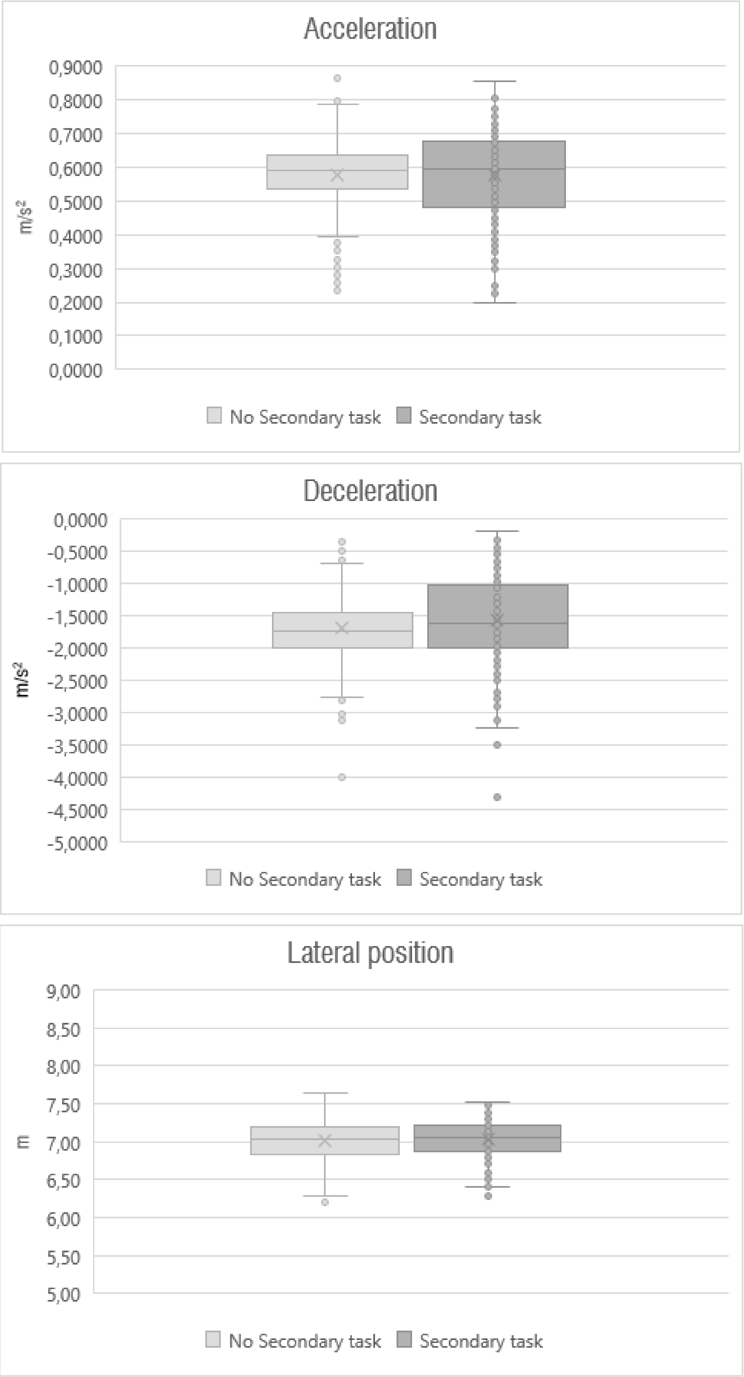
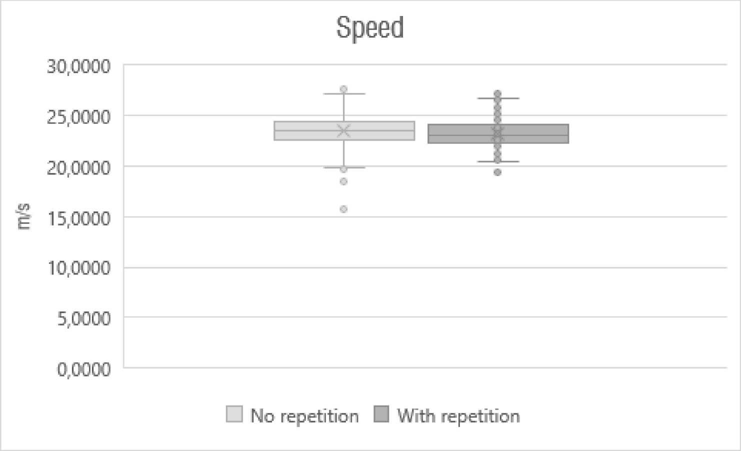


Figure 31 – Influence of Secondary Tasks on dependent variables

The experiment, as explained in the previous paragraphs, was characterised by five different scenarios, each of which was characterised by two phases. The variable "Phase repetition" took into account the repetition of the phase and in this study was used to study possible familiarity with the ACC system and with the route. The term "With repetition" indicates that the phase was already previously presented to the driver identically.

The repetition influenced acceleration considerably; the distance from the lead vehicle was slightly influenced. Speed, deceleration and lateral position were not influenced by the repetition.



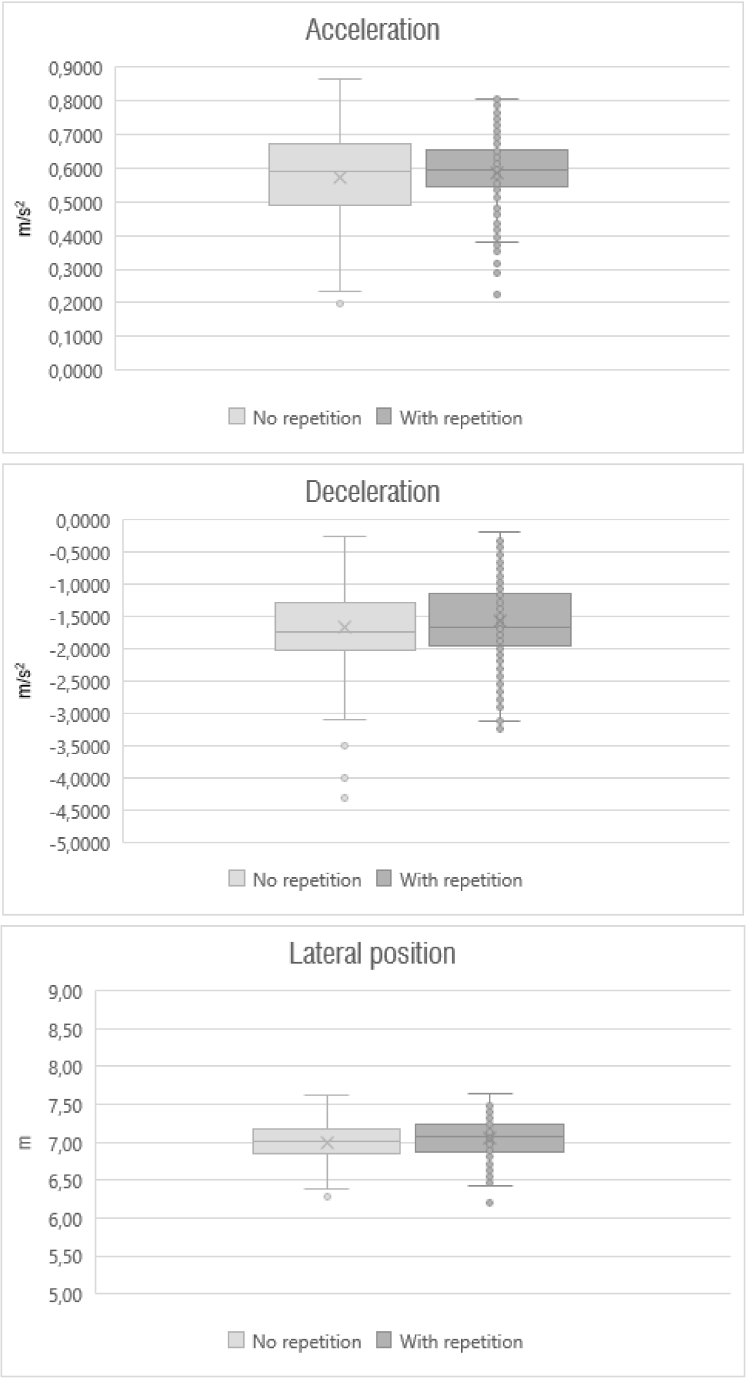
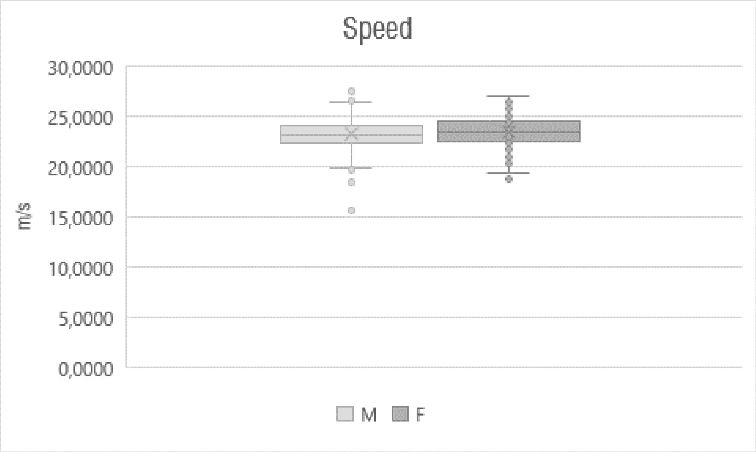
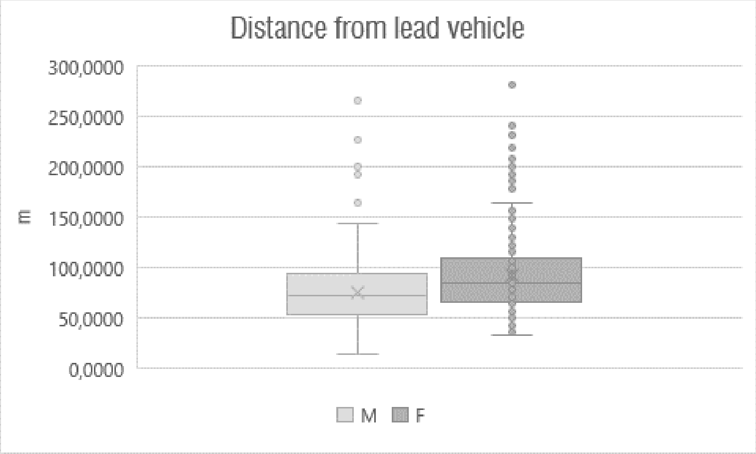


Figure 32 – Influence of Phase repetition on dependent variables

Sex greatly influenced the distance from the lead vehicle. This distinction slightly influenced acceleration and lateral position, but it did not influence the other variables.





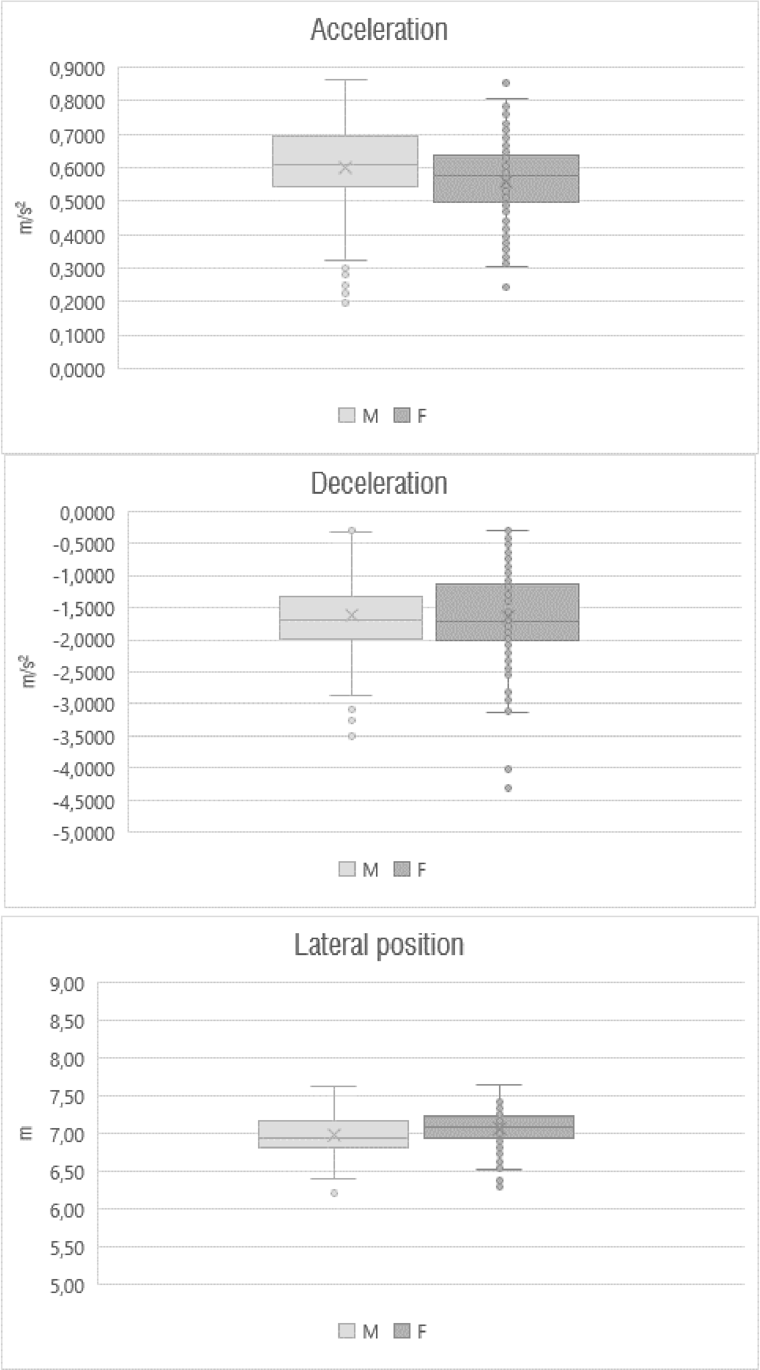
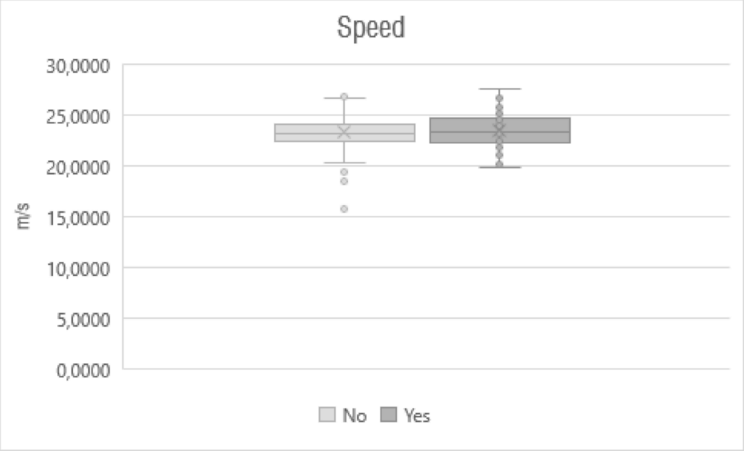


Figure 33 – Influence of Sex on dependent variables

In the questionnaires, drivers were asked whether they usually perform other tasks while they are driving. The attitude to perform secondary tasks influenced the acceleration, the distance from the lead vehicle and lateral position. The other variables were not influenced by this independent variable.



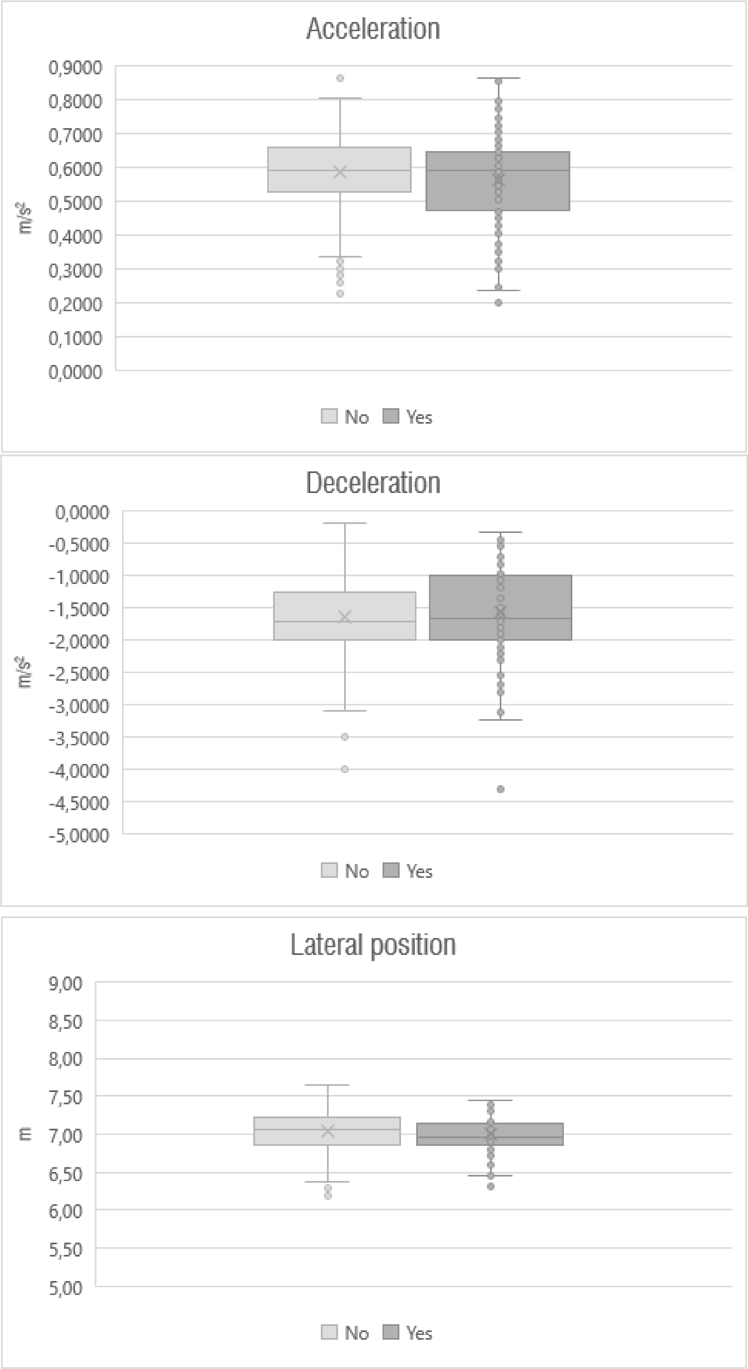


Figure 34 – Influence of attitude to perform secondary tasks during the driving on dependent variables

Table 11 summarizes the influence of the independent variables on the dependent variables, as based on the exploratory analysis performed in this section.

Table 11 – Influence of independent variables on dependent variables: Overall data

	ACC system	**Presence of secondary tasks**	**Phase repetition**	**Sex of participants**	**Attitude to perform secondary tasks**
Speed	-	-	-	-	-
Distance from lead vehicle	✓	-	✓	✓	✓
Acceleration	✓	-	✓	✓	✓
Deceleration	✓	✓	-	-	-
Lateral position	-	-	-	✓	✓

4.3.2 Descriptive statistics related to secondary tasks

For each of the three secondary tasks of the six repetitions, the averages of the dependent variables (lateral position, speed, acceleration and distance from the lead vehicle) in the three seconds preceding ("Pre") the secondary task and in the three seconds following the reaction time τ ("Post") were calculated.

The relative difference, which is the ratio of the difference between the Post and Pre values and the Pre values itself, was calculated as follows. The relative difference, expressed in Equation 7, was used in the following statistical analyses.

$$Relative\ difference = \frac{Value\ Post\ Secondary\ task - Value\ Pre\ Secondary\ task}{Value\ Pre\ Secondary\ task} \qquad \text{(Eq. 7)}$$

The average values and the relative difference of the dependent variables, divided according to the scenario and type of secondary task, are listed in Table 12.

The first two columns of the following table show respectively the scenario characterising the simulation (scenarios defined at page 58) and the type of secondary tasks (Secondary task 1 and Secondary task 3: questions to the driver; Secondary task 2: message sent to the driver's mobile phone). The third column indicates the averages of the recorded values for the individual dependent variables (fourth, fifth, sixth and seventh column) in the three seconds preceding the secondary task ("Pre" Value) and in the three seconds following the reaction time τ ("Post" Value).

Table 12 – Average values for the analysis of the influence of secondary tasks

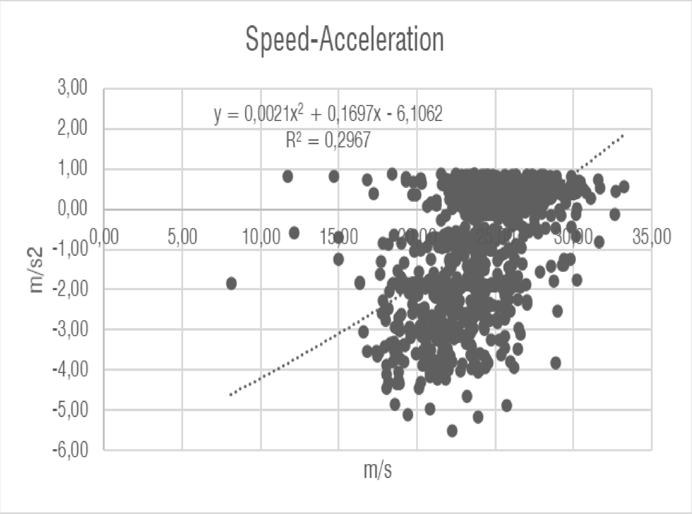
Scenario	**Secondary task**		**Lateral Position (mm)**		**Speed (m/s)**		**Acceleration (m/s²)**		**Distance lead vehicle (m)**	
			Value	Relative difference	Value	Relative difference	Value	Relative difference	Value	Relative difference
0	1 ^	Pre	6948,07	0,0137	25,18	-0,0940	0,12	-7,2454	49,47	-0,2491
		Post	7035,63		22,74		-2,55		36,79	
	2 ^	Pre	6942,28	0,0012	26,06	0,0595	0,53	-1,4533	68,91	0,0660
		Post	6948,79		27,51		-0,38		75,75	
	3 ^	Pre	6910,58	-0,0049	24,32	-0,0587	0,05	5,0429	55,31	-0,1988
		Post	6859,72		22,79		-1,95		46,34	
1S	1 ^	Pre	6958,71	0,0150	24,49	-0,0711	0,09	2,3957	43,78	-0,2267
		Post	7059,83		22,66		-2,51		33,32	
	2 ^	Pre	6852,43	0,0437	25,95	-0,1615	0,55	-4,5565	94,68	0,1884
		Post	7136,65		21,83		-1,89		111,20	
	3 ^	Pre	6799,95	0,0495	25,85	-0,1448	0,50	-2,9210	136,87	-0,1666
		Post	7114,65		22,05		-1,24		123,38	
1	1 ^	Pre	6985,92	0,0020	25,06	-0,1422	0,15	-15,5302	42,53	-0,2742
		Post	6988,74		21,54		-2,75		31,34	
	2 ^	Pre	6893,67	0,0236	27,24	-0,1557	0,46	-3,9794	64,99	0,2158
		Post	7041,07		22,98		-1,93		75,90	
	3 ^	Pre	7033,96	0,0111	26,11	-0,1547	0,40	-3,4113	91,29	-0,1748
		Post	7096,69		22,04		-1,26		77,31	

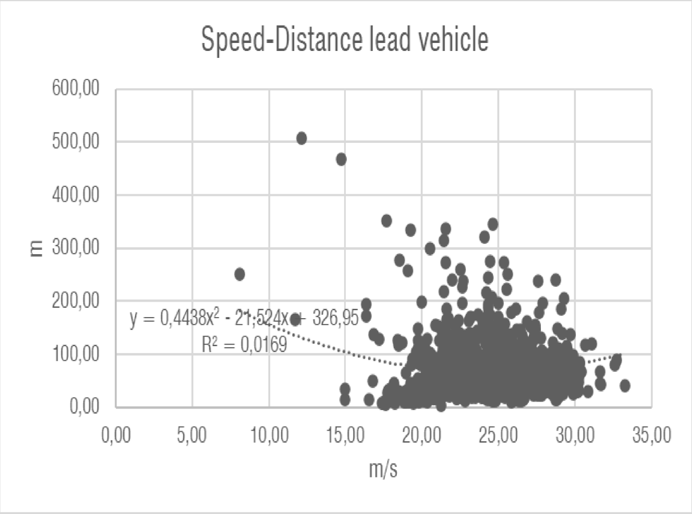
1S	1^	Pre	7102,49	0,0001	25,28	-0,1494	0,22	-4,5502	43,39	-0,2512
		Post	7099,70		21,38		-2,48		32,20	
	2^	Pre	6896,82	0,0166	26,86	-0,1557	0,51	-4,8784	70,19	0,1898
		Post	7003,01		22,70		-1,94		82,45	
	3^	Pre	6959,03	0,0192	26,00	-0,1486	0,53	-3,7746	100,33	-0,1817
		Post	7081,66		22,11		-1,40		85,93	
2	1^	Pre	7026,62	0,0109	25,40	-0,1223	0,26	-23,7594	48,75	-0,2865
		Post	7099,57		22,24		-2,89		35,03	
	2^	Pre	7009,87	0,0148	26,21	-0,1410	0,54	-4,5734	84,65	0,1693
		Post	7105,32		22,44		-1,83		99,34	
	3^	Pre	6901,84	0,0336	25,92	-0,1406	0,48	-3,1956	121,04	-0,1333
		Post	7109,52		22,18		-1,25		107,16	
3	1^	Pre	7031,63	0,0039	24,82	-0,1177	0,18	-18,8377	44,91	-0,2313
		Post	7055,65		21,79		-2,50		34,91	
	2^	Pre	6878,20	0,0121	25,84	0,0622	0,57	-1,1194	73,13	0,0823
		Post	6947,49		27,32		-0,12		81,12	
	3^	Pre	6876,27	0,0289	25,07	-0,0707	0,29	-18,5736	60,16	-0,2599
		Post	7055,67		23,04		-2,14		47,07	

As in the previous section, the dependent variable speed was than related to the other dependent variables, i.e., acceleration, distance from the lead vehicle and lateral position, in order to identify possible relationships.

Also in this case, the variables were linked by second-square polynomial regression curves, as shown in the Equation 6, in which the coefficients vary according to the specific case.

The graphs below only show an interesting correlation between speed and acceleration (R^2 equal to 0.297), while the other variables did not appear to be correlated.


Speed-Acceleration
y = 0,0021x² + 0,1697x - 6,1062
R² = 0,2967
3,00
2,00
1,00
0,00
-1,00
-2,00
-3,00
-4,00
-5,00
-6,00
m/s2
0,00
5,00
10,00
15,00
20,00
25,00
30,00
35,00
m/s


Speed-Distance lead vehicle
600,00
500,00
400,00
300,00
200,00
100,00
0,00
m
y = 0,4438x² - 21,524x + 326,95
R² = 0,0169
0,00
5,00
10,00
15,00
20,00
25,00
30,00
35,00
m/s

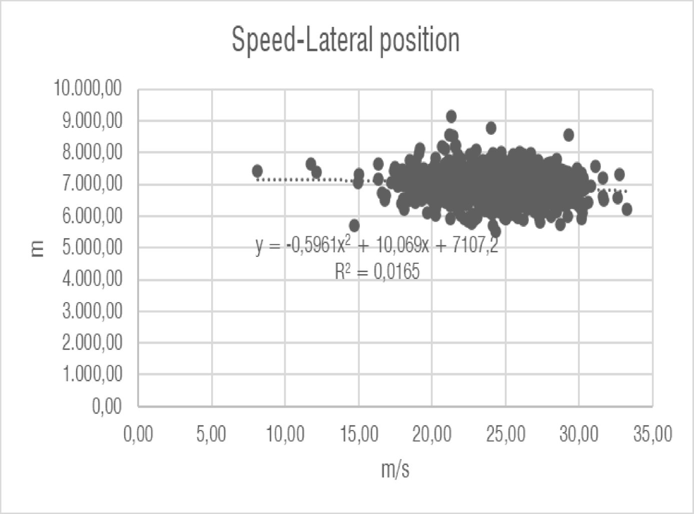


Figure 35 – Correlations between speed and the other dependent variables: focus on secondary tasks

Comparing the graphs concerning correlations between speed and the other dependent variables, it could be seen that the only correlation found was: Speed-Acceleration.

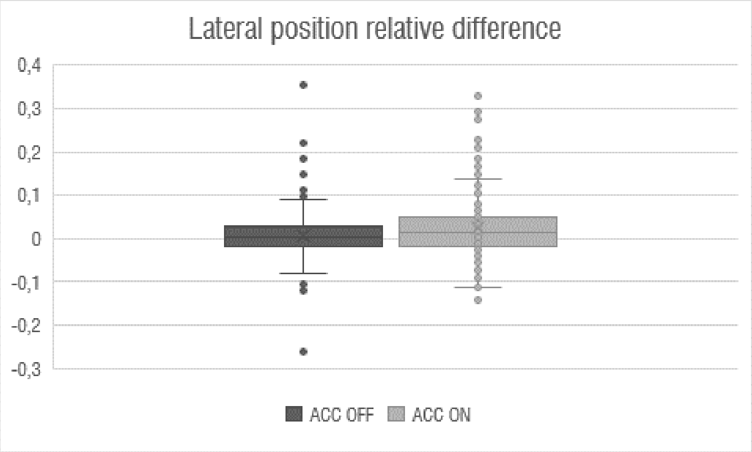
Table 13 – Correlation between dependent variables: Secondary tasks

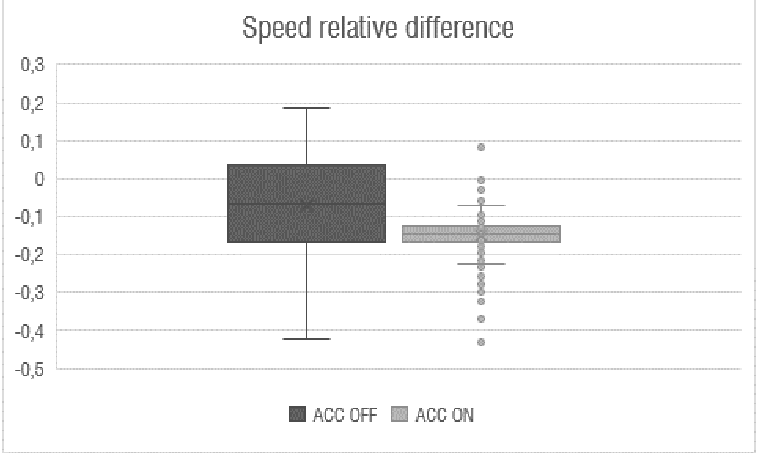
	Correlation between variables
Speed – Lateral position	Not correlated
Speed - Acceleration	Correlated
Speed – Distance from lead vehicle	Not correlated

The independent variables considered in the present study were ACC system, presence of secondary tasks, phase repetition, sex, attitude to perform secondary tasks during the driving.

The ACC system has a strong influence on the distance from the lead vehicle and on the speed. Lateral position is slightly affected by the ACC system.

The box plots concerning the acceleration variable were characterised by many extreme outlier values and were therefore excluded from the present analysis.


Lateral position relative difference


Speed relative difference

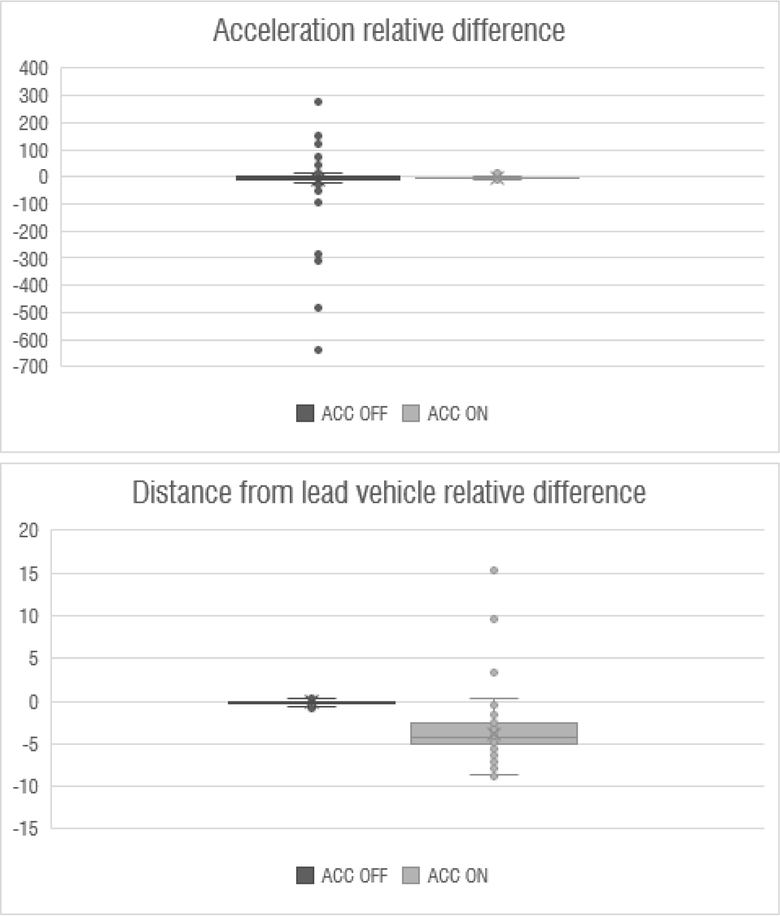
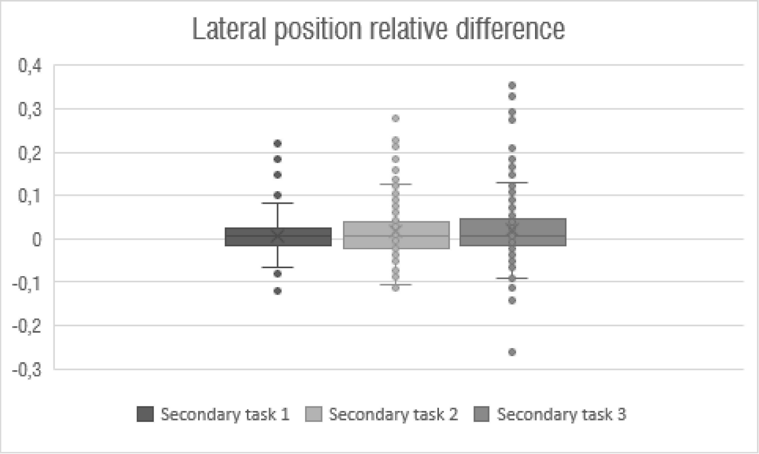
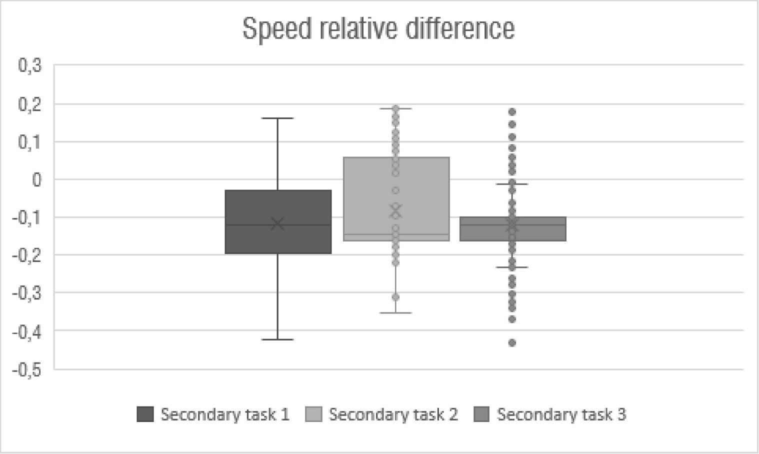


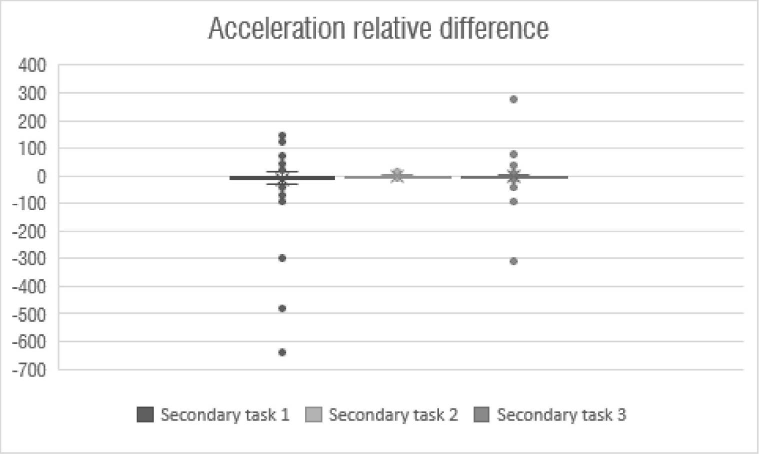
Figure 36 – Influence of ACC on dependent variables for secondary tasks

The three secondary tasks had a strong influence on the distance from the lead vehicle. Speed and lateral position were also influenced by the secondary tasks.

The box plots concerning the acceleration variable were characterised by many extreme outlier values and were therefore excluded from the present analysis.


Lateral position relative difference
0,4
0,3
0,2
0,1
0
-0,1
-0,2
-0,3
Secondary task 1
Secondary task 2
Secondary task 3


Speed relative difference
0,3
0,2
0,1
0
-0,1
-0,2
-0,3
-0,4
-0,5
Secondary task 1
Secondary task 2
Secondary task 3


Acceleration relative difference
400
300
200
100
0
-100
-200
-300
-400
-500
-600
-700
Secondary task 1
Secondary task 2
Secondary task 3

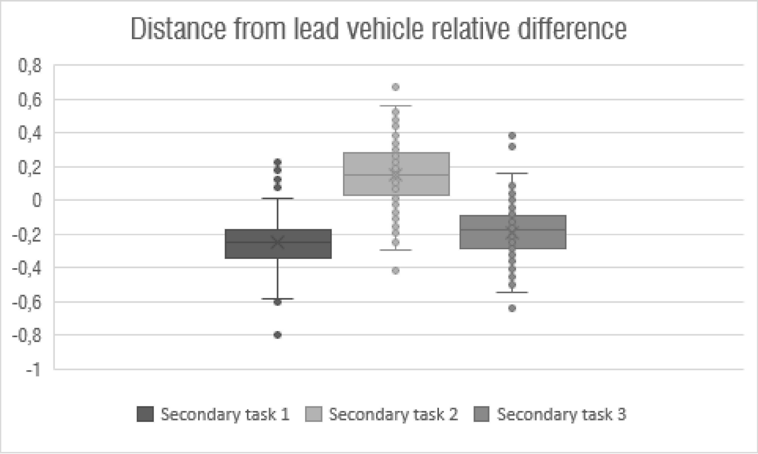
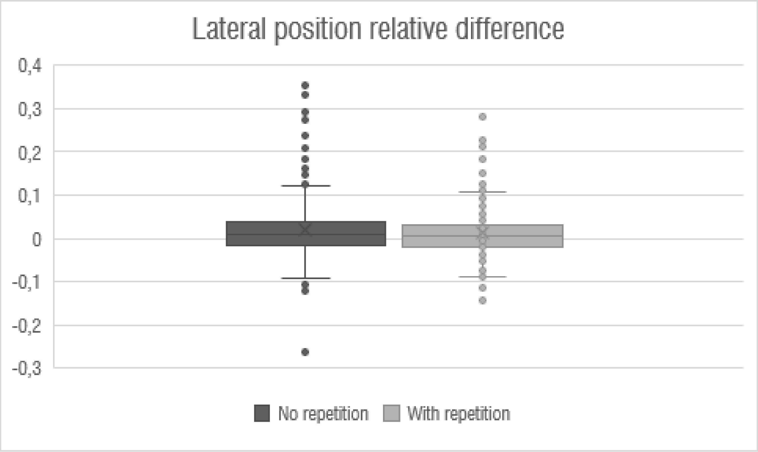


Figure 37 – Influence of Secondary Tasks on dependent variables for secondary tasks

The phase repetition influenced the speed, while the other variables did not appear to be influenced by the phase repetition.

The box plots concerning the acceleration variable were characterised by many extreme outlier values and were therefore excluded from the present analysis.



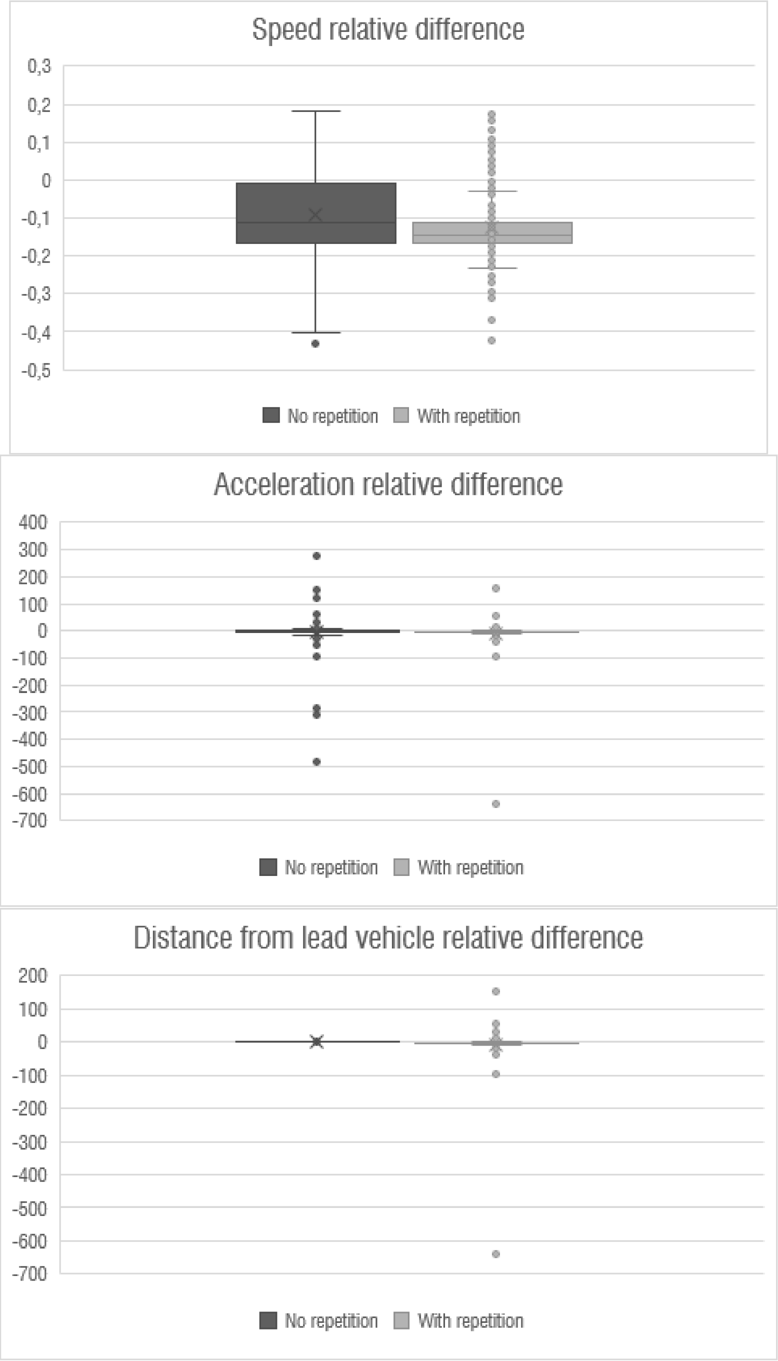
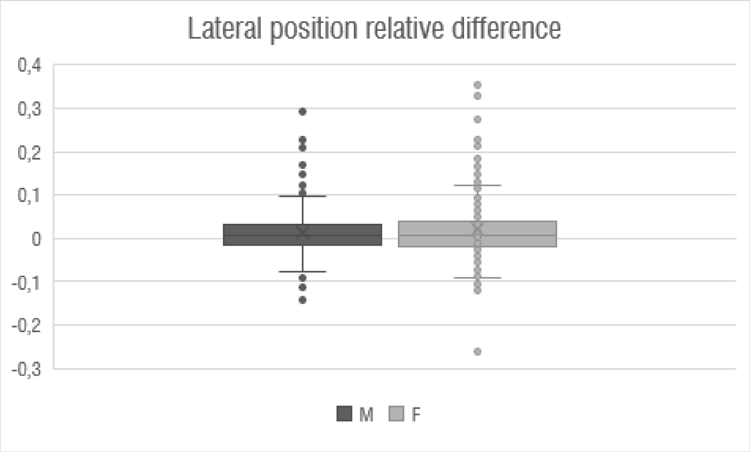
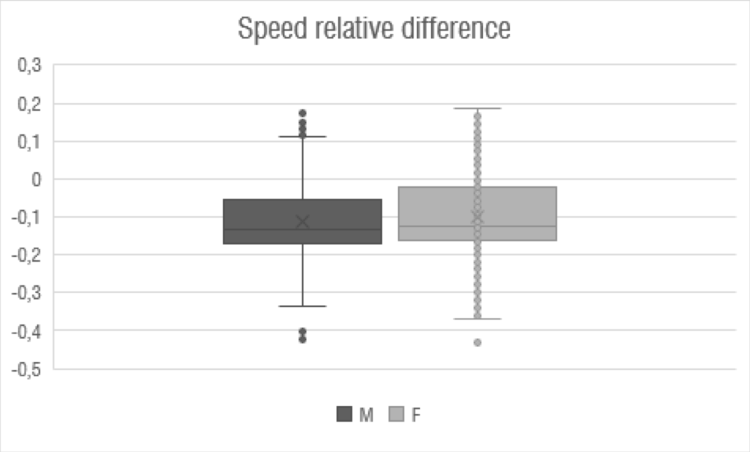


Figure 38 – Influence of Phase repetition on dependent variables for secondary tasks

Sex slightly influences the speed, while the other variables did not appear to be influenced by sex.

The box plots concerning the acceleration variable were characterised by many extreme outlier values and were therefore excluded from the present analysis.





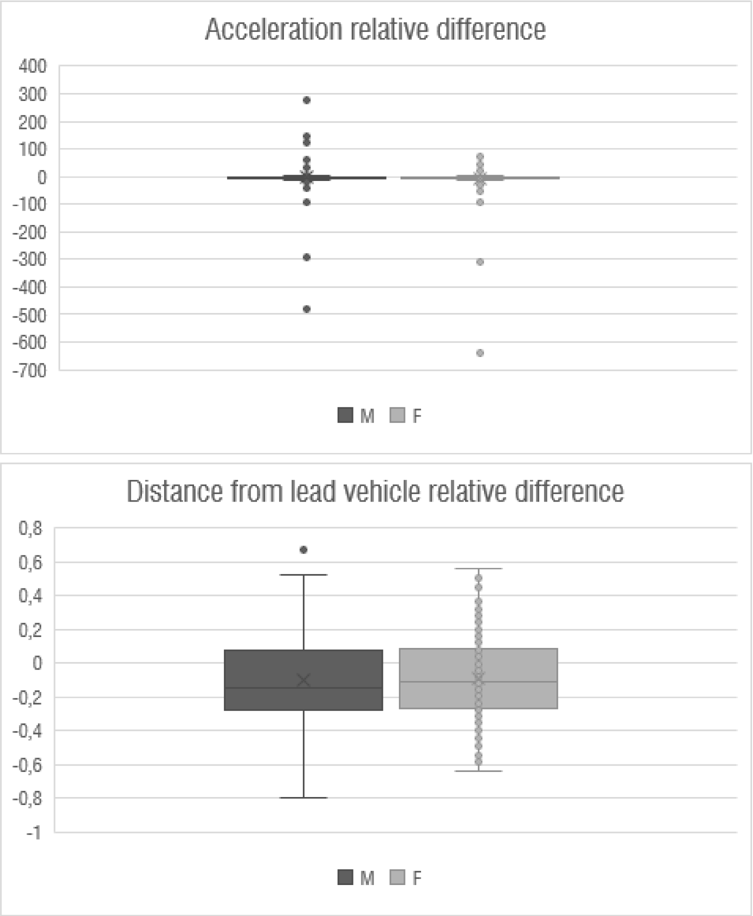
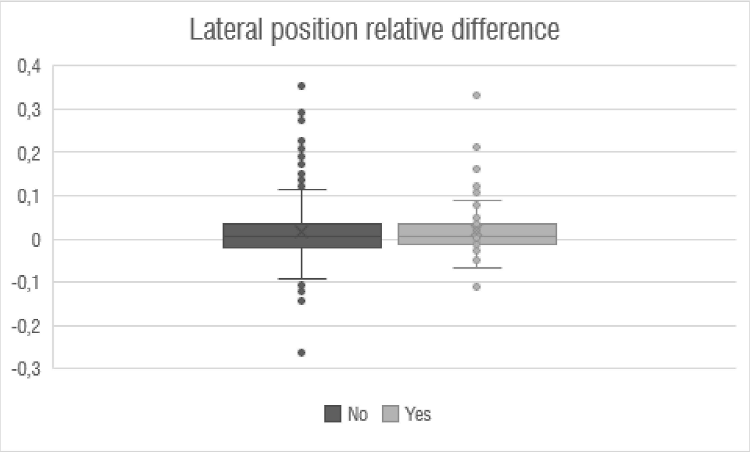
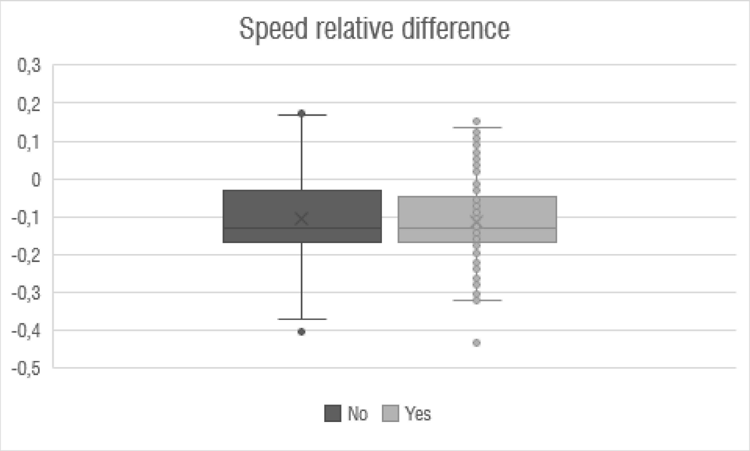


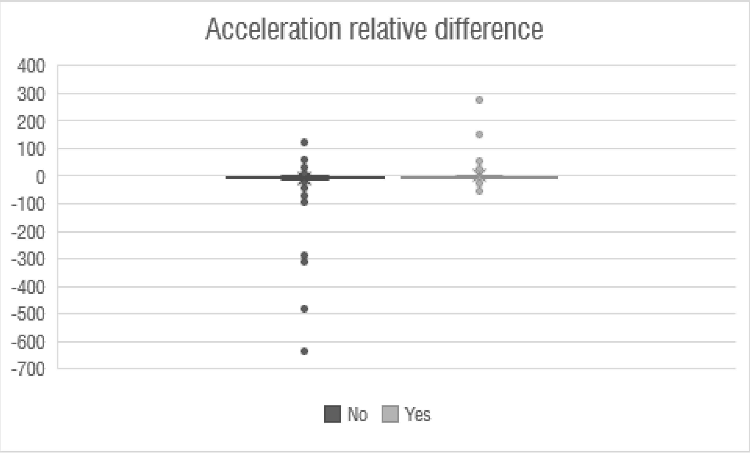
Figure 39 – Influence of Sex on dependent variables for secondary tasks

The attitude to perform secondary tasks during driving did not appear to influence the dependent variables.

The box plots concerning the acceleration variable were characterised by many extreme outlier values and were therefore excluded from the present analysis.


Lateral position relative difference
0,4
0,3
0,2
0,1
0
-0,1
-0,2
-0,3
No
Yes


Speed relative difference
0,3
0,2
0,1
0
-0,1
-0,2
-0,3
-0,4
-0,5
No
Yes


Acceleration relative difference
400
300
200
100
0
-100
-200
-300
-400
-500
-600
-700
No
Yes

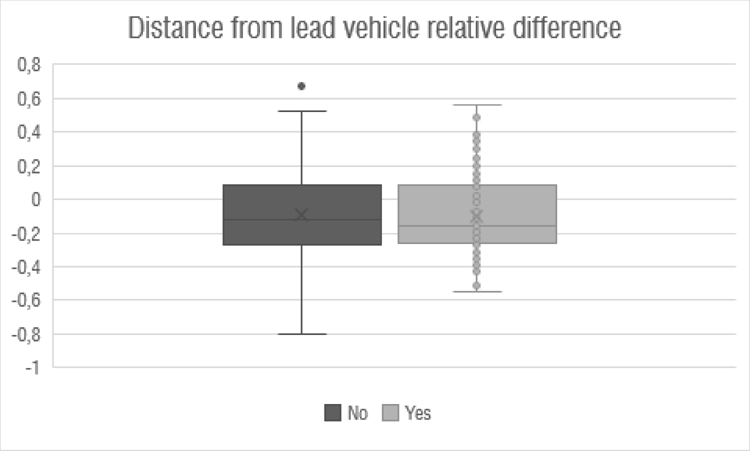


Figure 40 – Influence of attitude to perform secondary tasks during the driving on dependent variables for secondary tasks

The Table 14 summarizes the influence of the independent variables on the dependent variables, as based on the exploratory analysis performed, focused on the application of secondary tasks.

Table 14 – Influence of independent variables on dependent variables: Secondary tasks

	ACC system	**Presence of secondary tasks**	**Phase repetition**	**Sex of participants**	**Attitude to perform secondary tasks**
Speed	✓	✓	✓	✓	-
Distance from lead vehicle	✓	✓	-	-	-
Acceleration	-	-	-	-	-
Lateral position	✓	✓	-	-	-

Considering the dispersion of data emerged from the box plots depicted for the acceleration variable, it was decided to exclude acceleration from the subsequent analyses, as this would violate the assumptions underlying the employed models.

4.4 STATISTICAL ANALYSES

4.4.1 Statistical analyses related to overall data

The above defined data are treated by means of statistical analyses. A relationship between the dependent variables (speed, acceleration, deceleration, lateral position, distance) and the independent variables (ACC system, phase repetition, secondary tasks, the attitude to perform secondary tasks during the driving, sex) was searched.

In particular, both the mean and the standard deviation values of the variables referred to each phase of the driving scenarios were considered as dependent variables.

The dataset has a panel data structure, since measures are repeated on the same individuals over time (the same drivers were asked to repeat six times five different driving scenarios).

Hence, generalized linear models for panel data were run, having one of the above defined variables per time as dependent variables and the others as potential predictors (independent variables). The final models for each variable included only predictors for which statistically significant coefficients at the 10% significance level were estimated.

The estimated models are reported below.

Statistical analyses showed that the ACC system led to an increase in average speed, but reduces the variation in speed, as shown by the resulting negative coefficient for the standard deviation. Phase repetition and secondary task, on the other hand, increased the variation in speed. From this analysis, it was found that women have a greater propensity for speed variation.

Table 15 – Results of statistical models: Speed

Mean	**Coefficient**	**Std. err.**	**z**	**P>|z|**	**[95% conf. interval]**	
ACC	-.3523651	.146754	-2.40	0.016	-.6399977	-.0647324
Const.	23.45838	.1367296	171.57	0.000	23.1904	23.72637
R-squared (Overall)	0.0117					
Wald chi2 (1)	5.77					
Prob > chi2	0.0163					

Standard Deviation	**Coefficient**	**Std. err.**	**z**	**P>|z|**	**[95% conf. interval]**	
Repetition	1.243581	.1765056	7.05	0.000	.8976364	1.589526
ACC	-3.57968	.2001385	-17.89	0.000	-3.971945	-3.187416
Secondary task (ST)	.4398453	.1886924	2.33	0.020	.070015	.8096756
Sex	.3609243	.1765056	2.04	0.041	.0149797	.7068689
Const.	5.991752	.2028992	29.53	0.000	5.594076	6.389427
R-squared (Overall)	0.5327					
Wald chi2 (4)	459.33					
Prob > chi2	0.0000					

Statistical analyses showed that the phase repetition led to a shift to the right of the axis of the lead vehicle and reduces the variation itself, as shown in the following tables. ACC system increased the variation of the lateral position. From this analysis, it was found that women have a greater propensity for lateral position variation.

Table 16 – Results of statistical models: Lateral position

Mean	**Coefficient**	**Std. err.**	**z**	**P>|z|**	**[95% conf. interval]**	
Repetition	47.08464	17.60104	2.68	0.007	12.58724	81.58205
Const.	7000.052	32.61725	214.61	0.000	6936.124	7063.981
R-squared (Overall)						0.0089
Wald chi2 (1)						7.16
Prob > chi2						0.0075

Standard Deviation	**Coefficient**	**Std. err.**	**z**	**P>|z|**	**[95% conf. interval]**	
Repetition	-39.39245	12.41303	-3.17	0.002	-63.72155	-15.06335
ACC	42.85082	13.16601	3.25	0.001	17.04592	68.65573
Sex	73.64957	33.92465	2.17	0.030	7.158475	140.1407
Const.	263.2855	25.16391	10.46	0.000	213.9651	312.6058
R-squared (Overall)						0.0838
Wald chi2 (3)						25.38
Prob > chi2						0.0000

Statistical analyses showed that the ACC system led to an increase of the acceleration mean value, while the women were on lower acceleration values. Phase repetition and the presence of women generated an increase in the variability of acceleration values, while the ACC system decreased the variation of the acceleration.

Table 17 – Results of statistical models: Acceleration

Mean	**Coefficient**	**Std. err.**	**z**	**P>|z|**	**[95% conf. interval]**	
ACC	.0473809	.0112284	4.22	0.000	.0253736	.0693882
Sex	-.0394392	.023951	-1.65	0.100	-.0863823	.0075039
Const.	.5825124	.0173446	33.58	0.000	.5485177	.6165071
R-squared (Overall)	0.0557					
Wald chi2 (2)	20.52					
Prob > chi2	0.0000					

Standard Deviation	**Coefficient**	**Std. err.**	**z**	**P>|z|**	**[95% conf. interval]**	
Repetition	.0313246	.0059814	5.24	0.000	.0196012	.043048
ACC	-.1571456	.0063443	-24.77	0.000	-.1695802	-.1447111
Sex	.0266066	.0156785	1.70	0.090	-.0041227	.057336
Const.	.2498049	.0116758	21.40	0.000	.2269207	.2726891
R-squared (Overall)	0.5275					
Wald chi2 (3)	643.84					
Prob > chi2	0.0000					

Statistical analyses showed that the phase repetition led to an increase in deceleration mean value. The ACC system led to a decrease in deceleration mean value and a reduction of the variation. From this analysis, it was found that women tend to smaller variations of deceleration values.

Table 18 – Results of statistical models: Deceleration

Mean	**Coefficient**	**Std. err.**	**z**	**P>|z|**	**[95% conf. interval]**	
Repetition	.0998001	.0543774	1.84	0.066	-.0067776	.2063778
ACC	-.2899412	.0576759	-5.03	0.000	-.4029839	-.1768985
Const.	-1.589966	.0690513	-23.03	0.000	-1.725304	-1.454628
R-squared (Overall)	0.0508					
Wald chi2 (2)	28.64					
Prob > chi2	0.0000					

Standard Deviation	**Coefficient**	**Std. err.**	**z**	**P>|z|**	**[95% conf. interval]**	
ACC	-.7043746	.0293541	-24.00	0.000	-.7619076	-.6468416
Sex	.1599693	.0738576	2.17	0.030	.0152112	.3047275
Const.	1.446891	.0531339	27.23	0.000	1.34275	1.551031
R-squared (Overall)	0.5034					
Wald chi2 (2)	580.49					
Prob > chi2	0.00					

Statistical analyses showed that the ACC system led to an increase in average distance from the lead vehicle and reduced its variation. The phase repetition reduced the distance from the lead vehicle, and it appeared that women tend to stay closer to the lead vehicle. From this analysis, it was found that women have a greater propensity for distance variation.

Table 19 – Results of statistical models: Distance from lead vehicle

Mean	**Coefficient**	**Std. err.**	**z**	**P>|z|**	**[95% conf. interval]**	
Repetition	-7.724554	3.376137	-2.29	0.022	-14.34166	-1.107448
ACC	7.704799	3.580934	2.15	0.031	.6862976	14.7233
Sex	17.388	6.763732	2.57	0.010	4.131328	30.64467
Const.	76.21453	5.210413	14.63	0.000	66.0023	86.42675
R-squared (Overall)	0.0678					
Wald chi2 (3)	16.47					
Prob > chi2	0.0009					

Standard Deviation	**Coefficient**	**Std. err.**	**z**	**P>|z|**	**[95% conf. interval]**	
ACC	-6.888314	2.664638	-2.59	0.010	-12.11091	-1.66572
Sex	9.681746	3.796499	2.55	0.011	2.240745	17.12275
Const.	31.97986	2.827653	11.31	0.000	26.43776	37.52195
R-squared (Overall)	0.0461					
Wald chi2 (2)	13.19					
Prob > chi2	0.0014					

The results of the statistical analyses concerning the influence of the independent variables (Phase repetition, ACC system, Secondary Tasks, Sex of participants, Attitude to perform secondary tasks) on the dependent variables (Speed, Lateral position, Acceleration, Deceleration, Distance from the lead vehicle) regarding the overall data are shown in Table 23 and discussed in section 4.5.1.

4.4.2 Statistical analyses related to secondary tasks

Similarly to the overall data, general linear models for panel data were run having the percentage difference of speed, lateral position and distance as dependent variable, and the other variables, i.e. ACC system, phase repetition, various secondary tasks (1-3 questions to the driver; 2-mobile phone message), the attitude to perform secondary tasks during the driving, sex, as independent variables.

Considering the dispersion of the acceleration data resulting from previous analyses, it was decided to exclude it from the statistical analyses, as this would violate the assumptions underlying the linear models used.

Statistical analyses showed that the ACC system led to a reduction of the percentage variation of the speed. The percentage variation of the speed was greater with the second secondary task, namely reading a message on the mobile phone, compared to the first and third secondary tasks, namely the question to the driver.

Table 20 – Results of statistical models for the analysis of the effect of secondary tasks: Percentage variation of speed

		Coefficient	Std. err.	z	P>|z|	[95% conf. interval]	
ACC		-.1489068	.0096651	-15.41	0.000	-.1678501	-.1299636
Secondary tasks (base condition “message”)	**1**	-.1324847	.0111603	-11.87	0.000	-.1543585	-.110611
	3	-.0375543	.0091123	-4.12	0.000	-.0554142	-.0196945
Const.		.0168702	.0100766	1.67	0.094	-.0028795	.0366199
R-squared (Overall)		0.2832					
Wald chi2 (3)		257.70					
Prob > chi2		0.0000					

Statistical analyses showed that the phase repetition led to a decrease of the percentage variation of the lateral position, which could be translated as a shift to the right of the lead vehicle axis. The ACC system led to an increase of the percentage variation of the lateral position, which could be translated as a shift to the left of the lead vehicle axis.

Table 21 – Results of statistical models for the analysis of the effect of secondary tasks: Percentage variation of lateral position

	Coefficient	Std. err.	z	P>|z|	[95% conf. interval]	
Repetition	-.014639	.0050478	-2.90	0.004	-.0245325	-.0047456
ACC	.0229536	.0050478	4.55	0.000	.0130601	.032847
Const.	.0125799	.0045606	2.76	0.006	.0036412	.0215185
R-squared (Overall)	0.0337					
Wald chi2 (2)	22.94					
Prob > chi2	0.0000					

Statistical analyses showed that the ACC system led to an increase of the percentage variation of the distance from the lead vehicle. The percentage variation of the distance from the lead vehicle was greater with the second secondary task, namely reading a message on the mobile phone, compared to the first and third secondary tasks, namely the question to the driver.

Table 22 – Results of statistical models for the analysis of the effect of secondary tasks: Percentage variation of distance from lead vehicle

		Coefficient	Std. err.	z	P>|z|	[95% conf. interval]	
ACC		.0893911	.015721	5.69	0.000	.0585785	.1202037
Secondary	**1**	-.345569	.018153	-19.04	0.000	-.3811483	-.3099897

tasks (base condition “message”)	**3**	-.3417951	.0148219	-23.06	0.000	-.3708455	-.3127447
Const.		.0932816	.0155858	5.99	0.000	.062734	.1238291
R-squared (Overall)		0.5879					
Wald chi2 (3)		897.18					
Prob > chi2		0.0000					

The results of the statistical analyses concerning the influence of the independent variables (Phase repetition, ACC system, Secondary Tasks, Sex of participants, Attitude to perform secondary tasks) on the dependent variables (Speed, Lateral position, Distance from the lead vehicle) regarding the secondary tasks data are shown in Table 24 and discussed in section 4.5.2.

4.5 DISCUSSION

The present experiment investigated the influence of ACC system, secondary tasks and route familiarity on driver behaviour. All the obtained results were discussed below, making a distinction between overall data and specific data related to secondary tasks.

4.5.1 Overall data

The first aspect concerned the possible correlations between the dependent variables. The comparison from Table 10 showed that the only evidently correlated dependent variables were Speed-Distance from the lead vehicle and Speed-Acceleration; the other dependent variables were not correlated. Despite of these correlations, the estimated models showed that different independent variables were associated to the dependent variables (i.e., speed or distance, speed or acceleration) preliminarily identified as correlated, as shown in Table 23.

Secondly, the preliminary analysis of descriptive statistics showed that speed was not influenced by the independent variables, whereas the statistical analyses concerning speed revealed the influence of the ACC system on the average speed and the influence of all other independent variables on the standard deviations.

Based on descriptive statistics, distance from the lead vehicle and acceleration seemed to be influenced by all independent variables except for the presence of the secondary tasks, and this was confirmed by the statistical analyses.

Both statistical analyses and descriptive statistics revealed the influence of the independent variables on the deceleration, with the exception of the influence of sex on the standard deviation, which was highlighted only by the statistical analyses.

From the descriptive statistics, it emerged that the lateral position was influenced by the sex of the participants and the attitude to perform secondary tasks, while the statistical analyses showed that it was also influenced by phase repetition and ACC system.

The results from the statistical analysis showed that phase repetition led to an increase in the average deceleration value, a shift to the right of the axis of the lead vehicle, and a decrease in distance from the lead vehicle. With regard to lateral position, it is important to point out that in non-repeating phases the driver was in line with the axis, whereas after phase repetition, he/she moved to the right of the lead vehicle axis. These three findings could be explained by the concept of familiarity, as knowledge of the scenario led to greater awareness and thus to more aggressive behaviour. This was also demonstrated by the greater variability in speed and acceleration data, and with the reduction of variability in lateral position. The result concerning the average speed, which in this study was not influenced by repetition, is in contrast with previous research (see Colonna et al., 2016), in which an increase in speed with the repetitions was noted. Similar findings were also highlighted by Wu & Xu (2018), who argued that decelerating more and at shorter distances from the target point was a phenomenon associated with familiar drivers.

The ACC led to an increase in the average values of acceleration and distance from the lead vehicle and a reduction in the average value of speed and deceleration. The reduction in the distance from the lead vehicle was demonstrated by Pauwelussen et al. (2010). In this study, it was found that after the participants deactivated the ACC by pressing the brake pedal, the gap with the lead vehicle was decreased. Resuming the ACC by activating the system or by releasing the throttle after overruling the system resulted in a larger gap between participant and lead vehicle than an overruled ACC or the ACC turned off.

The presence of the ACC reduced the variability of speed, acceleration, deceleration and distance from the lead vehicle. This can be explained through an increase in the level of driving safety. Tapani (2012) conducted a study in which he confirmed that the ACC system led to a reduction of acceleration and deceleration rates. The greater variability in lateral position, on the other hand, was attributable to a decreased control of the vehicle. This is also demonstrated in literature, such as by McDonald et al. (2018), who found that drivers demonstrated low levels of knowledge about emerging technologies (i.e., Adaptive Cruise Control) and self-reported potentially unsafe behavioural adaptation in response to these technologies, experiencing less control of the vehicle.

These results are also demonstrated by Hoedemaeker (2000), who claims that ACC system reduced speed variability and led to various benefits in terms of traffic efficiency. On the other hand, Stanton et al. (2005) showed that the ACC mode made the driver perceive to lose vehicle control and consequently a wide variability in the position maintained along the route.

Secondary tasks were only associated to greater speed variability. This result was also confirmed by Onate-Vega et al. (2020), who highlighted a great higher standard deviation of speed under the effect of secondary tasks.

In all the estimated models, women showed a higher variability of the dependent variables. In parallel, the women who participated to this experiment could be considered more cautious than the male ones, as shown by the increase in distance from the lead vehicle and the reduction in the average acceleration value. Ericsson (2000) showed similar results about the acceleration, since he emphasised that women had higher proportion of time in the lowest acceleration class.

Table 23 – Overall data results

Mean	**Repetition**		**ACC**		**Secondary Tasks (ST)**		**Sex**	
	Coefficient Mean value	**Coefficient St. Dev..**	**Coefficient Mean value**	**Coefficient St. Dev..**	**Coefficient Mean value**	**Coefficient St. Dev..**	**Coefficient Mean value**	**Coefficient St. Dev..**
Speed	-	1.244	-.352	-3.580	-	.440	-	.361
Acceleration	-	.031	.047	-.157	-	-	-.039	.027
Deceleration	.010	-	-.290	-.704	-	-	-	.160
Lateral position	47.085	-39.392	-	42.851	-	-	-	73.650
Distance lead vehicle	-7.725	-	7.705	-6.888	-	-	17.388	9.682

4.5.2 Secondary tasks

The correlations analysed in the descriptive statistics showed that the dependent variables were not highly correlated with each other, and this was also confirmed by the different influence of the independent variables on the dependent variables in the subsequent analyses.

From the descriptive statistics, it emerged that speed was influenced by all independent variables, except the attitude to perform secondary tasks, whereas the statistical analysis only confirmed the dependence on the ACC system and the type of secondary tasks.

The statistical analyses and descriptive statistics showed that the distance from the lead vehicle was influenced by the ACC system and the type of secondary tasks, as for the speed, although these two dependent variables were not qualitatively correlated with each other, as shown in Table 13.

Both statistical analyses and descriptive statistics reveal the influence of the ACC system on the lateral position. In addition to this, the influence of the secondary tasks was highlighted in the descriptive statistics, which was not confirmed by the estimated models, in which the influence of phase repetition was significant instead. This is in contrast with previous research, which showed that repetition has an influence on the driving behaviour while drivers undergo secondary tasks. He and Donmez (2019) discuss the results of a driving simulator study that compared inexperienced drivers with experienced drivers in relation to their secondary task engagement behaviours. They found that while using driving automation, those inexperienced drivers had a higher rate of secondary task performance than those who were experienced, with consequences in driving performance. These results led He and Donmez to conclude that with automation, experienced drivers are more conservative in their secondary task engagement behaviours, compared with inexperienced drivers.

The repetition of the phases in presence of secondary tasks caused a shift to the right of the lead vehicle axis. Indeed, in the case of phases where there were no secondary tasks, the driver tended to keep the regular position, in line with the axis of the lead vehicle. This is attributable to the familiarity of the scenario, as the driver tended to move less to the left to look at the route as he already knew what was in front of him.

The ACC system led to a reduction in speed variation and an increase in distance from the lead vehicle, thus to a safer condition. The shift to the left of the lead vehicle axis was attributable to reduced vehicle control due to the ACC system.

Analyses showed that secondary task 2, i.e., reading the message on the mobile phone, led to a greater variation in speed and a greater variation in distance from the lead vehicle. It follows that there was a difference in behaviour between the secondary tasks and that the second secondary task appeared to have greater negative effects on the driver, due to visual distraction.

From literature review, it is evident that drivers engaging in visual-manual interaction have greater difficulty managing the secondary task demands than drivers engaged in cognitive interactions, such as answering to a question. The implication is that different levels of complexity of mobile phone interactions result in different behavioural responses. Choudhary et al. (2017) showed that mobile phone distracted drivers reduce more their speed compared to drivers that were speaking, as revealed in the findings presented here. Onate-Vega et al. (2020) highlighted that the largest standard deviation of the recorded speed was that of the visual-manual distraction, compared to the cognitive distraction and the non-distraction condition.

Regardless of the type of secondary tasks, but considering only engagement in secondary tasks, a decrease in the distance from the lead vehicle could be observed. This was widely discussed in the literature: studies of the risk of secondary task engagement in conventional driving found that drivers were much more likely to experience a crash or near-crash event when performing secondary tasks (Guo et al., 2017; Klauer et al., 2014). Dingus et al. (2008) showed that engaging in a task that is at least “moderately complex” can significantly elevate crash/near crash risk compared to driving while performing no secondary tasks.

Behavioural changes due to secondary tasks were not influenced by sex of participants.

Table 24 – Secondary task results

Mean	Repetition	ACC	Secondary Task 1 (ST)	Secondary Task 3 (ST)	Sex
	Coefficient Relative difference	Coefficient Relative difference	Coefficient Relative difference	Coefficient Relative difference	Coefficient Relative difference
Speed	-	-.149	-.132	-.038	-
Lateral position	-.015	.023	-	-	-
Distance lead vehicle	-	.089	-.346	-.342	-

CHAPTER 5

SUMMARY, CONCLUSIONS AND LIMITATIONS

This research aimed at providing an answer to some safety concerns that can be introduced by the Partially Automated Vehicles (PAVs) in the traffic flow.

In fact, PAVs still require the human interventions and actions, even after the human disengagement from the driving task. This transition from disengagement to engagement combined with the management of all the other inputs from the driving environment can lead to high risky situations.

Moreover, PAVs can only help the drivers in easy driving tasks, thus taking over requires a fast response and readiness to also manage complex tasks due to the traffic stream. It is evident that the transition from automation to human intervention represents a blind spot for safety, which needs to be assessed.

For this reason, it was decided to use a driving simulator, defined as SAE Level 2 of automation, to analyse the driving behaviour. The aim of the experiment was to analyse the influence of ACC, secondary tasks and route familiarity on the driver behaviour. In particular, this research wanted to explore the following aspects:

- The influence of Adaptive Cruise Control system on the kinematic vehicle parameters of the vehicles (speed, acceleration) and on its position on the route (lateral position, distance from the lead vehicle).
- The effect of performing secondary tasks on the driver. In fact, the same above cited parameters were determined to assess differences due to the driver being distracted by secondary tasks.

- The possible influence of familiarity on the driving task. Tests were run multiple times on the same reproduced road section to assess whether behavioural changes can be attributed to the route familiarity acquired through test repetitions.

The driver behaviour was investigated while participants were asked to perform a dynamic driving task in the simulator. Thirty-seven participants were selected for the driving simulation experiment in order to create a meaningful sample for the analysis and each of these was asked to repeat the driving simulation six times.

The six repetitions differed from each other for the presence of the ACC and secondary tasks, generating 5 different scenarios. The first 4 repetitions followed a fixed order, with the aim of investigate the route familiarity; the last two were alternated in random order and involved the introduction of 3 Secondary tasks during the simulation.

It is important to highlight some limitations of the experiment: the sample was characterized by young drivers aged between 21 and 34 years old; the driving simulator reproduced a Peugeot 406, namely a large family car with automatic gearbox; the driving scenario represented a rural road. Drivers rated the driving experience positively, as shown by the answers to the questionnaires illustrated in the paragraph 3.3.1. An important finding also relates to driving performance. One of the questionnaire's questions was required to evaluate the own performance on the driving simulator, giving a grade from 1 to 20. The resulting average valuation for that indicator was 7,95.

Through statistical analyses, the influence of the independent variables (ACC system, presence of secondary tasks, phase repetition, sex of participants, self-reported attitude to perform secondary tasks during everyday driving) on the dependent variables (speed, acceleration, deceleration, lateral position, distance from the lead vehicle) was analysed. The statistical analyses conducted were of two types, the first concerning the average and standard deviation values assumed by each independent variable during the different simulation phases, and the other concerning the difference in the values of the same independent variables between the moments “Pre” and “Post” application of secondary tasks.

For what concerns overall data, results from the statistical analysis showed that the phase repetition led to an increase in the average deceleration value, a shift to the right of the axis of the lead vehicle, and a decrease in distance from the lead vehicle. These three findings could be explained by the concept of familiarity, as knowledge of the scenario led to greater awareness and thus to more aggressive behaviour. This was also demonstrated by the greater variability in speed and acceleration data, and with the reduced variability in lateral position.

The presence of the ACC system led to an increase in the average values of acceleration and distance from the lead vehicle and a reduction in the average value of speed and deceleration. The presence of the ACC reduced the variability of speed, acceleration, deceleration and distance from the lead vehicle. This can be explained through an increase in the level of driving safety. The greater variability in lateral position, on the other hand, resulted in the driver having less control while driving.

In all analyses, women showed a higher variability of the dependent variables, an increase in distance from the lead vehicle and the reduction in the average acceleration values, interpretable as a more cautious and a less aware behaviour.

The presence of the secondary tasks caused a shift to the right of the lead vehicle axis, as the number of repetitions increase. This is attributable to the familiarity with the scenario, as the driver tended to move less to the left to look at the route as he/she already knew what was in front of him.

The analysis of “Pre” and “Post” values for the secondary tasks showed that the ACC system led to a reduction in speed variation and an increase in distance from the lead vehicle, thus to a safer condition. The shift to the left of the lead vehicle axis was attributable to reduced vehicle control due to the ACC system.

Analyses showed that secondary task 2, i.e., reading the message on the phone, led to a greater variation in speed and a greater variation in distance from the lead vehicle. It follows that the behavioural response was different between the secondary tasks and that the second secondary task appeared to have greater negative effects on the driver, due to visual distraction.

In conclusion, these experiments showed that ACC lead to less variability in user behaviour and greater safety, a major variability in the driving behaviour of women, less distraction in case of cognitive secondary tasks with respect to visual secondary tasks.

Under this light, it is possible to understand that this research work aims to pave the ground for future research in the field of partially automated vehicles and the consequent relation of them with driving behaviour. The implications of performing secondary tasks during regular and partially automated driving should be studied in more detail as well.

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MEAN VALUES

Driver	Number of repetition	Scenario	Duration (s)	PHASE I						
				Duration (s)	Speed (m/s)	Average Acceleration (m/s^2)	Lateral Position (mm)	Distance lead vehicle (m)	Acceleration (m/s^2)	Deceleration (m/s^2)
D1	1	0	258,5	204,50	25,09	0,15	7219,31	92,78	0,50	-0,60
	2	1S	260,5	206,50	25,03	0,14	7316,62	119,98	0,45	-0,74
	3	1	188,5	134,00	22,53	0,18	7231,32	63,37	0,54	-1,18
	4	1S	176	121,50	22,11	0,26	7274,19	65,22	0,72	-1,27
	5	2	208	153,50	23,55	0,17	7295,20	72,73	0,60	-1,26
	6	3	179,5	125,50	21,27	0,21	7258,31	64,33	0,65	-1,13
D2	1	0	184,5	130,00	22,12	0,22	7079,19	65,89	0,53	-2,18
	2	1S	163,5	109,50	29,85	0,38	7285,28	-217,62	0,39	-0,18
	3	1	188,5	134,00	22,53	0,18	7231,32	63,37	0,54	-1,18
	4	1S	176	121,50	22,11	0,26	7274,19	65,22	0,72	-1,27
	5	3	208	153,50	23,55	0,17	7295,20	72,73	0,60	-1,26
	6	2	179,5	125,50	21,37	0,13	7252,89	63,53	0,65	-1,29
D3	1	0	243	189,00	23,94	0,14	7143,95	97,83	0,53	-0,78
	2	1S	247,5	193,00	24,04	0,15	7246,05	164,02	0,41	-1,34
	3	1	229,5	175,50	23,35	0,18	7213,67	98,79	0,55	-1,50
	4	1S	162,5	108,00	21,70	0,29	7002,43	39,41	0,68	-1,84
	5	3	214	159,50	22,22	0,20	7279,59	61,78	0,42	-0,57
	6	2	225,5	171,00	23,86	0,18	7332,50	64,58	0,55	-2,44
D4	1	0	236,5	182,00	19,82	0,16	7076,17	71,79	0,45	-1,19
	2	1S	395	340,50	27,00	0,09	6911,94	109,58	0,25	-0,50
	3	1	317	262,50	26,06	0,12	6871,76	105,28	0,35	-0,55
	4	1S	284,5	230,00	25,12	0,14	7124,14	101,30	0,39	-0,67
	5	2	452	397,50	26,18	0,08	6853,38	99,20	0,24	-0,42
	6	3	361,5	307,50	26,63	0,09	6994,00	107,34	0,30	-0,42
D5	1	0	172,5	118,00	20,22	0,18	6881,16	32,99	0,86	-2,19
	2	1S	204,5	151,00	22,48	0,18	7068,70	57,31	0,62	-1,50
	3	1	180	125,50	21,25	0,19	6651,06	46,40	0,67	-1,36
	4	1S	170,5	116,00	20,50	0,24	7113,53	34,51	0,75	-2,69
	5	3	182	128,00	21,45	0,20	6984,36	55,44	0,81	-2,55
	6	2	182	128,00	21,48	0,23	7186,06	52,86	0,79	-3,25
D6	1	0	492	437,50	25,70	0,07	6860,81	101,96	0,28	-0,30
	2	1S	470,5	416,50	25,49	0,08	6810,25	105,91	0,30	-0,27
	3	1	598	544,00	25,74	0,06	6740,52	97,93	0,23	-0,21
	4	1S	392	338,50	26,87	0,09	6745,68	99,63	0,38	-0,35
	5	3	284	230,00	25,49	0,13	6811,02	95,22	0,46	-0,51
	6	2	396	342,00	26,71	0,10	6797,18	91,73	0,36	-0,32
D7	1	0	181,5	127,50	21,71	0,21	7092,13	53,32	0,70	-2,12
	2	1S	191,5	137,50	23,03	0,22	7251,22	61,41	0,62	-1,13
	3	1	175,5	121,00	22,49	0,24	7337,65	57,74	0,77	-1,78
	4	1S	175	120,50	22,51	0,22	7270,26	53,50	0,73	-1,70
	5	2	185	131,00	22,88	0,21	7260,51	61,38	0,64	-1,47
	6	3	187,5	133,00	22,94	0,20	7236,75	62,10	0,56	-0,90
D8	1	0	190	135,50	22,80	0,20	6813,73	66,93	0,75	-2,24
	2	1S	267,5	213,50	22,70	0,23	6966,07	124,75	0,47	-0,79
	3	1	220	166,00	24,00	0,18	6727,66	82,26	0,52	-1,01
	4	1S	247	192,50	23,72	0,16	6951,49	192,86	0,44	-1,24
	5	2	210	155,50	21,47	0,19	6998,60	111,24	0,58	-1,27
	6	3	298,5	244,00	25,42	0,12	6833,69	130,77	0,39	-0,80
D9	1	0	238,5	184,00	23,72	0,18	6864,60	115,34	0,59	-1,35
	2	1S	192	137,50	21,37	0,22	6947,16	76,12	0,56	-0,93
	3	1	284	229,50	23,45	0,13	6915,62	93,17	0,44	-0,82
	4	1S	282	228,00	23,98	0,13	7036,33	94,41	0,44	-0,92
	5	3	381,5	326,50	25,45	0,09	6873,40	99,76	0,29	-0,42
	6	2	306,5	252,00	25,20	0,12	6919,84	86,89	0,38	-0,52

				PHASE I						
Driver	Number of repetition	Scenario	Duration (s)	Duration (s)	Speed (m/s)	Average Acceleration (m/s^2)	Lateral Position (mm)	Distance lead vehicle (m)	Acceleration (m/s^2)	Deceleration (m/s^2)
D10	1	0	216	162,00	23,23	0,17	6734,78	79,18	0,62	-0,69
	2	1S	184	130,00	22,49	0,19	6726,94	71,12	0,68	-1,46
	3	1	175,5	121,00	22,22	0,26	6708,63	67,98	0,69	-1,36
	4	1S	194,5	140,00	21,95	0,19	6843,09	72,00	0,73	-1,34
	5	3	224,5	170,00	24,65	0,19	6717,36	78,21	0,60	-0,94
	6	2	176,5	122,50	22,37	0,26	6816,77	67,25	0,71	-1,14
D11	1	0	162,5	108,00	21,90	0,25	7076,37	44,32	0,80	-1,35
	2	1S	177	122,50	22,27	0,20	6838,52	53,07	0,60	-1,47
	3	1	161	106,50	22,25	0,23	6806,22	45,45	0,60	-0,81
	4	1S	162	107,50	22,01	0,26	6847,52	39,50	0,71	-0,98
	5	3	160,5	107,00	22,11	0,27	6919,63	42,13	0,63	-0,65
	6	2	164,5	110,50	21,83	0,25	6934,70	59,39	0,61	-1,01
D12	1	0	213	159,00	23,46	0,20	7359,07	89,76	0,49	-1,00
	2	1S	212	158,00	22,62	0,18	7015,13	84,54	0,56	-0,96
	3	1	237	183,00	22,53	0,17	7357,52	99,81	0,55	-1,09
	4	1S	192,5	138,00	20,96	0,22	7252,85	73,68	0,60	-1,92
	5	2	249,5	195,50	23,35	0,13	7177,31	123,72	0,48	-2,08
	6	3	191,5	137,00	22,09	0,21	7336,07	61,22	0,62	-1,86
D13	1	0	389,5	335,00	27,06	0,06	7201,50	138,53	0,53	-0,85
	2	1S	249	194,50	23,06	0,09	7220,57	124,31	0,51	-0,97
	3	1	241	187,00	21,83	0,15	7160,22	91,88	0,58	-2,04
	4	1S	279	224,50	23,09	0,12	7057,66	106,44	0,53	-1,15
	5	3	247,5	193,00	23,05	0,16	7123,39	148,40	0,58	-2,32
	6	2	204,5	150,00	22,05	0,21	7037,41	88,27	0,71	-4,10
D14	1	0	192,5	138,50	21,29	0,21	7045,30	83,41	0,57	-1,32
	2	1S	460	406,00	27,52	0,08	6911,43	85,71	0,34	-0,34
	3	1	246,5	192,00	24,76	0,14	6866,85	89,48	0,43	-0,57
	4	1S	302	247,50	24,76	0,12	6873,76	97,81	0,39	-0,45
	5	2	375	320,50	27,20	0,10	6897,90	82,43	0,32	-0,38
	6	3	274	219,50	25,16	0,13	6873,98	116,14	0,46	-0,72
D15	1	0	218	163,50	23,64	0,14	6865,61	87,35	0,50	-2,81
	2	1S	214,5	160,00	23,71	0,15	7124,48	129,76	0,64	-2,28
	3	1	174,5	120,00	22,44	0,24	6870,48	54,17	0,54	-2,12
	4	1S	197,5	144,00	23,23	0,20	7167,82	68,96	0,53	-3,13
	5	2	179	124,50	22,79	0,18	7047,62	44,57	0,61	-3,12
	6	3	180	125,50	22,45	0,23	6801,57	53,33	0,66	-2,79
D16	1	0	163	108,00	21,73	0,29	6935,14	41,68	0,86	-1,45
	2	1S	172,5	118,00	22,38	0,21	6945,44	52,86	0,74	-2,24
	3	1	161	106,00	22,06	0,29	7116,12	43,26	0,70	-1,33
	4	1S	169	114,50	22,44	0,27	7093,06	49,93	0,66	-2,04
	5	3	160,5	106,50	22,24	0,26	7130,58	43,91	0,67	-1,47
	6	2	160,5	106,50	22,28	0,21	7131,86	43,67	0,59	-1,94
D17	1	0	243	188,50	23,93	0,16	7366,86	177,61	0,51	-1,51
	2	1S	227	172,50	23,92	0,17	7070,81	108,76	0,57	-2,51
	3	1	207,5	153,00	22,14	0,16	7011,14	60,97	0,64	-2,88
	4	1S	162,5	108,00	21,94	0,29	7015,25	43,93	0,65	-1,92
	5	2	175,5	121,50	21,41	0,24	7378,62	73,51	0,68	-2,07
	6	3	276	221,50	24,53	0,15	7200,34	118,79	0,52	-0,88
D18	1	0	389	334,50	26,36	0,10	7066,84	87,75	0,38	-0,51
	2	1S	380,5	326,50	26,74	0,10	7060,72	116,51	0,39	-0,59
	3	1	160,5	106,50	22,34	0,24	7210,11	44,60	0,66	-0,80
	4	1S	160,5	106,50	22,38	0,29	7239,11	42,72	0,70	-1,22
	5	3	179,5	125,00	22,94	0,22	7271,71	55,74	0,57	-1,07
	6	2	181	126,50	23,04	0,24	7231,00	54,37	0,59	-1,29
D19	1	0	212,5	158,00	21,49	0,21	7108,25	72,76	0,69	-4,01
	2	1S	217	163,00	24,18	0,18	7034,15	71,97	0,58	-1,23
	3	1	208,5	154,00	23,62	0,19	7040,42	87,92	0,59	-1,78

Driver	Number of repetition	Scenario	Duration (s)	PHASE I						
				Duration (s)	Speed (m/s)	Average Acceleration (m/s^2)	Lateral Position (mm)	Distance lead vehicle (m)	Acceleration (m/s^2)	Deceleration (m/s^2)
D19	4	1S	187	133,00	22,76	0,23	7090,57	77,66	0,63	-1,82
	5	2	234	179,50	24,79	0,16	6973,88	84,29	0,69	-2,08
	6	3	197,5	143,50	22,97	0,22	7182,81	75,85	0,56	-1,69
D20	1	0	375,5	321,50	26,45	0,09	7046,37	192,84	0,31	-1,38
	2	1S	354	299,50	26,08	0,10	6994,96	156,27	0,37	-0,45
	3	1	245,5	191,00	25,02	0,16	7086,71	105,95	0,48	-2,26
	4	1S	280	226,00	25,15	0,14	7072,28	117,31	0,39	-0,93
	5	2	212,5	158,00	23,13	0,18	6887,42	87,94	0,59	-2,47
	6	3	238,5	184,00	24,83	0,15	6991,65	87,96	0,53	-1,05
D21	1	0								
	2	1S								
	3	1	160,5	106,00	22,05	0,27	6962,99	43,90	0,58	-0,10
	4	1S	160,5	106,00	22,09	0,29	6946,15	40,69	0,70	-0,43
	5	3	187	133,00	22,62	0,18	7031,77	61,27	0,54	-0,60
	6	2	160,5	106,00	22,02	0,27	7129,65	41,09	0,61	-0,72
D22	1	0	502,5	448,00	25,81	0,05	7038,80	200,75	0,33	-0,62
	2	1S	275,5	221,00	23,05	0,14	7023,42	90,26	0,42	-1,75
	3	1	280,5	226,00	23,99	0,13	7109,33	117,70	0,48	-0,62
	4	1S	171,5	117,50	19,44	0,25	7215,91	65,40	0,65	-1,64
	5	3	230,5	176,00	22,88	0,16	7062,06	105,51	0,63	-1,10
	6	2	224	169,50	23,35	0,14	7079,66	74,30	0,59	-2,26
D23	1	0	662,5	608,50	26,45	0,05	6869,69	284,76	0,24	-0,31
	2	1S	463	409,00	26,69	0,06	6997,98	219,47	0,37	-0,74
	3	1	368,5	314,00	25,83	0,10	6867,80	134,32	0,31	-0,73
	4	1S	403	348,50	26,53	0,09	6906,29	139,65	0,37	-0,41
	5	2	219	164,50	22,52	0,19	7064,70	105,29	0,52	-0,87
	6	3	312	257,50	25,00	0,11	6947,07	143,88	0,42	-1,20
D24	1	0	212	157,50	21,00	0,20	6838,18	75,52	0,71	-1,15
	2	1S	182,5	128,00	21,87	0,17	6836,74	64,95	0,64	-1,27
	3	1	176,5	122,00	22,33	0,24	6909,33	53,80	0,69	-1,03
	4	1S	174,5	120,50	22,43	0,24	6979,08	47,47	0,74	-2,19
	5	3	175,5	121,00	22,42	0,25	7093,26	48,13	0,79	-2,31
	6	2	177	123,00	21,89	0,21	6956,19	59,71	0,75	-2,63
D25	1	0	196	141,50	23,00	0,19	7064,28	83,28	0,75	-2,23
	2	1S	392,5	338,00	25,65	0,09	7074,54	143,11	0,66	-1,60
	3	1	220,5	166,00	23,36	0,19	7068,70	101,63	0,69	-2,36
	4	1S	191	136,50	22,45	0,23	7142,23	84,29	0,79	-2,60
	5	3	193	138,50	22,13	0,25	7321,58	99,17	0,71	-1,78
	6	2	221	166,50	23,77	0,19	7268,42	109,30	0,77	-2,14
D26	1	0	333	279,00	23,97	0,10	6872,85	104,28	0,45	-0,73
	2	1S	175,5	121,00	21,36	0,17	6898,37	68,93	0,78	-2,74
	3	1	265,5	211,00	24,75	0,15	6922,78	87,64	0,48	-1,24
	4	1S	181	126,50	22,52	0,22	6855,90	67,39	0,64	-3,09
	5	2	274	218,50	24,33	0,13	6967,10	96,89	0,32	-1,22
	6	3	188,5	134,00	20,68	0,22	7110,43	91,86	0,60	-1,65
D27	1	0	189,5	135,00	22,37	0,20	7399,85	71,63	0,75	-2,77
	2	1S	179	124,50	21,51	0,25	7449,16	72,15	0,68	-2,86
	3	1	178	124,00	21,23	0,24	7217,54	78,99	0,67	-1,47
	4	1S	228	173,50	22,98	0,17	7322,69	83,78	0,59	-1,55
	5	3	279	221,00	24,80	0,14	7401,58	87,81	0,59	-1,43
	6	2	323	263,00	25,86	0,12	7290,94	92,59	0,44	-0,78
D28	1	0	232	144,50	22,30	0,17	6867,26	87,32	0,51	-2,01
	2	1S	346,5	292,00	25,26	0,11	7145,90	127,20	0,40	-0,68
	3	1	259,5	205,00	24,01	0,14	7055,92	78,88	0,48	-1,49
	4	1S	308	253,50	22,26	0,11	7070,83	109,59	0,62	-0,96
	5	2	314	259,50	25,28	0,10	6957,97	102,53	0,43	-0,64
	6	3	216,5	162,50	21,98	0,19	7121,31	92,88	0,68	-2,77

Driver	Number of repetition	Scenario	Duration (s)	PHASE I						
				Duration (s)	Speed (m/s)	Average Acceleration (m/s^2)	Lateral Position (mm)	Distance lead vehicle (m)	Acceleration (m/s^2)	Deceleration (m/s^2)
D29	1	0	518,5	464,00	26,35	0,06	6762,71	164,71	0,39	-0,72
	2	1S	250,5	196,00	23,63	0,16	7042,31	88,32	0,53	-0,92
	3	1	184	129,50	20,88	0,23	6826,09	61,10	0,73	-2,91
	4	1S	290,5	236,50	25,11	0,11	6904,99	93,28	0,50	-1,22
	5	2	187,5	133,00	21,00	0,24	7093,57	67,91	0,70	-2,74
	6	3	185,5	131,00	20,57	0,23	7066,22	66,99	0,66	-2,41
D30	1	0	211,5	157,00	19,74	0,31	6765,32	104,25	0,76	-3,02
	2	1S	193,5	139,50	22,49	0,23	6667,71	73,67	0,73	-2,37
	3	1	183,5	129,50	22,66	0,20	6546,76	61,20	0,72	-2,30
	4	1S	176,5	122,00	22,40	0,21	6652,35	55,96	0,72	-1,75
	5	3	175	120,50	22,09	0,26	6776,29	60,21	0,75	-1,77
	6	2	207,5	153,00	23,88	0,21	6416,73	71,98	0,69	-1,63
D31	1	0	498	444,00	25,94	0,07	6939,96	143,42	0,30	-0,57
	2	1S	314,5	260,00	24,53	0,12	7345,93	104,34	0,48	-0,73
	3	1	262	207,50	23,91	0,14	7435,96	93,74	0,56	-0,84
	4	1S	197	143,00	20,80	0,21	7090,71	82,45	0,57	-1,08
	5	2	246,5	192,00	23,50	0,16	7314,08	94,01	0,51	-1,09
	6	3	221	166,50	22,29	0,17	7422,86	77,78	0,52	-1,83
D32	1	0	175	120,50	22,40	0,30	7413,97	54,77	0,80	-2,67
	2	1S	175,5	121,00	22,52	0,23	7311,18	45,56	0,75	-2,00
	3	1	175	120,50	22,59	0,22	7453,72	43,22	0,74	-2,11
	4	1S	176,5	122,00	22,33	0,24	7454,64	45,45	0,66	-1,97
	5	3	184	129,50	21,39	0,24	7536,47	62,45	0,77	-1,85
	6	2	176,5	122,00	22,28	0,23	7395,04	45,29	0,70	-1,94
D33	1	0	282	227,50	24,69	0,15	7166,90	183,66	0,59	-1,33
	2	1S	189	134,50	22,11	0,24	7303,51	77,59	0,70	-2,68
	3	1	197	142,50	23,14	0,18	7326,28	73,74	0,76	-2,68
	4	1S	228,5	174,50	24,61	0,18	6984,41	144,31	0,74	-3,09
	5	3	188,5	134,00	23,23	0,22	7061,99	68,29	0,81	-3,23
	6	2	209	154,50	21,47	0,21	7048,51	71,55	0,74	-3,09
D34	1	0	222,5	168,50	23,97	0,19	6937,28	110,51	0,75	-2,69
	2	1S	189	134,50	22,10	0,21	7015,50	78,63	0,78	-5,15
	3	1	188,5	134,00	22,93	0,23	7261,24	67,47	0,77	-4,05
	4	1S	191	136,50	22,49	0,22	6958,86	75,37	0,74	-3,42
	5	3	241,5	187,00	25,30	0,14	7077,81	198,61	0,67	-4,26
	6	2	184	129,50	21,57	0,23	7076,89	78,33	0,74	-3,29
D35	1	0	184,5	130,00	22,60	0,24	6875,39	82,95	0,79	-2,65
	2	1S	182	127,50	21,52	0,24	6860,12	78,66	0,71	-1,72
	3	1	179,5	125,50	22,60	0,23	6883,88	62,28	0,63	-1,63
	4	1S	195	141,00	23,12	0,20	7009,26	80,94	0,72	-1,84
	5	2	202	147,50	23,25	0,21	6818,34	86,99	0,64	-2,00
	6	3	237,5	183,00	23,64	0,17	6848,67	89,21	0,58	-1,39
D36	1	0	439,5	385,50	25,17	0,08	7161,95	135,44	0,41	-0,43
	2	1S	253	198,50	23,00	0,14	7191,51	100,60	0,53	-1,05
	3	1	199,5	145,00	21,17	0,21	7178,55	75,56	0,54	-1,02
	4	1S	319	264,50	25,07	0,11	7376,51	120,65	0,47	-0,51
	5	2	415,5	361,00	25,17	0,09	7200,25	123,52	0,36	-0,36
	6	3	390,5	336,00	25,15	0,09	7237,64	119,61	0,63	-1,02
D37	1	0	295,5	241,00	23,68	0,13	7178,07	129,40	0,59	-1,56
	2	1S	349,5	295,00	26,08	0,06	7297,33	130,21	0,48	-0,55
	3	1	199,5	145,00	21,60	0,21	7068,55	75,30	0,64	-2,40
	4	1S	300	246,00	23,44	0,18	7195,27	124,76	0,81	-0,65
	5	3	310,5	256,00	21,47	0,11	7323,36	95,49	0,48	-1,35
	6	2	225,5	171,50	22,33	0,18	7483,69	73,56	0,62	-1,92

MEAN VALUES										
				PHASE II						
Driver	Number of repetition	Scenario	Duration (s)	Duration (s)	Speed (m/s)	Average Acceleration (m/s^2)	Lateral Position (mm)	Distance lead vehicle (m)	Acceleration (m/s^2)	Deceleration (m/s^2)
D1	1	0	258,5	54,00	33,49	0,12	6449,31	-197,56	0,31	-0,11
	2	1S	260,5	54,00	22,27	-0,13	7211,98	103,32	0,64	-1,78
	3	1	188,5	54,50	22,64	0,01	7280,24	99,74	0,63	-1,67
	4	1S	176	54,50	22,16	-0,19	7187,82	86,87	0,65	-1,89
	5	2	208	54,50	23,65	-0,13	7192,41	53,32	0,59	-1,84
	6	3	179,5	54,00	23,07	-0,05	7292,19	61,09	0,76	-2,12
D2	1	0	184,5	54,50	24,85	-0,21	7129,68	66,54	0,50	-1,20
	2	1S	163,5	54,00	32,67	-0,21	7256,36	-1166,47	0,32	-1,65
	3	1	188,5	54,50	22,64	0,01	7280,24	99,74	0,63	-1,67
	4	1S	176	54,50	22,16	-0,19	7187,82	86,87	0,65	-1,89
	5	3	208	54,50	23,65	-0,13	7192,41	53,32	0,59	-1,84
	6	2	179,5	54,00	22,98	0,13	7310,09	62,88	0,76	-2,00
D3	1	0	243	54,00	24,67	-0,15	6799,13	83,03	0,30	-1,49
	2	1S	247,5	54,50	24,99	-0,04	7291,42	93,60	0,54	-1,60
	3	1	229,5	54,00	22,55	-0,15	7168,26	67,99	0,63	-1,97
	4	1S	162,5	54,50	22,83	-0,13	7038,42	59,54	0,62	-2,00
	5	3	214	54,50	23,30	-0,20	7425,52	39,63	0,67	-2,48
	6	2	225,5	54,50	21,27	-0,14	6866,70	102,46	0,69	-1,81
D4	1	0	236,5	54,50	24,05	-0,14	6896,01	70,80	0,23	-0,79
	2	1S	395	54,50	23,88	-0,18	7162,77	39,40	0,72	-1,98
	3	1	317	54,50	23,98	-0,16	6876,59	43,35	0,63	-1,67
	4	1S	284,5	54,50	21,89	-0,14	6457,42	96,29	0,67	-1,70
	5	2	452	54,50	23,27	-0,12	6992,83	88,44	0,77	-1,91
	6	3	361,5	54,00	25,29	-0,14	6809,63	89,09	0,20	-1,01
D5	1	0	172,5	54,50	22,66	-0,09	7052,98	27,47	0,80	-2,60
	2	1S	204,5	53,50	22,31	-0,07	6916,75	58,48	0,63	-1,79
	3	1	180	54,50	22,85	0,03	6983,33	99,76	0,62	-1,58
	4	1S	170,5	54,50	21,94	-0,06	6922,29	74,02	0,64	-1,82
	5	3	182	54,00	23,60	-0,08	6931,24	29,62	0,74	-2,79
	6	2	182	54,00	21,52	-0,11	7134,00	92,29	0,61	-2,07
D6	1	0	492	54,50	24,09	-0,23	6874,44	69,31	0,55	-0,58
	2	1S	470,5	54,00	24,07	-0,30	6989,04	62,08	0,72	-2,03
	3	1	598	54,00	24,79	-0,15	6678,65	67,85	0,65	-1,75
	4	1S	392	53,50	24,12	-0,09	6848,48	66,52	0,71	-1,73
	5	3	284	54,00	24,49	-0,21	6862,65	65,66	0,48	-1,06
	6	2	396	54,00	21,13	-0,17	6938,08	110,93	0,75	-1,83
D7	1	0	181,5	54,00	23,10	-0,17	7231,27	23,90	0,61	-1,64
	2	1S	191,5	54,00	23,09	-0,23	7413,38	35,16	0,58	-1,93
	3	1	175,5	54,50	22,87	-0,17	7308,57	41,08	0,59	-1,99
	4	1S	175	54,50	21,35	-0,08	7222,97	91,91	0,61	-1,70
	5	2	185	54,00	21,98	-0,09	7323,01	76,57	0,60	-1,70
	6	3	187,5	54,50	23,41	-0,13	7316,42	28,37	0,52	-1,28
D8	1	0	190	54,50	23,84	-0,13	6937,73	56,17	0,54	-1,60
	2	1S	267,5	54,00	26,45	-0,02	6672,93	100,56	0,48	-1,89
	3	1	220	54,00	23,65	-0,11	6820,39	79,55	0,56	-1,62
	4	1S	247	54,50	22,52	-0,13	6830,38	102,59	0,59	-1,66
	5	2	210	54,50	25,03	-0,21	6485,29	82,92	0,53	-2,05
	6	3	298,5	54,50	24,35	-0,21	6623,62	71,50	0,40	-1,44
D9	1	0	238,5	54,50	24,52	-0,25	6758,19	68,03	0,49	-1,46
	2	1S	192	54,50	23,26	-0,12	7014,59	102,36	0,58	-1,57
	3	1	284	54,50	24,67	-0,16	6760,00	89,49	0,54	-1,68
	4	1S	282	54,00	24,56	-0,14	6647,32	67,70	0,54	-1,67
	5	3	381,5	55,00	24,14	-0,14	6590,48	62,75	0,32	-1,14
	6	2	306,5	54,50	24,56	-0,11	6738,99	65,23	0,56	-1,50

Driver	Number of repetition	Scenario	Duration (s)	PHASE II						
				Duration (s)	Speed (m/s)	Average Acceleration (m/s^2)	Lateral Position (mm)	Distance lead vehicle (m)	Acceleration (m/s^2)	Deceleration (m/s^2)
D10	1	0	216	54,00	23,62	-0,15	6615,55	47,02	0,52	-1,29
	2	1S	184	54,00	22,82	-0,01	6738,93	97,67	0,58	-1,69
	3	1	175,5	54,50	23,27	-0,15	6695,80	63,88	0,59	-2,15
	4	1S	194,5	54,50	23,25	-0,12	6822,36	68,00	0,57	-1,90
	5	3	224,5	54,50	23,68	-0,16	6593,08	42,20	0,63	-2,12
	6	2	176,5	54,00	23,64	-0,17	6848,70	49,29	0,55	-1,85
D11	1	0	162,5	54,50	22,98	-0,13	6943,37	35,25	0,69	-2,18
	2	1S	177	54,50	22,97	0,02	6813,61	77,51	0,61	-1,65
	3	1	161	54,50	23,39	-0,09	6824,64	42,34	0,61	-1,85
	4	1S	162	54,50	23,25	-0,14	6816,84	39,01	0,62	-2,01
	5	3	160,5	53,50	22,32	-0,14	6851,23	82,13	0,65	-1,85
	6	2	164,5	54,00	23,36	-0,17	6977,90	74,86	0,58	-1,77
D12	1	0	213	54,00	23,27	-0,26	7273,50	51,86	0,52	-1,58
	2	1S	212	54,00	24,76	-0,13	7213,31	69,55	0,55	-1,82
	3	1	237	54,00	23,10	-0,20	7251,79	42,35	0,60	-2,00
	4	1S	192,5	54,50	24,53	-0,15	6911,12	42,55	0,55	-1,72
	5	2	249,5	54,00	23,23	-0,13	6891,49	41,50	0,61	-2,03
	6	3	191,5	54,50	24,24	-0,05	7289,81	67,12	0,39	-2,00
D13	1	0	389,5	54,50	23,92	-0,03	7333,53	36,86	0,63	-2,94
	2	1S	249	54,50	20,55	0,11	6739,52	196,80	0,71	-1,61
	3	1	241	54,00	25,05	-0,04	7650,85	207,21	0,53	-1,67
	4	1S	279	54,50	24,52	-0,02	6811,78	240,87	0,56	-1,60
	5	3	247,5	54,50	23,48	-0,14	6509,65	36,67	0,76	-2,21
	6	2	204,5	54,50	21,33	-0,15	6929,50	109,21	0,69	-1,98
D14	1	0	192,5	54,00	23,70	-0,23	7103,53	65,01	0,46	-1,53
	2	1S	460	54,00	24,51	-0,21	6773,98	75,25	0,72	-1,72
	3	1	246,5	54,50	25,00	-0,04	6641,82	140,11	0,53	-1,66
	4	1S	302	54,50	24,98	-0,14	6588,04	106,53	0,54	-1,85
	5	2	375	54,50	24,04	-0,08	6833,25	102,12	0,70	-1,76
	6	3	274	54,50	25,11	-0,20	6779,66	103,48	0,35	-1,15
D15	1	0	218	54,50	23,66	-0,11	7099,85	31,87	0,67	-2,46
	2	1S	214,5	54,50	23,22	-0,03	7081,04	60,02	0,60	-1,60
	3	1	174,5	54,50	23,29	-0,06	6734,82	59,66	0,60	-1,94
	4	1S	197,5	53,50	23,16	-0,09	7320,11	49,68	0,61	-1,96
	5	2	179	54,50	22,18	0,05	7162,90	105,22	0,64	-1,63
	6	3	180	54,50	23,30	-0,24	6314,08	35,97	0,86	-4,31
D16	1	0	163	55,00	23,19	-0,24	7056,71	28,29	0,66	-1,93
	2	1S	172,5	54,50	23,41	-0,02	6911,88	51,29	0,60	-1,55
	3	1	161	55,00	23,18	-0,13	7108,41	53,32	0,61	-1,92
	4	1S	169	54,50	22,85	-0,13	7184,68	65,81	0,62	-1,85
	5	3	160,5	54,00	22,97	-0,23	7148,52	27,72	0,67	-1,94
	6	2	160,5	54,00	22,29	0,02	7183,67	92,05	0,63	-1,78
D17	1	0	243	54,50	24,44	-0,27	7073,39	47,46	0,44	-1,98
	2	1S	227	54,50	21,35	-0,10	7077,11	106,79	0,68	-1,89
	3	1	207,5	54,50	23,12	0,02	6947,43	65,59	0,61	-1,59
	4	1S	162,5	54,50	22,82	-0,27	7469,51	35,81	0,64	-2,44
	5	2	175,5	54,00	24,86	-0,24	7114,62	99,68	0,54	-1,99
	6	3	276	54,50	24,17	-0,27	6741,71	39,64	0,73	-1,74
D18	1	0	389	54,50	22,75	-0,19	7040,51	121,96	0,54	-1,85
	2	1S	380,5	54,00	23,22	-0,11	7085,72	61,28	0,74	-2,01
	3	1	160,5	54,00	23,01	-0,09	7319,24	45,22	0,62	-2,10
	4	1S	160,5	54,00	21,41	-0,15	7293,30	82,81	0,67	-2,09
	5	3	179,5	54,50	23,54	-0,19	7143,37	46,20	0,32	-0,83
	6	2	181	54,50	22,02	-0,12	7309,17	78,18	0,66	-1,81
D19	1	0	212,5	54,50	23,41	-0,27	7061,85	45,73	0,49	-2,55
	2	1S	217	54,00	22,98	-0,12	7057,24	89,50	0,61	-1,83
	3	1	208,5	54,50	24,89	-0,19	7162,74	74,33	0,55	-2,13

Driver	Number of repetition	Scenario	Duration (s)	PHASE II						
				Duration (s)	Speed (m/s)	Average Acceleration (m/s^2)	Lateral Position (mm)	Distance lead vehicle (m)	Acceleration (m/s^2)	Deceleration (m/s^2)
D19	4	1S	187	54,00	22,41	-0,14	7123,20	116,66	0,63	-1,88
	5	2	234	54,50	22,52	-0,09	7054,35	117,29	0,64	-2,07
	6	3	197,5	54,00	24,14	-0,24	7165,26	62,96	0,43	-1,96
D20	1	0	375,5	54,00	24,27	-0,13	6447,46	69,75	0,35	-1,66
	2	1S	354	54,50	25,16	-0,25	7030,14	109,86	0,63	-2,25
	3	1	245,5	54,50	22,08	-0,17	6630,00	71,31	0,65	-2,23
	4	1S	280	54,00	22,78	-0,13	6738,72	90,44	0,61	-1,88
	5	2	212,5	54,50	25,34	-0,05	6842,23	117,42	0,53	-1,61
	6	3	238,5	54,50	23,30	-0,06	6856,54	80,85	0,32	-0,29
D21	1	0								
	2	1S								
	3	1	160,5	54,50	23,98	-0,12	7022,05	34,62	0,57	-1,62
	4	1S	160,5	54,50	23,65	-0,13	6945,39	42,06	0,58	-1,88
	5	3	187	54,00	25,53	-0,09	7124,95	56,41	0,24	-1,09
	6	2	160,5	54,50	23,67	-0,10	7137,17	51,42	0,58	-1,71
D22	1	0	502,5	54,50	23,61	-0,17	5950,53	1767,38	0,60	-2,50
	2	1S	275,5	54,50	22,25	-0,12	6292,54	98,09	0,64	-1,87
	3	1	280,5	54,50	23,72	-0,13	6679,19	72,42	0,58	-1,96
	4	1S	171,5	54,00	24,71	-0,20	7180,58	74,74	0,55	-1,97
	5	3	230,5	54,50	23,92	-0,17	6998,12	55,10	0,45	-1,36
	6	2	224	54,50	21,17	0,03	6772,90	132,54	0,70	-1,80
D23	1	0	662,5	54,00	24,44	-0,24	7207,81	105,91	0,54	-0,90
	2	1S	463	54,00	23,63	-0,02	6759,19	62,30	0,73	-1,71
	3	1	368,5	54,50	23,84	-0,17	6942,30	94,59	0,67	-1,99
	4	1S	403	54,50	25,24	-0,23	6821,24	65,32	0,70	-2,45
	5	2	219	54,50	22,43	-0,14	7375,60	86,38	0,64	-1,99
	6	3	312	54,50	24,13	-0,17	6761,21	105,83	0,65	-2,19
D24	1	0	212	54,50	23,40	-0,27	6879,15	25,83	0,59	-1,87
	2	1S	182,5	54,50	21,51	0,02	6873,67	226,47	0,61	-1,58
	3	1	176,5	54,50	23,62	-0,11	6778,88	46,94	0,56	-1,70
	4	1S	174,5	54,00	23,26	-0,24	7136,92	20,96	0,57	-2,06
	5	3	175,5	54,50	23,42	-0,19	7145,23	13,68	0,66	-2,22
	6	2	177	54,00	23,72	-0,02	6858,74	100,08	0,57	-1,59
D25	1	0	196	54,50	23,78	-0,17	7111,78	105,68	0,75	-2,66
	2	1S	392,5	54,50	15,68	-0,30	7240,45	265,13	0,75	-2,10
	3	1	220,5	54,50	23,85	-0,13	7205,84	75,52	0,57	-1,72
	4	1S	191	54,50	23,02	-0,15	7090,96	88,31	0,58	-1,68
	5	3	193	54,50	24,59	-0,28	7169,00	75,37	0,79	-3,51
	6	2	221	54,50	23,41	-0,12	7414,02	109,94	0,58	-2,05
D26	1	0	333	54,00	26,89	-0,11	6546,02	116,61	0,59	-0,87
	2	1S	175,5	54,50	20,35	0,04	7005,20	281,71	0,63	-1,56
	3	1	265,5	54,50	23,34	-0,22	6802,84	46,43	0,58	-1,94
	4	1S	181	54,50	23,80	-0,13	6949,15	53,91	0,56	-2,01
	5	2	274	55,50	24,59	-0,02	6865,46	148,89	0,55	-1,61
	6	3	188,5	54,50	26,15	-0,22	7158,87	96,79	0,33	-1,65
D27	1	0	189,5	54,50	23,16	-0,17	7482,72	36,50	0,62	-3,09
	2	1S	179	54,50	23,13	-0,13	7379,86	101,78	0,58	-1,70
	3	1	178	54,00	23,09	-0,12	7462,52	136,16	0,58	-1,63
	4	1S	228	54,50	24,86	-0,16	7421,50	87,03	0,54	-1,70
	5	3	279	58,00	23,66	-0,31	7336,11	70,06	0,49	-2,03
	6	2	323	60,00	18,50	-0,21	6867,70	200,43	0,68	-2,06
D28	1	0	232	87,50	24,80	-0,19	6981,83	66,73	0,25	-1,02
	2	1S	346,5	54,50	23,23	-0,12	7298,66	80,99	0,63	-1,84
	3	1	259,5	54,50	22,47	-0,10	6891,37	57,65	0,59	-1,61
	4	1S	308	54,50	21,78	-0,09	6801,56	81,48	0,60	-1,75
	5	2	314	54,50	23,24	0,00	7025,99	65,27	0,59	-1,70
	6	3	216,5	54,00	25,50	-0,13	7381,20	80,26	0,24	-0,63

Driver	Number of repetition	Scenario	Duration (s)	PHASE II						
				Duration (s)	Speed (m/s)	Average Acceleration (m/s^2)	Lateral Position (mm)	Distance lead vehicle (m)	Acceleration (m/s^2)	Deceleration (m/s^2)
D29	1	0	518,5	54,50	23,43	-0,23	6380,53	66,67	0,26	-1,00
	2	1S	250,5	54,50	23,52	-0,12	6764,19	61,78	0,57	-1,75
	3	1	184	54,50	20,74	-0,15	6942,96	115,04	0,63	-1,85
	4	1S	290,5	54,00	23,47	-0,01	6586,19	69,95	0,58	-1,65
	5	2	187,5	54,50	21,32	-0,17	6890,90	108,38	0,63	-2,08
	6	3	185,5	54,50	23,26	-0,13	7197,29	55,47	0,47	-1,14
D30	1	0	211,5	54,50	26,46	0,04	6457,11	42,45	0,71	-2,15
	2	1S	193,5	54,00	21,63	-0,17	6489,44	99,88	0,61	-1,98
	3	1	183,5	54,00	23,61	-0,12	6197,70	54,78	0,57	-1,80
	4	1S	176,5	54,50	23,31	-0,01	6603,24	70,60	0,58	-1,59
	5	3	175	54,50	24,37	-0,17	6629,79	42,81	0,74	-2,33
	6	2	207,5	54,50	21,78	-0,16	6398,67	98,48	0,61	-1,86
D31	1	0	498	54,00	24,80	-0,31	6453,00	64,54	0,37	-1,02
	2	1S	314,5	54,50	23,27	-0,13	6705,06	77,61	0,60	-1,78
	3	1	262	54,50	24,71	-0,21	7357,46	77,74	0,55	-2,00
	4	1S	197	54,00	23,89	-0,10	7333,29	114,87	0,55	-1,69
	5	2	246,5	54,50	24,24	-0,23	7295,56	56,71	0,54	-1,89
	6	3	221	54,50	23,20	-0,24	7330,52	41,35	0,43	-2,07
D32	1	0	175	54,50	23,40	-0,35	7312,44	16,28	0,64	-2,43
	2	1S	175,5	54,50	21,67	-0,09	7630,44	70,80	0,61	-1,75
	3	1	175	54,50	22,48	-0,05	7516,00	46,56	0,59	-1,59
	4	1S	176,5	54,50	22,86	-0,08	7348,04	45,02	0,59	-1,67
	5	3	184	54,50	23,48	-0,31	7529,59	23,53	0,65	-2,33
	6	2	176,5	54,50	23,27	-0,12	7413,99	28,58	0,58	-1,95
D33	1	0	282	54,50	24,44	-0,29	7044,05	61,64	0,78	-2,37
	2	1S	189	54,50	21,53	-0,17	7396,17	89,88	0,62	-1,89
	3	1	197	54,50	23,78	-0,01	6884,52	68,95	0,57	-1,60
	4	1S	228,5	54,00	22,43	-0,15	6881,15	66,57	0,61	-2,01
	5	3	188,5	54,50	23,77	-0,09	7251,40	27,21	0,80	-2,32
	6	2	209	54,50	18,46	-0,22	7243,35	158,10	0,67	-2,10
D34	1	0	222,5	54,00	22,87	-0,35	7115,90	31,74	0,73	-3,13
	2	1S	189	54,50	25,16	-0,04	7103,22	149,30	0,53	-1,66
	3	1	188,5	54,50	22,63	-0,15	7105,81	80,89	0,60	-1,77
	4	1S	191	54,50	24,71	-0,20	7308,15	52,57	0,54	-1,81
	5	3	241,5	54,50	23,14	-0,17	7164,95	32,46	0,63	-4,19
	6	2	184	54,50	25,79	-0,05	7170,44	123,62	0,52	-1,61
D35	1	0	184,5	54,50	24,15	-0,26	6798,73	54,81	0,72	-2,17
	2	1S	182	54,50	24,46	-0,27	6829,87	48,33	0,55	-2,31
	3	1	179,5	54,00	23,05	-0,14	7102,68	67,27	0,57	-1,89
	4	1S	195	54,00	23,49	-0,20	7187,44	54,77	0,57	-2,03
	5	2	202	54,50	22,49	-0,14	6866,25	98,40	0,60	-1,70
	6	3	237,5	54,50	24,46	-0,21	6867,33	92,20	0,71	-1,77
D36	1	0	439,5	54,00	23,99	-0,15	7422,39	79,80	0,32	-2,32
	2	1S	253	54,50	24,87	-0,03	7019,65	186,10	0,54	-1,60
	3	1	199,5	54,50	24,62	-0,18	7135,48	67,10	0,54	-1,78
	4	1S	319	54,50	25,24	-0,07	7407,01	134,93	0,57	-1,74
	5	2	415,5	54,50	24,30	-0,17	6880,74	67,14	0,68	-2,03
	6	3	390,5	54,50	25,78	-0,12	6819,46	106,22	0,47	-1,79
D37	1	0	295,5	54,50	24,15	-0,20	6569,21	67,61	0,48	-2,09
	2	1S	349,5	54,50	18,72	0,09	7439,60	231,44	0,70	-1,66
	3	1	199,5	54,50	24,25	-0,17	7034,69	59,59	0,54	-1,67
	4	1S	300	54,00	26,85	-0,01	7000,07	97,52	0,52	-1,18
	5	3	310,5	54,50	23,04	-0,25	6295,29	74,92	0,75	-2,89
	6	2	225,5	54,00	19,08	-0,19	7218,04	157,07	0,66	-2,01

STANDARD DEVIATION

Driver	Number of repetition	Scenario	Duration (s)	PHASE I					
				Speed (m/s)	Average Acceleration (m/s^2)	Lateral Position (mm)	Distance lead vehicle (m)	Acceleration (m/s^2)	Deceleration (m/s^2)
D1	1	0	258,5	7,23	0,80	265,33	56,71	0,36	0,96
	2	1S	260,5	7,53	0,83	260,19	75,43	0,30	1,17
	3	1	188,5	7,09	1,05	199,30	18,10	0,42	1,52
	4	1S	176	7,23	1,17	212,68	12,23	0,48	1,44
	5	2	208	7,59	1,07	183,71	18,14	0,43	1,32
	6	3	179,5	8,18	1,07	175,98	12,89	0,44	1,33
D2	1	0	184,5	6,97	1,05	365,53	30,31	0,26	1,68
	2	1S	163,5	11,34	0,37	238,99	303,42	0,37	0,00
	3	1	188,5	7,09	1,05	199,30	18,10	0,42	1,52
	4	1S	176	7,23	1,17	212,68	12,23	0,48	1,44
	5	3	208	7,59	1,07	183,71	18,14	0,43	1,32
	6	2	179,5	8,06	1,16	175,08	13,26	0,43	1,39
D3	1	0	243	8,12	1,00	326,13	46,28	0,35	1,38
	2	1S	247,5	8,22	0,98	298,07	134,07	0,34	1,78
	3	1	229,5	8,44	1,18	384,39	73,91	0,37	1,97
	4	1S	162,5	6,74	1,21	231,51	18,52	0,46	1,77
	5	3	214	6,46	0,81	291,95	29,35	0,50	1,18
	6	2	225,5	8,48	1,32	488,69	30,75	0,38	2,50
D4	1	0	236,5	10,63	0,74	126,80	15,81	0,29	1,12
	2	1S	395	6,82	0,53	322,13	41,98	0,30	0,78
	3	1	317	7,05	0,65	212,51	51,42	0,30	0,89
	4	1S	284,5	7,87	0,74	248,63	46,08	0,33	1,10
	5	2	452	5,49	0,57	358,34	29,23	0,28	0,88
	6	3	361,5	6,55	0,64	266,35	40,21	0,32	0,89
D5	1	0	172,5	8,62	1,54	217,75	19,25	0,47	1,98
	2	1S	204,5	8,12	1,19	259,50	32,99	0,46	1,73
	3	1	180	8,09	1,24	252,80	19,02	0,45	1,79
	4	1S	170,5	8,23	1,41	227,85	18,35	0,44	1,91
	5	3	182	8,93	1,50	284,13	32,96	0,16	1,94
	6	2	182	9,24	1,56	247,20	33,08	0,16	2,18
D6	1	0	492	6,94	0,49	315,05	44,44	0,30	0,55
	2	1S	470,5	7,70	0,50	195,50	36,56	0,29	0,58
	3	1	598	6,15	0,42	195,57	25,62	0,26	0,49
	4	1S	392	8,04	0,60	162,00	45,96	0,30	0,67
	5	3	284	7,76	0,65	110,75	35,94	0,31	0,64
	6	2	396	7,66	0,58	159,80	30,50	0,34	0,63
D7	1	0	181,5	8,97	1,39	257,75	36,89	0,24	2,10
	2	1S	191,5	7,13	1,04	152,55	36,26	0,25	1,46
	3	1	175,5	7,52	1,24	241,06	27,53	0,18	1,44
	4	1S	175	7,36	1,15	160,65	30,34	0,21	1,23
	5	2	185	7,19	1,12	184,75	30,11	0,24	1,56
	6	3	187,5	6,98	0,88	157,94	28,18	0,29	1,15
D8	1	0	190	7,18	1,29	218,65	29,03	0,14	1,28
	2	1S	267,5	9,09	0,69	266,21	61,17	0,21	1,04
	3	1	220	7,46	0,92	280,21	31,04	0,22	1,35
	4	1S	247	10,16	0,85	291,63	164,14	0,16	1,37
	5	2	210	9,91	0,96	330,88	66,18	0,19	1,26
	6	3	298,5	8,27	0,75	322,51	69,14	0,23	1,12
D9	1	0	238,5	9,14	1,05	187,53	64,07	0,26	1,42
	2	1S	192	8,62	0,92	183,54	34,36	0,27	1,30
	3	1	284	8,91	0,84	251,09	27,12	0,27	1,27
	4	1S	282	9,37	0,88	232,34	31,29	0,27	1,40
	5	3	381,5	7,63	0,63	348,63	38,38	0,26	0,96
	6	2	306,5	7,89	0,73	215,43	26,70	0,27	1,04
D10	1	0	216	8,51	0,93	154,59	25,49	0,29	1,11
	2	1S	184	7,34	1,09	133,15	19,30	0,22	1,25

Driver	Number of repetition	Scenario	Duration (s)	PHASE I					
				Speed (m/s)	Average Acceleration (m/s^2)	Lateral Position (mm)	Distance lead vehicle (m)	Acceleration (m/s^2)	Deceleration (m/s^2)
D10	3	1	175,5	7,50	1,11	167,96	22,82	0,21	1,54
	4	1S	194,5	8,71	1,14	171,64	19,78	0,22	1,39
	5	3	224,5	7,63	1,00	194,21	25,58	0,31	1,33
	6	2	176,5	7,36	1,09	145,75	22,37	0,21	1,47
D11	1	0	162,5	6,90	1,20	148,05	14,36	0,40	1,34
	2	1S	177	7,07	1,06	138,65	20,49	0,39	1,32
	3	1	161	5,40	0,90	146,04	12,51	0,48	1,02
	4	1S	162	5,90	1,08	117,17	12,73	0,46	1,30
	5	3	160,5	5,05	0,89	159,03	13,15	0,47	1,05
	6	2	164,5	5,24	1,00	118,34	13,53	0,48	1,27
D12	1	0	213	7,60	1,01	295,13	62,63	0,29	1,78
	2	1S	212	9,18	1,04	264,38	58,27	0,39	1,57
	3	1	237	9,59	1,17	462,30	71,14	0,34	2,03
	4	1S	192,5	9,21	1,25	368,99	37,07	0,27	2,37
	5	2	249,5	8,79	1,14	347,29	104,54	0,37	1,93
	6	3	191,5	8,20	1,18	443,94	30,19	0,39	1,73
D13	1	0	389,5	7,56	1,11	511,37	75,70	0,27	1,48
	2	1S	249	9,53	1,08	487,09	100,02	0,33	1,60
	3	1	241	8,91	1,34	383,91	47,89	0,44	2,26
	4	1S	279	9,16	1,23	466,87	57,02	0,42	1,97
	5	3	247,5	10,23	1,35	498,94	127,43	0,34	2,32
	6	2	204,5	9,94	1,63	347,78	63,23	0,39	2,31
D14	1	0	192,5	9,47	1,00	133,67	36,25	0,33	1,44
	2	1S	460	5,73	0,64	255,29	19,94	0,30	0,81
	3	1	246,5	6,54	0,76	118,33	34,61	0,37	0,98
	4	1S	302	7,57	0,69	169,09	33,06	0,33	0,91
	5	2	375	5,79	0,65	198,62	18,64	0,31	0,86
	6	3	274	7,59	0,85	131,28	49,26	0,31	1,16
D15	1	0	218	7,09	1,28	357,25	55,98	0,31	2,09
	2	1S	214,5	9,93	1,49	316,94	126,09	0,37	2,37
	3	1	174,5	22,44	0,24	274,42	54,17	0,41	1,73
	4	1S	197,5	7,65	1,19	357,52	42,30	0,34	1,76
	5	2	179	7,20	1,39	362,26	22,62	0,42	1,91
	6	3	180	7,10	1,41	312,35	19,25	0,35	2,23
D16	1	0	163	6,81	1,30	175,69	15,37	0,45	1,50
	2	1S	172,5	7,09	1,43	228,39	15,03	0,38	1,86
	3	1	161	6,08	1,14	165,70	15,45	0,42	1,60
	4	1S	169	6,55	1,20	198,50	18,90	0,40	1,69
	5	3	160,5	6,03	1,18	146,00	10,74	0,43	1,68
	6	2	160,5	5,69	1,15	146,75	10,96	0,42	1,55
D17	1	0	243	9,65	1,18	459,01	143,65	0,35	2,06
	2	1S	227	7,78	1,28	257,37	91,18	0,30	1,90
	3	1	207,5	8,85	1,39	340,42	32,84	0,29	1,98
	4	1S	162,5	6,56	1,25	348,08	16,38	0,48	2,09
	5	2	175,5	7,14	1,41	400,66	33,08	0,37	2,38
	6	3	276	8,32	1,05	393,95	86,74	0,37	1,53
D18	1	0	389	7,51	0,71	271,94	21,87	0,32	0,91
	2	1S	380,5	6,57	0,75	249,89	57,23	0,29	1,00
	3	1	160,5	6,15	0,92	161,24	15,57	0,40	1,02
	4	1S	160,5	5,89	1,03	161,95	14,93	0,41	1,17
	5	3	179,5	5,67	0,95	229,25	17,68	0,40	1,21
	6	2	181	6,73	0,94	204,88	16,83	0,38	1,15
D19	1	0	212,5	10,28	1,48	208,94	23,80	0,29	1,99
	2	1S	217	6,79	1,28	177,49	21,35	0,34	2,13
	3	1	208,5	7,57	1,20	226,95	36,05	0,34	1,81
	4	1S	187	7,59	1,26	117,49	18,62	0,36	2,05
	5	2	234	7,38	1,43	188,74	22,74	0,36	1,98

Driver	Number of repetition	Scenario	Duration (s)	PHASE I					
				Speed (m/s)	Average Acceleration (m/s^2)	Lateral Position (mm)	Distance lead vehicle (m)	Acceleration (m/s^2)	Deceleration (m/s^2)
D19	6	3	197,5	7,50	1,20	170,29	22,16	0,34	2,12
D20	1	0	375,5	8,22	0,93	555,11	114,47	0,19	1,97
	2	1S	354	7,66	0,87	433,69	96,26	0,26	1,31
	3	1	245,5	8,31	1,08	281,05	62,20	0,24	1,75
	4	1S	280	8,29	0,90	479,92	68,99	0,27	1,60
	5	2	212,5	8,36	1,30	317,84	41,60	0,22	2,06
	6	3	238,5	7,92	1,10	353,36	39,67	0,36	1,68
D21	1	0							
	2	1S							
	3	1	160,5	4,54	0,54	231,58	16,69	0,58	0,03
	4	1S	160,5	5,56	1,01	322,65	18,25	0,56	1,20
	5	3	187	5,66	0,91	311,65	28,19	0,48	1,14
	6	2	160,5	5,36	0,87	205,07	17,69	0,44	1,03
D22	1	0	502,5	7,34	0,84	457,99	131,01	0,38	1,23
	2	1S	275,5	8,30	1,02	301,24	35,96	0,25	2,03
	3	1	280,5	8,99	0,97	420,60	69,18	0,28	1,47
	4	1S	171,5	8,54	1,17	353,66	23,26	0,35	2,02
	5	3	230,5	10,36	1,20	245,61	76,61	0,57	1,60
	6	2	224	8,75	1,29	480,41	34,43	0,38	1,87
D23	1	0	662,5	7,26	0,64	477,17	251,87	0,29	0,90
	2	1S	463	9,24	0,88	478,12	151,81	0,27	1,35
	3	1	368,5	7,93	0,76	355,53	60,22	0,25	1,32
	4	1S	403	7,96	0,78	380,03	60,37	0,32	1,07
	5	2	219	9,20	1,02	260,69	70,02	0,33	1,71
	6	3	312	9,50	0,99	329,30	85,16	0,35	1,69
D24	1	0	212	10,63	1,13	169,79	27,51	0,29	1,48
	2	1S	182,5	7,04	1,12	177,80	30,29	0,29	1,48
	3	1	176,5	7,22	1,05	106,84	32,14	0,24	1,40
	4	1S	174,5	7,57	1,29	138,19	34,43	0,18	1,59
	5	3	175,5	8,06	1,37	214,54	35,61	0,13	1,68
	6	2	177	8,01	1,43	316,30	35,65	0,16	1,78
D25	1	0	196	8,47	1,36	392,61	31,19	0,21	1,57
	2	1S	392,5	7,63	1,19	755,97	61,82	0,22	1,31
	3	1	220,5	9,77	1,38	434,43	39,80	0,25	1,92
	4	1S	191	8,03	1,42	377,85	22,30	0,16	1,60
	5	3	193	9,11	1,24	431,27	47,04	0,26	1,76
	6	2	221	9,73	1,39	407,96	49,07	0,18	1,70
D26	1	0	333	8,04	0,91	351,46	46,13	0,24	1,32
	2	1S	175,5	7,61	1,47	118,75	30,47	0,16	1,47
	3	1	265,5	7,60	0,96	162,55	24,98	0,25	1,48
	4	1S	181	7,83	1,30	136,75	23,58	0,24	1,62
	5	2	274	8,57	0,78	183,91	39,85	0,28	1,51
	6	3	188,5	8,64	1,03	123,88	52,24	0,25	1,44
D27	1	0	189,5	8,61	1,45	214,86	32,89	0,19	1,70
	2	1S	179	8,42	1,34	251,43	31,43	0,24	1,71
	3	1	178	7,97	1,12	185,17	34,45	0,22	1,60
	4	1S	228	8,19	1,04	211,88	25,64	0,22	1,34
	5	3	279	7,29	1,07	228,54	23,45	0,22	1,35
	6	2	323	7,25	0,83	260,05	29,03	0,30	1,14
D28	1	0	232	9,28	1,11	214,09	32,50	0,23	1,99
	2	1S	346,5	8,31	0,89	469,60	55,00	0,26	1,40
	3	1	259,5	8,41	1,13	287,59	28,35	0,29	2,04
	4	1S	308	9,52	1,15	422,36	59,86	0,19	1,66
	5	2	314	8,41	0,92	429,50	49,18	0,31	1,36
	6	3	216,5	10,07	1,34	316,30	38,07	0,21	1,78
D29	1	0	518,5	7,59	0,86	511,59	79,85	0,32	1,20
	2	1S	250,5	9,39	0,96	283,52	38,97	0,25	1,45

Driver	Number of repetition	Scenario	Duration (s)	PHASE I					
				Speed (m/s)	Average Acceleration (m/s^2)	Lateral Position (mm)	Distance lead vehicle (m)	Acceleration (m/s^2)	Deceleration (m/s^2)
D29	3	1	184	9,01	1,38	444,23	27,97	0,16	1,85
	4	1S	290,5	7,93	1,07	215,45	34,14	0,29	1,61
	5	2	187,5	9,59	1,39	323,10	29,82	0,19	2,37
	6	3	185,5	9,41	1,22	370,71	26,72	0,27	1,82
D30	1	0	211,5	11,05	1,34	188,94	45,66	0,18	1,67
	2	1S	193,5	8,64	1,33	207,75	40,06	0,20	1,65
	3	1	183,5	7,34	1,35	295,97	25,81	0,20	1,72
	4	1S	176,5	7,51	1,28	199,54	29,59	0,21	1,70
	5	3	175	7,74	1,31	200,77	34,85	0,22	1,87
	6	2	207,5	7,89	1,26	235,06	29,67	0,24	1,76
D31	1	0	498	7,67	0,77	502,47	84,53	0,28	1,21
	2	1S	314,5	8,32	0,89	327,24	47,39	0,28	1,26
	3	1	262	8,98	1,06	280,18	32,35	0,24	1,58
	4	1S	197	9,13	0,99	278,92	36,40	0,21	1,61
	5	2	246,5	9,23	1,05	268,43	40,27	0,28	1,70
	6	3	221	8,82	1,11	399,21	30,32	0,28	1,94
D32	1	0	175	8,29	1,53	261,68	34,90	0,15	2,41
	2	1S	175,5	7,81	1,29	257,01	36,37	0,20	1,61
	3	1	175	7,55	1,36	335,80	37,36	0,20	1,82
	4	1S	176,5	7,98	1,20	248,55	36,52	0,28	1,66
	5	3	184	9,19	1,33	349,02	32,97	0,20	1,90
	6	2	176,5	7,96	1,28	287,49	36,85	0,24	1,81
D33	1	0	282	10,06	1,22	238,62	125,24	0,25	1,82
	2	1S	189	9,65	1,39	228,69	53,71	0,21	1,98
	3	1	197	9,22	1,51	305,87	54,01	0,18	1,88
	4	1S	228,5	11,98	1,64	324,11	132,13	0,19	2,40
	5	3	188,5	8,85	1,57	313,47	33,44	0,12	1,72
	6	2	209	9,82	1,39	268,90	37,16	0,18	1,42
D34	1	0	222,5	11,47	1,61	228,90	90,01	0,20	2,43
	2	1S	189	9,09	1,90	208,90	44,22	0,13	2,31
	3	1	188,5	8,38	1,71	306,49	25,82	0,14	2,31
	4	1S	191	8,77	1,63	296,73	32,61	0,19	2,44
	5	3	241,5	13,22	1,71	360,23	199,64	0,24	2,27
	6	2	184	7,73	1,52	200,49	43,90	0,18	1,95
D35	1	0	184,5	8,41	1,42	209,60	23,15	0,14	1,65
	2	1S	182	8,36	1,14	202,01	30,05	0,19	1,36
	3	1	179,5	7,62	1,07	221,68	30,94	0,22	1,47
	4	1S	195	8,47	1,27	243,89	28,55	0,21	1,59
	5	2	202	8,46	1,13	327,40	38,40	0,17	1,40
	6	3	237,5	8,00	1,03	292,25	30,37	0,23	1,35
D36	1	0	439,5	7,40	0,81	572,51	57,16	0,29	1,07
	2	1S	253	9,53	1,07	287,59	46,49	0,24	1,71
	3	1	199,5	8,67	0,99	202,93	26,75	0,30	1,64
	4	1S	319	9,07	0,88	412,46	54,79	0,29	1,21
	5	2	415,5	7,07	0,68	576,68	58,51	0,32	0,87
	6	3	390,5	8,79	1,19	473,68	57,03	0,24	1,59
D37	1	0	295,5	9,89	1,16	304,46	82,62	0,21	1,66
	2	1S	349,5	8,78	0,93	505,37	67,84	0,30	1,21
	3	1	199,5	9,28	1,20	294,63	28,07	0,21	1,68
	4	1S	300	9,42	1,12	328,50	50,86	0,13	1,34
	5	3	310,5	10,61	0,90	350,70	46,26	0,30	1,34
	6	2	225,5	9,26	1,21	449,32	30,03	0,22	1,89

STANDARD DEVIATION

Driver	Number of repetition	Scenario	Duration (s)	PHASE II					
				Speed (m/s)	Average Acceleration (m/s^2)	Lateral Position (mm)	Distance lead vehicle (m)	Acceleration (m/s^2)	Deceleration (m/s^2)
D1	1	0	258,5	2,52	0,26	877,74	146,78	0,21	0,06
	2	1S	260,5	2,85	1,21	166,30	43,24	0,14	0,78
	3	1	188,5	3,41	1,07	129,27	22,06	0,14	0,62
	4	1S	176	3,06	1,34	185,58	38,61	0,14	1,02
	5	2	208	3,39	1,20	129,52	8,58	0,13	0,84
	6	3	179,5	3,72	1,52	113,34	13,35	0,29	1,45
D2	1	0	184,5	4,44	1,30	200,71	26,92	0,23	1,53
	2	1S	163,5	3,31	0,93	226,25	138,91	0,07	0,57
	3	1	188,5	3,41	1,07	129,27	22,06	0,14	0,62
	4	1S	176	3,06	1,34	185,58	38,61	0,14	1,02
	5	3	208	3,39	1,20	129,52	8,58	0,13	0,84
	6	2	179,5	3,79	1,38	101,56	12,70	0,29	1,50
D3	1	0	243	3,02	1,26	305,89	23,69	0,23	1,96
	2	1S	247,5	2,72	0,99	287,37	20,51	0,11	0,52
	3	1	229,5	2,86	1,31	411,07	36,89	0,13	0,99
	4	1S	162,5	3,08	1,26	278,12	31,67	0,15	0,80
	5	3	214	4,52	1,72	312,67	19,42	0,25	1,84
	6	2	225,5	3,61	1,28	568,74	60,12	0,18	0,83
D4	1	0	236,5	2,25	0,81	149,23	14,19	0,10	1,06
	2	1S	395	3,63	1,36	1057,87	10,77	0,17	0,80
	3	1	317	3,09	1,19	522,05	16,94	0,13	0,82
	4	1S	284,5	3,37	1,17	335,67	50,34	0,16	0,53
	5	2	452	3,52	1,36	849,55	32,84	0,14	0,85
	6	3	361,5	2,23	0,64	351,29	25,66	0,09	0,64
D5	1	0	172,5	4,29	1,85	189,17	7,37	0,35	2,03
	2	1S	204,5	2,89	1,19	229,29	34,28	0,17	0,84
	3	1	180	3,32	1,02	315,12	19,14	0,13	0,56
	4	1S	170,5	2,65	1,19	235,44	42,09	0,15	0,76
	5	3	182	3,88	1,72	339,64	11,89	0,21	1,73
	6	2	182	3,44	1,40	341,77	40,39	0,09	1,44
D6	1	0	492	3,44	0,78	293,29	16,44	0,22	0,69
	2	1S	470,5	4,15	1,47	632,47	14,53	0,09	1,04
	3	1	598	3,04	1,19	627,46	22,68	0,16	0,58
	4	1S	392	3,04	1,25	614,79	22,77	0,08	0,88
	5	3	284	3,29	0,97	174,71	16,02	0,23	0,87
	6	2	396	3,76	1,33	526,72	68,26	0,08	0,85
D7	1	0	181,5	3,66	1,50	134,18	4,54	0,26	1,78
	2	1S	191,5	3,68	1,30	161,42	6,80	0,09	1,00
	3	1	175,5	3,44	1,30	69,82	11,29	0,07	1,01
	4	1S	175	2,59	1,10	197,21	49,74	0,10	0,59
	5	2	185	2,65	1,11	248,73	39,62	0,10	0,63
	6	3	187,5	3,05	1,20	97,24	6,40	0,27	1,35
D8	1	0	190	4,01	1,18	161,62	18,02	0,24	1,08
	2	1S	267,5	6,29	1,12	328,85	69,52	0,21	1,16
	3	1	220	2,84	1,05	205,92	20,06	0,10	0,52
	4	1S	247	2,76	1,10	220,69	39,49	0,08	0,58
	5	2	210	3,77	1,28	340,44	29,12	0,11	0,98
	6	3	298,5	3,20	1,09	317,15	16,32	0,11	1,16
D9	1	0	238,5	3,81	1,21	166,53	15,84	0,20	1,22
	2	1S	192	2,86	1,07	135,28	26,38	0,08	0,63
	3	1	284	3,37	1,08	361,10	23,50	0,10	0,56
	4	1S	282	3,09	1,06	288,71	20,31	0,11	0,52
	5	3	381,5	3,31	0,99	527,15	23,52	0,22	1,26
	6	2	306,5	2,73	1,03	353,36	16,05	0,09	0,61
D10	1	0	216	3,29	1,22	111,65	7,27	0,24	1,38
	2	1S	184	3,05	1,03	119,26	19,59	0,09	0,48

Driver	Number of repetition	Scenario	Duration (s)	PHASE II					
				Speed (m/s)	Average Acceleration (m/s^2)	Lateral Position (mm)	Distance lead vehicle (m)	Acceleration (m/s^2)	Deceleration (m/s^2)
D10	3	1	175,5	3,44	1,34	109,47	17,18	0,08	1,09
	4	1S	194,5	3,22	1,15	109,48	9,24	0,11	0,58
	5	3	224,5	4,12	1,50	190,07	9,03	0,28	1,52
	6	2	176,5	2,81	1,21	137,19	13,12	0,13	0,91
D11	1	0	162,5	3,35	1,49	166,99	8,20	0,23	1,33
	2	1S	177	3,28	1,02	108,42	17,81	0,15	0,45
	3	1	161	3,32	1,21	131,53	7,20	0,13	0,89
	4	1S	162	3,45	1,29	163,17	7,78	0,14	0,94
	5	3	160,5	2,81	1,25	106,87	34,24	0,12	0,83
	6	2	164,5	3,76	1,34	131,95	10,77	0,21	1,36
D12	1	0	213	3,90	1,64	221,00	27,17	0,26	2,10
	2	1S	212	3,13	1,17	317,65	21,07	0,11	0,86
	3	1	237	3,10	1,33	233,72	19,38	0,16	1,02
	4	1S	192,5	3,22	1,14	231,40	21,47	0,12	0,81
	5	2	249,5	3,59	1,36	310,71	7,78	0,14	1,25
	6	3	191,5	3,20	1,18	142,95	15,41	0,12	1,72
D13	1	0	389,5	3,88	1,55	669,05	10,69	0,39	1,44
	2	1S	249	4,32	1,06	405,60	51,10	0,23	0,49
	3	1	241	2,71	1,00	510,89	21,07	0,11	0,45
	4	1S	279	2,82	1,00	738,17	14,78	0,11	0,54
	5	3	247,5	4,20	1,80	493,42	16,69	0,27	2,10
	6	2	204,5	3,66	1,37	272,53	63,17	0,16	1,04
D14	1	0	192,5	3,96	1,23	78,88	14,60	0,20	1,31
	2	1S	460	3,11	1,27	463,45	19,94	0,12	0,75
	3	1	246,5	2,72	0,99	161,93	20,52	0,12	0,43
	4	1S	302	3,17	1,13	260,92	25,04	0,14	0,53
	5	2	375	2,87	1,20	404,06	24,50	0,15	0,59
	6	3	274	3,84	1,01	120,87	30,37	0,22	1,15
D15	1	0	218	4,21	1,61	495,31	15,60	0,28	1,71
	2	1S	214,5	3,14	1,04	305,24	13,00	0,14	0,52
	3	1	174,5	3,24	1,20	259,20	14,87	0,14	0,85
	4	1S	197,5	3,27	1,26	219,59	15,05	0,16	1,00
	5	2	179	3,56	1,03	433,99	28,28	0,16	0,46
	6	3	180	5,77	2,31	257,94	11,83	0,34	1,91
D16	1	0	163	4,22	1,55	143,44	6,76	0,25	1,58
	2	1S	172,5	3,09	1,01	167,36	11,91	0,13	0,53
	3	1	161	3,03	1,27	284,89	25,65	0,12	1,01
	4	1S	169	3,04	1,23	167,91	31,35	0,14	0,83
	5	3	160,5	4,32	1,69	180,27	7,22	0,32	1,93
	6	2	160,5	3,53	1,08	174,59	26,36	0,17	0,45
D17	1	0	243	4,13	1,63	154,27	16,92	0,17	2,22
	2	1S	227	2,88	1,32	335,66	56,21	0,14	1,07
	3	1	207,5	3,23	1,02	357,09	16,10	0,13	0,52
	4	1S	162,5	4,10	1,61	183,04	10,88	0,16	1,43
	5	2	175,5	3,82	1,31	338,89	26,56	0,14	1,06
	6	3	276	4,94	1,80	696,18	15,10	0,34	2,06
D18	1	0	389	4,98	1,31	413,07	28,00	0,20	1,28
	2	1S	380,5	3,84	1,38	523,87	31,91	0,16	0,97
	3	1	160,5	3,27	1,25	121,33	10,67	0,13	0,70
	4	1S	160,5	3,13	1,38	145,92	52,64	0,17	0,97
	5	3	179,5	3,17	1,04	264,29	18,91	0,24	1,28
	6	2	181	2,76	1,23	138,42	42,62	0,12	0,81
D19	1	0	212,5	4,17	1,71	171,35	12,67	0,23	2,19
	2	1S	217	2,63	1,20	149,58	31,51	0,14	0,81
	3	1	208,5	3,88	1,41	129,82	27,61	0,15	1,41
	4	1S	187	3,01	1,26	199,65	43,15	0,15	0,86
	5	2	234	3,60	1,35	172,28	25,47	0,14	1,20

Driver	Number of repetition	Scenario	Duration (s)	PHASE II					
				Speed (m/s)	Average Acceleration (m/s^2)	Lateral Position (mm)	Distance lead vehicle (m)	Acceleration (m/s^2)	Deceleration (m/s^2)
D19	6	3	197,5	3,95	1,43	115,65	14,46	0,20	1,79
D20	1	0	375,5	3,56	1,24	700,31	18,83	0,20	1,82
	2	1S	354	4,92	1,49	762,77	39,10	0,19	1,19
	3	1	245,5	3,04	1,45	288,02	36,39	0,14	1,17
	4	1S	280	2,95	1,24	352,95	38,27	0,15	0,85
	5	2	212,5	2,67	0,99	572,92	24,97	0,10	0,51
	6	3	238,5	2,53	0,78	306,20	27,85	0,11	0,92
D21	1	0							
	2	1S							
	3	1	160,5	2,45	1,07	349,47	12,94	0,10	0,57
	4	1S	160,5	2,68	1,19	157,57	19,30	0,12	0,78
	5	3	187	2,67	0,95	192,49	35,43	0,18	1,49
	6	2	160,5	2,44	1,11	275,17	18,12	0,10	0,66
D22	1	0	502,5	3,76	1,62	2283,71	6802,76	0,22	1,80
	2	1S	275,5	3,15	1,29	371,81	42,87	0,16	1,02
	3	1	280,5	3,86	1,23	681,33	24,71	0,16	0,88
	4	1S	171,5	3,58	1,32	210,52	23,08	0,14	1,18
	5	3	230,5	3,66	1,36	214,20	18,50	0,36	1,76
	6	2	224	4,03	1,19	502,18	42,82	0,20	0,84
D23	1	0	662,5	4,38	1,38	497,08	24,20	0,28	1,60
	2	1S	463	3,47	1,18	662,44	8,75	0,16	0,61
	3	1	368,5	2,98	1,32	517,20	15,29	0,15	0,82
	4	1S	403	5,11	1,58	677,55	37,26	0,17	1,22
	5	2	219	3,26	1,36	368,62	41,33	0,15	1,18
	6	3	312	6,74	1,67	609,03	47,43	0,24	2,00
D24	1	0	212	4,41	1,68	76,59	8,64	0,30	2,01
	2	1S	182,5	3,24	1,01	157,39	39,05	0,07	0,51
	3	1	176,5	2,45	1,10	228,07	20,05	0,10	0,68
	4	1S	174,5	3,75	1,36	76,39	6,42	0,10	1,12
	5	3	175,5	3,92	1,70	237,51	4,61	0,24	1,98
	6	2	177	2,90	1,00	266,03	10,80	0,09	0,55
D25	1	0	196	4,19	1,67	504,12	12,15	0,16	1,38
	2	1S	392,5	7,52	1,52	1476,35	173,66	0,12	1,06
	3	1	220,5	2,79	1,13	505,10	17,31	0,08	0,70
	4	1S	191	3,04	1,13	214,61	35,09	0,10	0,72
	5	3	193	6,41	1,97	253,79	26,87	0,17	1,31
	6	2	221	3,30	1,31	444,40	15,97	0,08	1,15
D26	1	0	333	3,71	1,19	440,92	52,24	0,17	1,36
	2	1S	175,5	3,44	1,02	150,69	56,51	0,08	0,55
	3	1	265,5	3,46	1,26	172,27	5,37	0,08	0,83
	4	1S	181	3,12	1,23	152,94	8,58	0,09	0,88
	5	2	274	2,78	0,99	335,16	14,98	0,08	0,54
	6	3	188,5	3,65	1,20	88,23	40,40	0,22	1,50
D27	1	0	189,5	4,02	1,70	148,80	11,11	0,16	1,67
	2	1S	179	2,70	1,14	212,57	30,54	0,07	0,75
	3	1	178	2,97	1,08	187,58	28,86	0,09	0,57
	4	1S	228	3,47	1,10	132,76	26,34	0,09	0,63
	5	3	279	3,90	1,33	322,46	12,92	0,13	1,12
	6	2	323	4,85	1,42	487,69	116,92	0,14	1,05
D28	1	0	232	3,11	1,09	188,41	20,79	0,15	1,56
	2	1S	346,5	3,00	1,26	569,75	31,63	0,10	0,97
	3	1	259,5	2,47	1,09	241,82	33,39	0,08	0,70
	4	1S	308	2,70	1,14	206,78	45,98	0,11	0,69
	5	2	314	3,15	1,03	504,78	16,71	0,10	0,38
	6	3	216,5	2,93	0,96	198,45	22,78	0,13	1,31
D29	1	0	518,5	2,49	1,02	481,39	12,33	0,17	1,31
	2	1S	250,5	2,55	1,13	441,77	21,40	0,10	0,76

Driver	Number of repetition	Scenario	Duration (s)	PHASE II					
				Speed (m/s)	Average Acceleration (m/s^2)	Lateral Position (mm)	Distance lead vehicle (m)	Acceleration (m/s^2)	Deceleration (m/s^2)
D29	3	1	184	3,00	1,26	390,26	66,39	0,07	0,93
	4	1S	290,5	2,98	1,01	329,42	12,98	0,09	0,44
	5	2	187,5	3,99	1,41	252,72	54,71	0,07	1,25
	6	3	185,5	3,74	1,27	302,32	20,02	0,29	1,62
D30	1	0	211,5	5,41	1,50	473,32	39,34	0,19	1,80
	2	1S	193,5	3,07	1,30	213,60	49,87	0,10	0,99
	3	1	183,5	3,17	1,15	264,38	8,54	0,09	0,78
	4	1S	176,5	2,96	1,00	327,61	14,02	0,08	0,53
	5	3	175	3,95	1,68	183,24	15,88	0,22	1,70
	6	2	207,5	2,93	1,27	167,37	49,87	0,07	0,96
D31	1	0	498	4,19	1,28	386,85	24,61	0,25	1,52
	2	1S	314,5	2,84	1,18	408,90	27,96	0,09	0,81
	3	1	262	3,71	1,30	162,90	22,81	0,09	1,07
	4	1S	197	2,52	1,07	201,08	16,05	0,11	0,57
	5	2	246,5	4,40	1,26	187,29	24,36	0,13	1,01
	6	3	221	4,03	1,40	189,44	9,93	0,15	1,68
D32	1	0	175	4,91	2,01	123,12	7,51	0,31	2,46
	2	1S	175,5	2,66	1,12	336,71	43,87	0,08	0,60
	3	1	175	2,41	1,05	193,72	29,46	0,08	0,60
	4	1S	176,5	2,69	1,12	457,21	23,29	0,07	0,82
	5	3	184	4,51	1,87	125,94	7,52	0,27	2,19
	6	2	176,5	3,17	1,24	244,84	10,89	0,07	0,98
D33	1	0	282	5,80	1,83	414,83	26,57	0,20	1,81
	2	1S	189	3,58	1,27	265,87	55,75	0,10	0,92
	3	1	197	2,89	1,00	318,56	10,74	0,08	0,52
	4	1S	228,5	3,50	1,31	352,22	34,04	0,07	1,02
	5	3	188,5	4,68	1,70	216,82	17,84	0,14	1,77
	6	2	209	4,77	1,44	318,35	114,97	0,12	1,12
D34	1	0	222,5	5,69	2,00	265,42	17,22	0,19	1,89
	2	1S	189	2,72	0,99	240,33	22,55	0,10	0,45
	3	1	188,5	3,10	1,23	377,66	36,20	0,08	0,97
	4	1S	191	3,97	1,24	611,27	28,56	0,09	1,05
	5	3	241,5	4,53	2,00	152,93	9,99	0,13	2,20
	6	2	184	2,66	0,98	222,44	31,28	0,08	0,52
D35	1	0	184,5	4,12	1,64	142,06	54,81	0,19	1,55
	2	1S	182	4,59	1,44	233,29	25,13	0,10	1,22
	3	1	179,5	3,11	1,21	187,89	15,56	0,09	0,86
	4	1S	195	3,65	1,30	143,50	7,90	0,08	0,95
	5	2	202	2,88	1,14	303,28	40,90	0,07	0,68
	6	3	237,5	5,68	1,48	313,71	34,83	0,22	1,42
D36	1	0	439,5	3,90	1,20	488,81	17,82	0,25	1,49
	2	1S	253	2,76	0,99	297,56	18,38	0,08	0,52
	3	1	199,5	3,46	1,17	144,45	22,24	0,09	0,81
	4	1S	319	2,91	1,09	706,62	26,80	0,08	0,65
	5	2	415,5	3,22	1,36	666,13	14,78	0,15	0,90
	6	3	390,5	4,77	1,35	501,97	34,38	0,32	1,74
D37	1	0	295,5	3,79	1,36	286,83	13,91	0,22	1,40
	2	1S	349,5	4,22	1,06	696,61	83,95	0,09	0,44
	3	1	199,5	2,63	1,11	213,63	12,69	0,11	0,69
	4	1S	300	6,12	1,12	490,04	66,19	0,21	1,38
	5	3	310,5	6,57	1,88	326,97	44,80	0,22	1,49
	6	2	225,5	3,96	1,41	317,36	98,40	0,11	1,19

CURRICULUM

Born in Martina Franca (Italy) on December 25th, 1994. The author obtained a master’s degree in Environmental Engineering with full marks in 2019 from the Politecnico di Bari, defending a thesis entitled “Effects of vertical traffic calming measures on road safety”. In the 2020, she started the Ph.D. course in "Risk, Environmental, Territorial and Building Development” (XXXVI cycle). During the three years of the doctorate school, the author deepened her knowledge concerning driver behaviour and autonomous vehicle, learning how to use traffic simulators, driving simulators and algorithms for driver behaviour analysis.

Part of the Ph.D. research was developed abroad at the Gustave Eiffel University in Paris, supervised by prof. Hocine Imine, who gave profound insights into driving simulator studies.

During her Ph.D., she was also involved in many other research activities, concerning mobility planning (she worked on the Sustainable Urban Mobility Plan of the Province of Bari). She was the author of some journal and conference papers. She supported the didactic activities for the “Road Safety” course (Master’s Degree in Civil Engineering, 2020/2021 chair: prof. P. Colonna) and for the “Construction of Roads, Railways and Airports” course (Bachelor degree in Civil Engineering, 2020/2021/2022/2023 chair: prof. V. Ranieri). The author is part of the AIIT and SIIV organization.