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RISK PERCEPTION DURING CONDITIONALLY AUTOMATED DRIVING IN LOW FIDELITY SIMULATOR

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Abstract

This work focuses on the type-3 self-driving cars, partially autonomous vehicles which can control themselves for most of the time and may ask the driver to take control of the car in case of specific situations.

The purpose of this study is to evaluate the perception of the simulated risk faced by the participants in a low fidelity simulation in relation with their background: the gaming and driving experience. The participants of the study drove in the simulator and answered a questionnaire about both the driving session and the background information. The simulated risk was assessed and compared with the information from the questionnaire. It was evaluated both the performance of each participant represented by the level of risk experienced while driving the simulation and the correct identification of the risk faced. The result data highlighted a positive correlation between the driving performance and the videogame experience.

Keywords: risk awareness, low-fidelity simulator, self-driving.

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1 Introduction

Self-driving vehicles are cars or trucks in which human drivers are never required to take control to safely operate the vehicle. Also known as autonomous or “driverless” cars, they combine sensors and software to control, navigate, and drive the vehicle. Different cars are capable of different levels of self-driving and are often described by researchers on a scale ranged from 0 (All major systems are controlled by humans) to 5 (The car is completely capable of self-driving in every situation).

This study focuses on the type 3 of self-driving cars: partially autonomous vehicles which may require a human driver to intervene if the system encounters uncertainty. The car, thus, can manage all safety-critical functions under certain conditions, but the driver is expected to take over when alerted (Shuttleworth, 2019). The type 3 self-driving is also named conditionally automated driving. During the automated driving periods, the driver is engaged in a non-driving related activity.

Nowadays, there are many problems involved in the experimentation of this kind of cars, thus, the usage of a simulation to research self-driving cars is still necessary. A simulator is a complex environment which replicates the real environment avoiding the risk of a real experiment while preserving, in some way, a certain degree of validity. This study focuses on low fidelity simulators, cheap and low immersive environment, and replicates in the design of the experiment the steps of an automated driving cycle.

This study analyses participants’ perception of risk during conditionally automated driving. The participants drove in the simulated environment and answered questions about their driving session and their usual videogame usage. The simulated faced risk was assessed and compared with the perceived one of each participant. It was evaluated both the performance of each participant represented by the level of risk experienced while driving the simulation and the correct identification of the risk faced. Then, the data from the questionnaire is correlated to the one from the driving simulation.

Although the driving simulation is held in a low fidelity environment, attention has been paid to replicate accurately the steps of the conditionally automated driving. In the next chapter, the definition of high and low fidelity in simulators and the context required to understand the conditionally automated driving are provided: first, a paragraph explaining the different levels of automation and, then, one other about the takeover process and the non-driving related activities.

2 Background

This section explores the useful concepts needed to understand the work, providing some context and notions in preparation of the problem.

2.1 Serious games

A videogame is a mental context, played with rules, with the goal of amusing or rewarding the player. A serious game uses the entertainment aspect of a game to promote training, education, health, public policy and communication objectives. A serious game differs from a videogame mainly in its “serious” purpose (Zyda, 2005).

The term was firstly introduced by Sawyer in 2002 when the U.S. Army released the videogame America's Army and the Serious Games Movement started. In 2004, the first Serious Games Summit was held and, as the Serious Games Moment gained creditability, funding started to be available (Gudmundsen, 2006).

Serious games can be used in several contexts: healthcare, government and education are only few use cases of this media (Susi, Johannesson, & Backlund, 2007). Several applications of the serious games have been developed during the years. They focus mostly on safety training and may be divided into three general application areas: construction, public and pedestrian safety (Ma, Oikonomou & Jain, 2011).

Serious games may be heterogeneous and, even in the context of the same application area, they may have huge differences. Hazmat: Hotzone (Carless, 2005) is a serious game that aims to train firefighters to handle hazardous material. It depicts a scenario of a terrorist attack in a New York subway and allows the player to interact with objects and people, giving the possibility to perform a variety of actions. Sidth (Backlund, et al., 2007) is a training simulator developed by the University of Skövde in collaboration with the Swedish Rescue Service Agency made with the aim of training firefighters for situation that require specific equipment, like breathing apparatuses; a kind of training usually done in specific areas. The usage of a simulation for this kind of training was made possible a specific simulator based on the “cave”: a hardware setup made of screens that completely surround the player giving complete immersivity (Cruz-Neira, et al., 1992).

A simulator is a specific environment designed to help the training. The training in the simulator can influence the skill acquisition, although it cannot replace totally the practice in a real environment. The amount of training transferred from the simulated to the real environment can be estimated by the cumulative transfer effectiveness function, which expresses the ration between time spent in the simulator and time saved in the real world (Nählinder, et al., 2009).

2.2 High and low fidelity in simulators

A simulator offers precision, reliability and controllability; it allows to safely study dangerous situations at a relatively low cost (Nilsson, 1993). The evolution of the simulations has been mostly technology driven, computer graphics has been integrated, images become more realistic, and, in some cases, external sources, like satellite imagery, were integrated in the software (Longridge, et al., 2001). The more complex a simulator, the more elements of the simulated environment it represents, but the more expensive it is (Nilsson, 1993).

It is possible to divide simulators based on their level of fidelity, or how faithfully the stimuli of the simulation reproduce. High fidelity simulators reproduce the simulated scenario in the most real possible way and aim to be as realistic as possible, including many elements and simulating the relationship among them. The best example is the flight simulator, a huge, expensive environment that reproduces all the stimuli as realistically as possible. On the other hand, low fidelity simulators reproduce the simulated scenario leaving out factors that the user might experience in real life. They are usually cheaper that their high-fidelity counterpart and provide less immersion (Dahlstrom, et al., 2008).

It is possible to make another distinction between the engineering or physical fidelity and the psychological or functional fidelity. Engineering fidelity is the extent to which the simulation replicates the physical characteristics of the actual task, while, psychological fidelity is the extent to which the skills of the real task are captured by the simulated task (Miller, 1954).

Four levels of simulation fidelity can be defined with the aim to develop a common language. These levels describe the amount of fidelity the simulator has, from level 1 (state of the art fidelity) to level 4 (low fidelity) (Matthews & Yachemetz, 2008).

Because of the heterogeneous variety of tasks that may be performed in a simulator, high fidelity is not always superior to low fidelity, even though it plays an important role in the choice of the simulation for a specific task (Munshi, Lababidi & Alyousef, 2015). For example, in the simulation-based driver training use case, high fidelity induces positive reactions amongst participants, improves the validity and credibility of the data, improves performance and learning but increases costs, induces simulator sickness and distraction (de Winter, et al., 2007). In the context of medical training, low fidelity has been proven more effective than high fidelity in laparoscopic simulator. Participants trained in a low fidelity environment demonstrated a greater ability to apply their skills to new environments (Tan, et al., 2012). The fidelity of the simulator does not influences the learning outcome of other kind of contexts, like learning the hearth sound (De Giovanni, et al., 2009) or intensive care paramedics using mannequins (Lee, Grantham & Boyd, 2009).

2.3 Validity of a driving simulator

Validation is the process that establish the credibility of simulator research results. The validity of a driving simulator is the degree that the simulator evokes the same behaviour as would be shown under similar circumstances in the real world (Allen, et al., 1991). Limitations in simulator validity are directly related to the information a specific simulator provides to the driver, such as visual information, sound or self-motion. It is possible to make a distinction between absolute and relative validity and between internal and external validity.

The simulator has absolute validity regarding a research question if the absolute size of the effect is comparable to the absolute size of the effect in real environment. A driving simulator has relative validity regarding a research question if the relative size of the effect of the measure is the same as in real environment.

Internal validity refers to the recognition of a possible apparent relation between a manipulation and an obtained effect. A research method has internal validity if there are no alternative explanations for an obtained effect. External validity refers to the extent that the results obtained with a specific set of subjects in a specific environment during a specific time period can be generalized to other persons, environments and time periods (Kaptein, Theeuwes & Van Der Horst, 1996).

2.4 Videogame usage and simulation

Historically, for real-time applications, engineers had to choose between high-fidelity and graphical realism. This division took place because of the division between tools for multimedia rendering and engineering computation. Over the years, engineering methods have evolved, and the simulation field is increasingly turning to technology and expertise from the videogame area.

Videogames have made computing pervasive worldwide much as other technologies, yielding products, tools and techniques that have high performance and low cost. Realistic multimedia, real time interaction, unique controls and interface and low-cost standardized platforms are only few aspects that characterize the gaming panorama (Rohde & Toschlog, 2009).

Playing videogames promotes a wide range of cognitive skills. Gamers tend to have faster and more accurate attention allocation, higher special resolution in visual processing and enhanced mental rotation abilities (Granic, Lobel & Engels, 2014).

A study on surgical simulator found that the usage of videogames increases the performance of surgical novices while using a virtual reality simulator. Thirty surgical novices were involved in five weeks of systematic videogames training in either Half Life, a first-person shooter game with high visual spatial demands, and Chessmaster, a videogame with mainly cognitive demands. Subjects in the two experimental groups were instructed to play with the videogames from a minimum of 30 to a maximum of 60 minutes per day for five weeks, while a control group of ten subject performed no videogame play. The results found that the usage of videogames improved performance in virtual reality simulation in both the groups that were assigned to play videogames (Schlickum, et al., 2009).

Another study, on virtual environment navigation tasks, examines the effects of previous gaming experience, user perceived gaming ability and actual gaming performance on navigation tasks in a virtual environment. Participants played two games, a breakout and a first-person shooter, and were assessed with three testing environments. Results indicated that the progress in the first-person shooter game showed significant correlation with performance in time-based navigation tasks (Smith & Du'Mont, 2009).

2.5 Levels of driving automation

It is possible to define 6 levels of driving automation, from level 0 (no automation) to level 5 (full vehicle autonomy). These levels define key terms to eliminate confusion across numerous disciplines, describe categorical distinctions for a stepwise progression through the levels and clarify, for each level, what role drivers have in performing the dynamic driving task while a driving automation system is engaged:

- **Level 0. No Automation:** the full-time performance by the human driver of all aspects of the dynamic driving task, even when enhanced by warning or intervention systems. The execution of steering and acceleration/deceleration, the monitoring of the driving environment and the fallback performance of dynamic driving task are managed by the human driver.

- **Level 1. Driver Assistance:** the driving mode-specific execution by a driver assistance system of either steering or acceleration/deceleration using information about the driving environment and with the expectation that the human driver performs all remaining aspects of the dynamic driving task. The execution of steering and acceleration/deceleration is managed by the human driver and the system while the monitoring of the driving environment and the fallback performance of dynamic driving task are managed by the human driver.

- **Level 2. Partial Automation:** the driving mode-specific execution by one or more driver assistance system of both steering and acceleration/deceleration using information about the driving environment and with the expectation that the human driver performs all remaining aspects of the dynamic driving task. The execution of steering and acceleration/deceleration is managed by the system while the monitoring of the driving environment and the fallback performance of dynamic driving task are managed by the human driver.

- **Level 3. Conditional Automation:** the driving mode-specific performance by an automated driving system of all aspects of the dynamic driving task with the expectation that the human driver will respond appropriately to a request to intervene. The execution of steering and acceleration/deceleration and the monitoring of the driving environment are managed by the system while the fallback performance of dynamic driving task is managed by the human driver.

- **Level 4. High Automation:** the driving mode-specific performance by an automated driving system of all aspects of the dynamic driving task, even if a human driver does not respond appropriately to a request to intervene. The execution of steering and acceleration/deceleration, the monitoring of the driving environment and the fallback performance of dynamic driving task are managed by the system.

- **Level 5. Full Automation:** the full-time performance by an automated driving system of all aspects of the dynamic driving task under all roadway and environmental conditions that can be managed by a human driver. The execution of steering and acceleration/deceleration, the monitoring of the driving environment and the fallback performance of dynamic driving task are managed by the human driver.

The **dynamic driving task** includes the operational (steering, braking, accelerating, monitoring the vehicle and roadway) and tactical (responding to events, determining when to change lanes, turn, use signals, etc.) aspects of the driving task, but not the strategic (determining destinations and waypoints) aspect of the driving task.

The **driving mode** is a type of driving scenario with characteristic dynamic driving task requirements (e.g., expressway merging, high speed cruising, low speed traffic jam, closed-campus operations, etc.).

The **request to intervene** is notification by the automated driving system to a human driver that s/he should promptly begin or resume performance of the dynamic driving task (SAE On-Road Automated Vehicle Standards Committee, 2014).

This study focuses on the level 3 self-driving cars: the driving is performed by an automated driving system of all aspects of the dynamic driving task with the expectation that the human driver will respond appropriately to a request to intervene. This type of self-driving is also named conditional automated driving (CAD).

2.6 Takeover

The response to a request to intervene is named "takeover" and consists of a task switch from the inactivity (or other non-driving related task) to the driving one in which the driver must re-configure its sensory, motoric and cognitive state to be able to control the vehicle. The takeover may be divided into 4 steps, each of which corresponds to specific requirements to successfully take over manual vehicle control (Shuttleworth, 2019):

1. **Maintaining fitness to drive during automated driving** (CAD engaged). The driver is engaged in a non-driving related task. This task should not have negative effect on the availability of the driver to take over manual vehicle control.
2. **Noticing the necessity to take over manual vehicle control as soon as the takeover request is issued** (CAD degraded). In this step the driver is alerted by the system to take over manual vehicle control. In this step a takeover request is performed.
3. **Interruption of the executed non-driving related task and interfacing with the control elements** (CAD disengagement). This step takes place as soon as the driver recognises the need to take over manual control.
4. **Focusing on subsequent manual driving** (Manual drive). The driver takes control of the vehicle.

While not driving, the driver may be engaged in non-driving related tasks. They consist in a heterogeneous range of different activities that range from the simple do-nothing to more complex actions. It is possible to divide them into categories, dividing them accordingly (Naujoks, et al., 2017):

- Primary modality of the task (visual vs. auditory).
- Interaction (active vs. passive).
- Interruptibility (easy vs. difficult).
- Coding of information (verbal vs. spatial).

2.7 Definition of risk

This study involves situations of simulated risk the participant will experience and label. This section provides the theoretical background for a standardized definition of risk.

A risk is a situation involving exposure to danger and there may be risk only because of a hazard, a source of danger. It is possible to define the risk as the combination of the probability and the consequence of a hazard. The risk definition considers the possibility that a hazard can harm the observer, thus, it is possible to have a definition of risk only in dependence of the context and relatively to the observer (Kaplan & Garrick, 1980).

Each field has its own specific definition of risk, according to the possible hazard that characterize the environment. The Automotive Safety Integrity Level (ASIL) is a risk classification scheme defined by the ISO 26262 "Functional Safety for Road Vehicles standard". It defines 4 levels of integrity requirements, from ASIL A (the lowest) to ASIL D (the highest):

*Risk = Exposure * Controllability * Severity*

The estimation of this risk, based on a combination of the probability of exposure, the possible controllability by a driver and the possible outcome's severity if a critical event occurs leads to the ASIL. The ASIL does not address the technologies used in the system; it is purely focused on the harm to the driver and other road users (National Instruments, 2019). For these reasons it is not possible to practically use the formula without making further considerations.

In literature it is possible to find many pragmatical approaches to assess the risk that turn its definition into approaches applicable in real contexts. For this work it was chosen to adopt the risk matrix approach (RMA). It is a method to assess and evaluate the risk that was first developed by the acquisition engineering team at the Air Force Electronic System Center in 1995 to assess the risk in the life cycle of programs. It originally referred to the possibility that a program's requirement could not be met by available technology or engineering procedures or processes, then it became successful and also applied in other fields (Garvey & Lansdowne, 1998).

The risk matrix is based on the definition of the risk, as the one presented above. It takes into consideration its components and combine them to output the risk in a graphical way. The risk matrix consists in a grid with only two input sources, one on the x-axis and one on the y-axis. The output of risk is determined by the combination of the two input coordinates: the controllability, which express the likelihood of a dangerous situation, and the severity, the impact that the dangerous situation may have.

The input elements are divided into more levels to increase the number of matrix cells and possible outputs. Once the controllability and the severity have been assessed, the graphical structure of the risk matrix allows to identify the correspondent risk level. Colours can be added to increase the readability of the matrix: red is used for the cells which represents higher level of risk, yellow for the middle-risk cells and green for the low-risk ones (Ni, Chen & Chen, 2010).

Even though in a simulated environment there is no real risk, the definition of risk applies to the simulated risk according to the potential impact it may have in the analogue real situation. In the next sections it is defined a matrix approach to the risk specifically for the goal of this work.

2.8 Unity3D

Unity3D is a development environment designed to build cross-platform games in a simplified manner. The interface allows the user to fully control the game elements, from the camera perspective to the animation. It allows both graphical interface and scripting system to assist the creation of games using both JavaScript and C#.

The current simulation of the University of Skövde is made in Unity3D and may run from a minimum of 1 to a maximum of 7 different screens. Unity3D was used to modify the simulation, making it suitable for the experiment.

3 Problem

A big challenge regarding the usage of a driving simulator in research is the correct awareness of the environment by the user. Participant must be aware of the surrounding elements and react accordingly as they would in a real environment. This is made possible by the realism and the correct perception of the simulated elements of the simulation.

The perception of the elements and the realism feeling as perceived by the driver become even more important when the simulation is used to study self-driving cars. Due to its design, a low fidelity simulation may cause a wrong perception of the simulated risk because of its too less immersivity in the simulation environment, leading to a fake feeling of safety which could potentially compromise the validity of the study.

The purpose of this study was to evaluate the perception of the simulated risk faced by the participants in a low fidelity simulation in relation with the individual videogame usage. Specifically:

1. Assess the experienced and faced simulated risk of the participants in a low fidelity simulator.
2. Determine how much the perceived risk of the participant differs from the faced one.
3. Evaluate if the videogame experience influences the simulated driving performance.

A low-fidelity ad-hoc simulator has been designed and tested using a simulation based on the one of the University of Skövde to evaluate the impact of a low fidelity environment on the driver. The designed simulator differs from the higher fidelity one already existing the University mostly in its hardware part; the chosen simulation for this work is based mostly on the already existing one (Lebram, Engström & Gustavsson, 2006).

3.1 Method

The participants of the study did a simulation of conditionally automated driving alternating periods of manual and automated driving. During the automated driving moment, the participants were asked to play a game as non-driving related task.

On the driving path, the participant had to face simulated moments of simulated risk previously assessed using a variation of the ASIL scheme. The information from the participants was collected through questionnaire and observation focusing on four specific moments of the driving experience specifically paying attention to:

- The level of exposure to simulated risk.
- The correct identification of the risk.

During the experiment, the driving performance of the participant was analysed through the gathering of some data. For completeness and to avoid data loss, the whole experiment was recorded: the simulation scene, the participant camera, the non-driving related task.

Before the experiment, individual information was asked to the participant regarding the driving experience and the usual videogame usage.

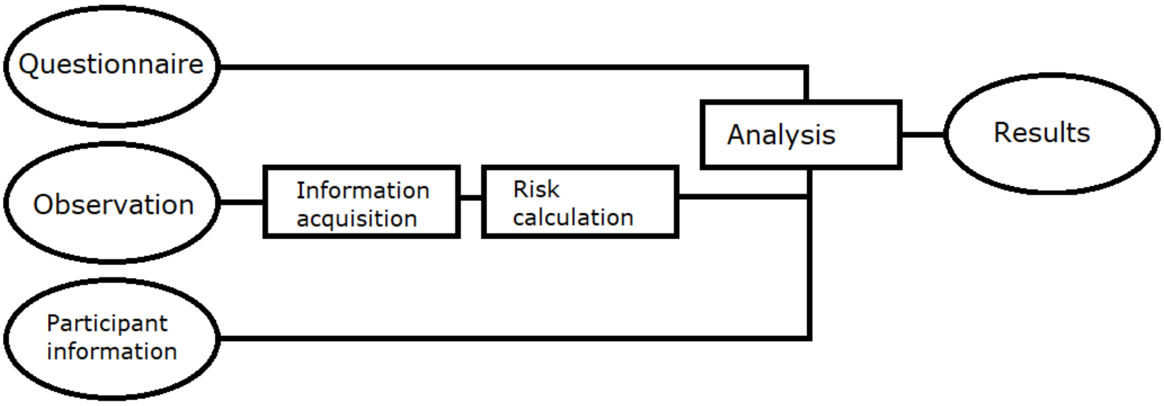

Figure 1 - Analysis routine

As shown in figure 1, the experiment produced three main data output: the questionnaire answers about the driving experience, the video observation and the participant information. Before the actual analysis, the video observation was processed with the aim of calculating the experienced risk of the participant, as show in the figure 1.

3.2 Ethical aspects

This kind of study would be problematic in real traffic. Even though the self-driving car is a growing field, there are still problems in the experimentation of this kind of vehicles in the real traffic, so, it is still necessary to setup a simulated environment to conduct experiments.

Volunteer students were selected to conduct the study. Each participant was informed on the purpose of the study, the procedure of the experiment and explained that all the personal data collected was either anonymized and confidential or deleted. The participants were informed of the possibility of motion sickness while driving in the simulation and it was reminded the voluntary participation and the possibility to leave the experiment at any time for any reason. All participants gave their informed consent (Appendix B) to take part in the study.

Because of circumstances due to the outbreak of the COVID-19, extraordinary hygiene measures were adopted in order to guarantee the safety of the participants.

4 Experiment

This section describes the procedure of the experiment.

4.1 Participants

Because of circumstances due to the outbreak of the COVID-19 and the subsequent closure of the university, it was difficult to find a consistent number of participants. The study involved 18 participants, from different nationalities, aged between 19 and 28. The average age was 22 years old and half of the participants was in between 24 and 21 years old.

All the participants had a driving license and different driving experience ranging from almost 0 to 10. The average driving experience was 3 years and half of the participants was in between 2 and 4 driving years' experience.

The participants were collected through convenience sampling. No person was previously informed on the experiment content or already interacted with the simulation, and reminded to keep secret any result, fact or opinion about the experience. During the simulation, the participants were left alone.

For this study, a low fidelity environment has been set up. It consisted in a single-screen laptop placed on a table with the addition of steering wheel and pedals to emulate an actual car as shown below:

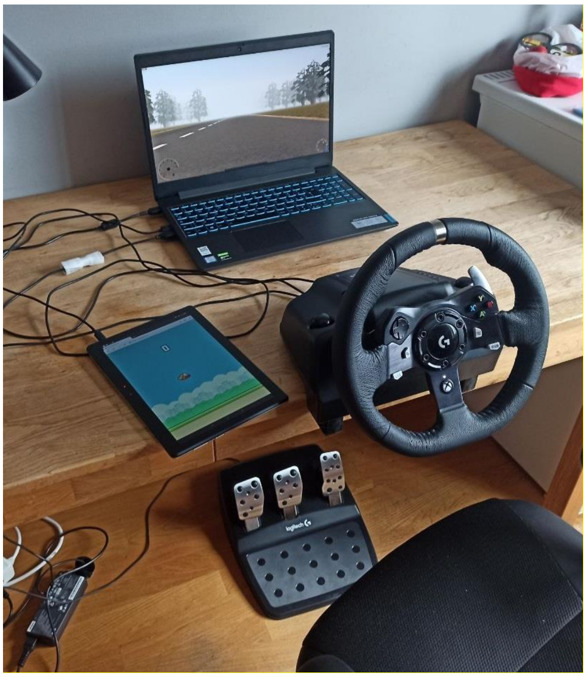

Figure 2 - Simulator setup

The setup was meant to replicate, in its proportions, the driver seat position of a Volvo S80, the car on which the simulator of the University of Skövde is based on. As it is possible to see in the figure 2, the simulator is designed as "low fidelity": a 14 inches monitor, placed on the table at half meter from its edge, displays the scene; the pedals are positioned at approximately one meter from the chair; a tablet is used to replicate the on-board monitor of the car. The whole setup is placed on the table of a room and the participant was surrounded with household items. Specific distractive elements such as posters or mirrors had been removed from the room and the front wall and the table itself were kept empty, with the exception of a lamp. The infrastructure provided low immersivity in the simulation, external every-day elements were present in the surrounding and the overall price of the tools can be considered "cheap" compared to other solutions.

4.2 Procedure

The experiment can be divided in 4 parts:

1. Introduction
2. Familiarization
3. Simulation
4. Assessment

In the introduction, the participant was welcomed and introduced to the procedure of the experiment, educated on the consent form and instructed on the tasks to perform. A written plot was designed to ensure a standardized introduction with the aim of explaining the input commands and solve any doubt regarding the interface. A copy of the text can be found in the Appendix A.

The participant would then read the consent form to give informed consent to take part of the experiment. The consent for can be found in the Appendix B. During the introduction, the participant was also asked to answer the first part of the questionnaire, asking information about its driving and videogame experience.

After the introduction, during the familiarization, the participant was made familiar with the tools s/he was going to use in the experiment practicing the non-driving related game for a standardized time.

During the simulation, the participant was asked to go to the destination alternating manual driving periods with self-driving one. S/he would face simulated risks during both the phases of the conditionally automated driving.

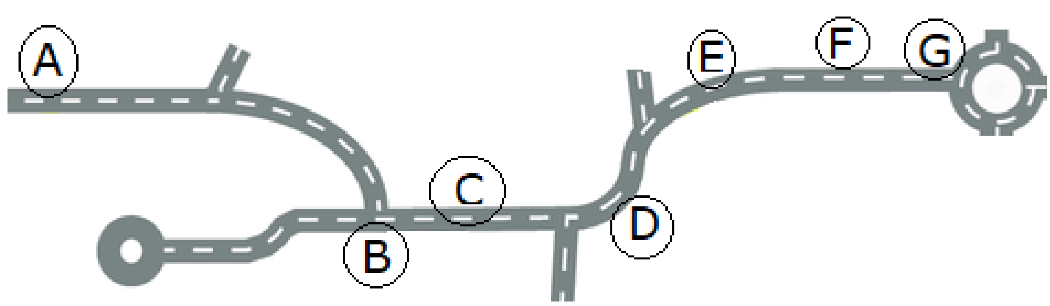

Figure 3 - Driving path

The figure 3 shows the driving path, same for all the participants, that can be summarized as follows:

A. The simulation starts with the automatic driving disabled;
B. The participant drives manually until the intersection and turn left as specified in the user interface;
C. After the turn, a request to intervene is shown and the automatic driving mode is enabled;
D. During that period, the participant is asked to engage the non-driving related task, a smartphone game;
E. While the car is automatically driving, a "risky situation" appears in the simulation: a truck crosses the street in front of the car (figure 4);
F. The control of the car is given again to the user;
G. The simulation ends.

Figure 4 - Truck cross

During the assessment, the participant was asked to answer a questionnaire regarding how much s/he considered risky some aspects of the simulation. Only four moments of the simulation are taken under review:

1. The first manual driving segment (from point A to point B in the figure 3).
2. The intersection (point B in the figure 3).
3. The automated driving segment (from C to F in the figure 3).
4. The truck road cross (point E in the figure 3).

The procedure was designed not to require the presence of a test operator in all the steps but the introduction. The screen, camera and tablet were recorded during all the procedure. Some "on screen" elements were designed to ensure that the participant would understand the actions to perform, even without an explicit preparation, as shown in figure 5.

Figure 5 - On screen element

4.3 Non-driving related tasks

Two different games were chosen to be played as non-driving related tasks: an online version of flappy bird and chess puzzles on the Lichess app. Half of the participants played one game, and the other half the other one.

Despite their apparent difference, these two games share many aspects. They are both visual games, controlled by the user, easy to interrupt and spatially encoding the information of the game. Anyway, they require a different level of attention due to their different nature. Flappy bird requires constant attention because of its fast gameplay; Chess, instead, does not require constant attention because of its turn-based nature.

4.4 Observation

The observation of the participant was made by the software OBS “Open Broadcaster Software”: a free and open source software for video recording and live streaming distributed under GNUv2 license.

OBS Studio allows the user to configure a scene as a recording environment as combination of different video and audio sources. For this work it a scene named “Record Thesis” has been configured as follows. The screen has been divided into 4 parts:

- The **background** image contains the recording scene of the simulation.
- The **upper-right** section contains the recording scene of the tablet.
- The **lower-left** section contains the recording scene of the camera.

All the sounds, except the one from the microphone of the laptop, have been muted. In the figure 6, a visual overview of the recording tool; for privacy reasons, the participant frame has been pixelated:

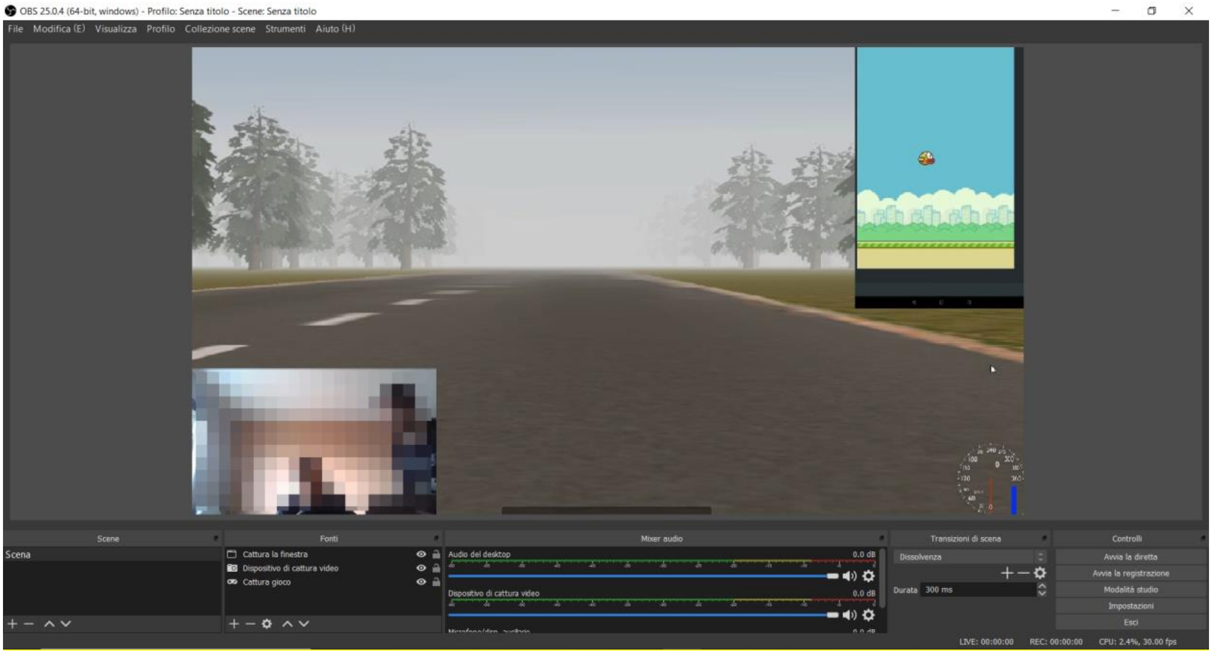

Figure 6 - Observation setup

The recording of the screen may be affected by lag. To avoid this problem, it is possible to decrease the framerate of the record from 60 to 30 fps and the screen resolution. For this experiment, the 30-fps setup was preferred.

The recording of the tablet has been done using the scrcpy software. An open source program which enables the mirroring of the content of the tablet screen.

In detail, the goal of the observation procedure is to acquire information on:

- The mode speed during the manual driving segment (The speed kept for the longest amount of time).
- The top speed during the manual driving segment.
- The number of times the car invades the left lane during the manual driving segment.
- The number of times the car exits the roadway during the manual driving segment.
- The presence of crashes during the manual driving segment.
- The instantaneous speed at the intersection.
- The presence of off-road moments at the intersection.
- The presence of crashes at the intersection.

This information was useful to assess the actual simulated risk faced by the participant and compare it with the result of the questionnaire.

4.5 Questionnaire

The questionnaire was designed to get structured information from the participant. It contained questions about the participant and the subjective identification of the risks in the map. It is divided in two parts: the first part contains question regarding the participant background and it is done before the simulated drive; the second part contains question regarding the four risk periods faced during the simulated driving and it is done after the simulated drive. The full questionnaire can be found in the Appendix C.

The first part contains question on the driving experience and the frequency the participants plays videogames, mobile games and racing games. The answers are made in a Likert scale from 1 (Not at all) to 6 (Every day, more hours per day). The first part of the questionnaire also contains questions about the driving experience of the participant. After the data collection and considering the answer provided, it has been necessary to exclude some participant with none or very little driving experience because of data invalidation.

The second part contains questions about the risk perception of the four moments of the driving experience introduced above. The answers are made in a Likert scale from 1 (Very low) to 6 (Extremely high). The questions ask made with the template “How would you rate the risk…?”.

5 Risk calculation

The experiment produced two data outputs: the answer sheet of the questionnaire and a video record as result of the observation. The questionnaire contains information on the perceived risk, whereas the observation information on the faced risk. While the data from the questionnaire was already structured and ready for the analysis, the one from the observation needed a further analysis, as described in this chapter. This section explains the calculation of the faced risk of the participant during the driving simulation.

A risk matrix is defined below. It combines the severity and the controllability of an event in order to correctly assess the faced simulated risk. Each participant experienced a different level of simulated risk and reacts differently. The video observation of each participant was processed as described below to gain structured information that can be analysed together with the result of the two parts of the questionnaire.

5.1 Risk assessment

Each risk factor was assessed using a risk matrix, which combines the severity of the risk with its probability. The value obtained by the matrix might be multiplied for the exposure time of the user. The risk matrix is shown in the figure 7.

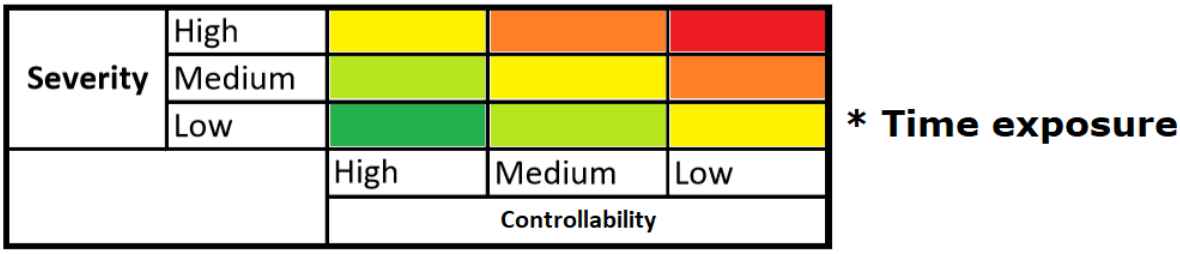

Figure 7 - Risk assessment matrix

The risk severity of an event was assessed as follows:

- **High risk severity** if it may cause serious or disabling personal injury, permanent disability, fatality or property damage for more than 100'000 Euro.
- **Medium risk severity** if it may cause injury requiring medical aid or property damage between 100'000 and 25'000 Euro.
- **Low risk severity** if it may cause no injury or minor injury requiring first aid or property damage for less than 25'000 Euro.

The risk controllability of an event was assessed as follows:

- **Low controllability** if the driver cannot avoid the risk without damaging the vehicle or does not realize its presence.
- **Medium controllability** if the driver realizes in time the presence of the event and can avoid it compromising the usual drive of the vehicle (for instance, avoiding an obstacle in front of the vehicle, but going outside the road).
- **High controllability** if the driver realizes in time the presence of the event and can avoid it without compromising the usual drive of the vehicle.

The time exposure might be measured in seconds, from the first moment the element of risk is observable on screen to the moment it is not visible anymore. However, due to the design of the experiment, the time exposure of the participant to the risk factor was considered constant and omitted.

Once a risk factor was placed in the risk matrix, it could be converted in a Likert based scale ranging from 1 to 5, as shown in the table 1.

Table 1 - Risk conversion

Severity	*Controllability*	*Likert value*
Low	**High**	***1***
Low	**Medium**	***2***
Low	**Low**	***3***
Medium	**High**	***2***
Medium	**Medium**	***3***
Medium	**Low**	***4***
High	**High**	***3***
High	**Medium**	***4***
High	**Low**	***5***

To match exactly the scale 1-6 of the questionnaire, and extra point was assigned in case of extraordinary situations as specified in the next sections.

To better understand the proposed system of risk assessment it is crucial to understand that, in our everyday life, we must never experience a risk factor higher than 1. Driving with a risk factor of at least 2 implies a higher chance of injuries and/or having little control of the vehicle, which may lead to inflict damage to objects or other people. However, the presence of an extraordinary external event, like in the simulation, may increase the severity and, sometimes, decrease the controllability of the vehicle. In the next paragraph the conversion from the raw data to the numerical risk value, for the road segment.

5.2 Risk during the manual driving segment

The manual driving segment was the first part of the simulation. During this segment, the participant drove manually until the intersection. The manual driving analysis differs from the intersection one and, for this reason, the two ones are considered separately.

The mode speed, the speed kept for the highest amount of time, and the top speed are used to calculate the severity component of the risk. The usage of the speed to assess the severity relies directly on the possibility to cause more damage to people and object in case of an impact at high speed. Considering the European parameters of safety and the type of road (European Commission, 2020).

The table 2 contains the labelling rule of the severity.

Table 2 - Severity at the manual driving segment

Mode speed	*Top speed*	*Severity*
<80 km/h	<90 km/h	***Low***
80-120 km/h	90-130 km/h	***Medium***
120-180 km/h	130-190 km/h	***High***
>180 km/h	>190 km/h	***High(+)***

In case even only one parameter met the requirement, the severity went into the correspondent category, thus, it was not necessary to meet both the requirements to have a specific severity classification. An extra point to the risk was added in case of extraordinary high speed, as shown in the last row of the table 2.

The number of times the car invaded the left lane, went off road or crashes during the manual driving segment were used to assess the controllability component of the risk. Even though also the speed influences the controllability (European Commission, 2020), it was decided to use only these parameters in the analysis. The table 3 contains the labelling rule of the controllability.

Table 3 - Controllability at the manual driving segment

Lane invasion	*Off road*	*Crashed*	*Controllability*
0	0	No	***High***
At least 1	0	No	***Medium***
0	At least 1	No	***Low***
At least 1 (and)	At least 1 (or)	Yes	***Low(+)***

In case even only one parameter met the requirement, the controllability went into the correspondent category, thus, it was not necessary to meet all the requirements to have a specific controllability classification. If not previously added, an extra point to the risk would be added in case of extraordinary low controllability (In case of at least 1 lane invasion and 1 off road, or in case of crash) as shown in the last row of the table 3.

5.3 Risk during the intersection

The manual driving segment ends with the intersection. During the intersection, the participant was still driving manually the car. The risk in the intersection was assessed using different observation data, with a procedure similar to the one of the first segment.

The instantaneous speed at the intersection was used to calculate the severity component of the risk as shown in the table 4.

Table 4 - Severity at the intersection

Instantaneous speed	*Severity*
<40 km/h	***Low***
40-80 km/h	***Medium***
80-120 km/h	***High***
>120 km/h	***High(+)***

As well as for the manual drive segment, an extra point to the risk was added in case of extraordinary high speed, as shown in the last row of the table 4.

The controllability component of the risk depended on the presence or absence of off-road moments and crashes at the intersection, as in the table 5.

Table 5 - Controllability at the intersection

Off-road	*Crashed*	*Controllability*
No	No	***High***
Yes	No	***Medium***
No	Yes	***Low***
Yes	Yes	***Low(+)***

If not previously added, an extra point to the risk would be added in case of extraordinary low controllability, as shown in the last row of the table 5.

5.4 Risk during the automated driving segment

After the intersection, the control of the car switched to "autonomous" and the participant lost the control over the car. For this reason, all the participants experienced the same level of risk, as in the table 6.

Table 6 - Risk during the automated driving segment

Mode speed	**Top speed**	**Severity**	**Lane invasion**	**Off-road**	**Crashed**	**Controllability**
50 km/h	50 km/h	**Low**	0	0	No	**High**

During the segment, a truck crosses the road. The risk components are classified as shown in the table 7.

Table 7 - Risk at the truck cross

Severity	*Controllability*
Medium	***Medium***

6 Results

This section focuses on the analysis of the data in order to:

1. Assess the experienced and perceived simulated risk of the participants in a low fidelity simulator.
2. Define how much the perceived risk of the participant differs from the faced one.
3. Evaluate if the videogame experience influences the simulated driving performance.

Data has been gathered from observation and questionnaire. From the observation, data has been extracted and further processed to obtain a structured overview of the risk.

In this chapter there is an overview of the data obtained in this way and the presentation of the results.

The next sections contain examples of individual analysis for a random sample of five participants. Those examples are provided to show the analysis process. All the data is available in the Appendix D.

6.1 Observation analysis

Before the quantification of the risk, each video observation of the participants was processed to calculate the experienced risk. All the participant information was analysed. This section presents the procedure explained in the chapter 5 for a random sample of 5 participants. The goal of this section is to present a summary of the data obtained by the observation and show how the faced risk is calculated.

At the first manual driving segment under review, the almost totality of the participants exceeded the speed limit and kept a very high speed for most of the time, the mode speed. The average mode speed observed was almost 150 km/h, and an average top speed of almost 170 km/h. Moreover, seven participant experienced loss of control of the vehicle. The table 8 shows the calculation of the risk for a random sample of five participants.

Table 8 - Example of risk calculation at the manual driving segment

Mode speed	**Top speed**	**Times lane invasion**	**Times outside road**	**Crashed**	**Severity**	**Controllability**	**Risk**
120 km/h	140 km/h	4	1	Yes	*High*	*Low(+)*	**6**
150 km/h	160 km/h	0	0	No	*High*	*High*	**3**
140 km/h	170 km/h	1	0	No	*High*	*Medium*	**4**
110 km/h	120 km/h	0	0	No	*Medium*	*High*	**2**

180 km/h	190 km/h	1	0	No	*High*	*Medium*	**2**

At the first driving intersection, the second segment under review, the observed average speed was of 135 km/h and twelve participants out of eighteen experienced loss of control. The table 9 shows the calculation of the risk for a sample of five participants:

Table 9 - Example of risk calculation at the intersection

Speed	**Crashed**	**Outside road**	**Severity**	**Controllability**	**Risk**
80 km/h	Yes	Yes	*Medium*	*Low(+)*	**5**
130 km/h	No	No	*High(+)*	*High*	**4**
110 km/h	Yes	No	*High*	*Medium*	**4**
100 km/h	No	Yes	*High*	*Low*	**5**
180 km/h	Yes	Yes	*High(+)*	*Low(+)*	**6**

During the automated driving period and the truck intersection, respectively the third and fourth segment under review, the average speed was set constant to 50 km/h and no participant experienced loss of control.

6.2 Risk quantification

This goal of this section is to explore the data and provide an analysis, paying attention on both the questionnaire and observation data, including the information on the participants, to provide a quantification of both the experienced and the perceived risk of the participants.

Figure 8 contains an overview on both the actual amount of risk during the whole manual segment and perceived one of a sample of five participants.

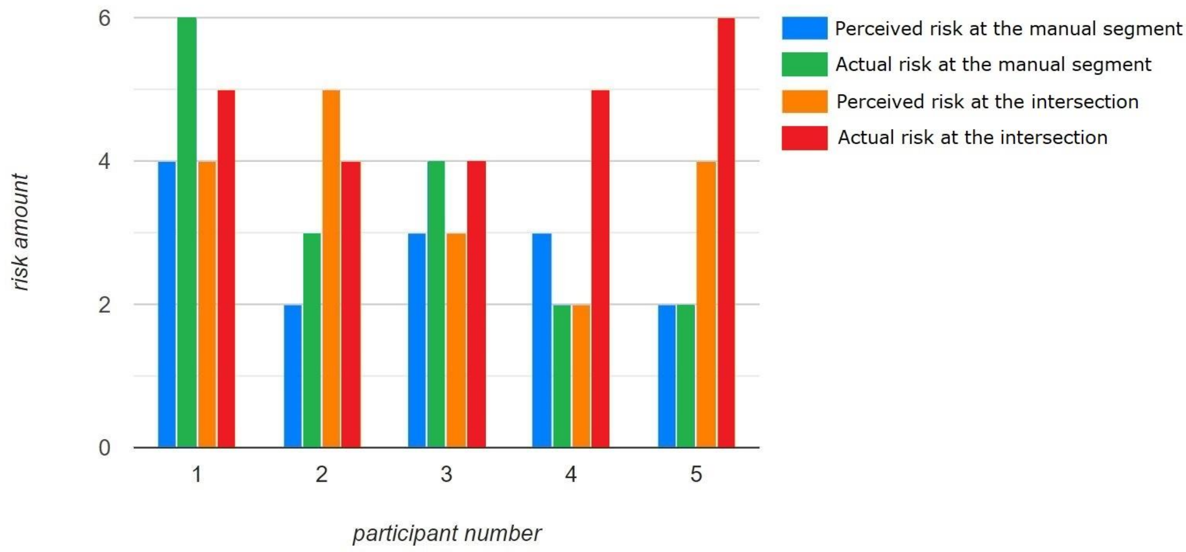

Figure 8 - Risk during manual driving

In the figure 9, instead, there is an overview on both the actual amount of risk during the whole automated driving segment and the perceived one from the same sample shown above:

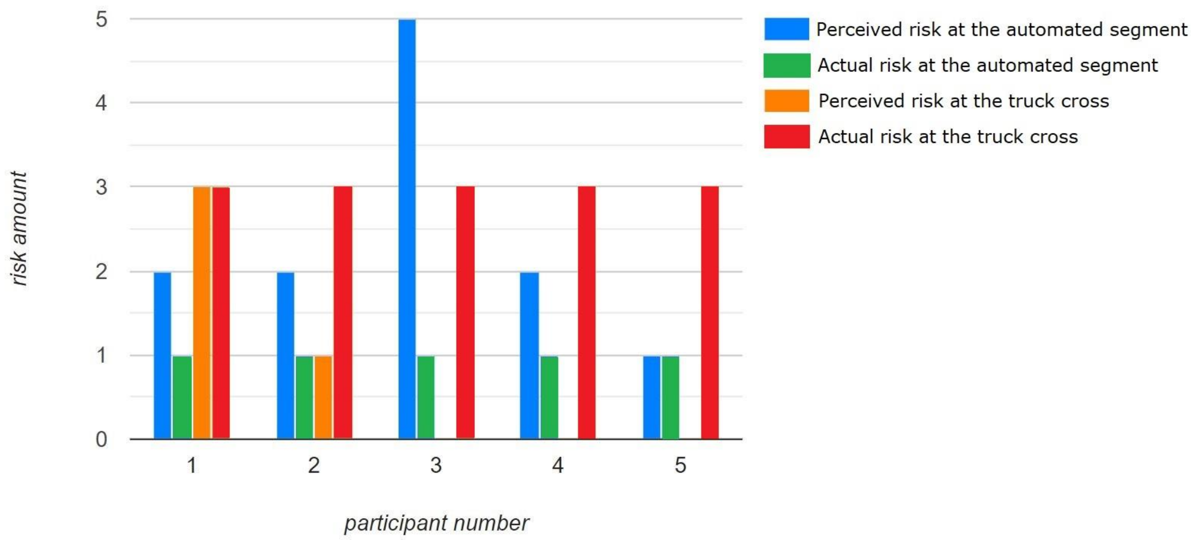

Figure 9 - Risk during automated driving

During the automated driving segment, the participants were engaged in a non-driving related task, as previously said. For this reason, some participants did not realize the presence of the truck crossing the road, so, their value of "perceived risk" is 0.

It is possible to calculate the average value of the different risks for all the participants, as shown in the figure 10:

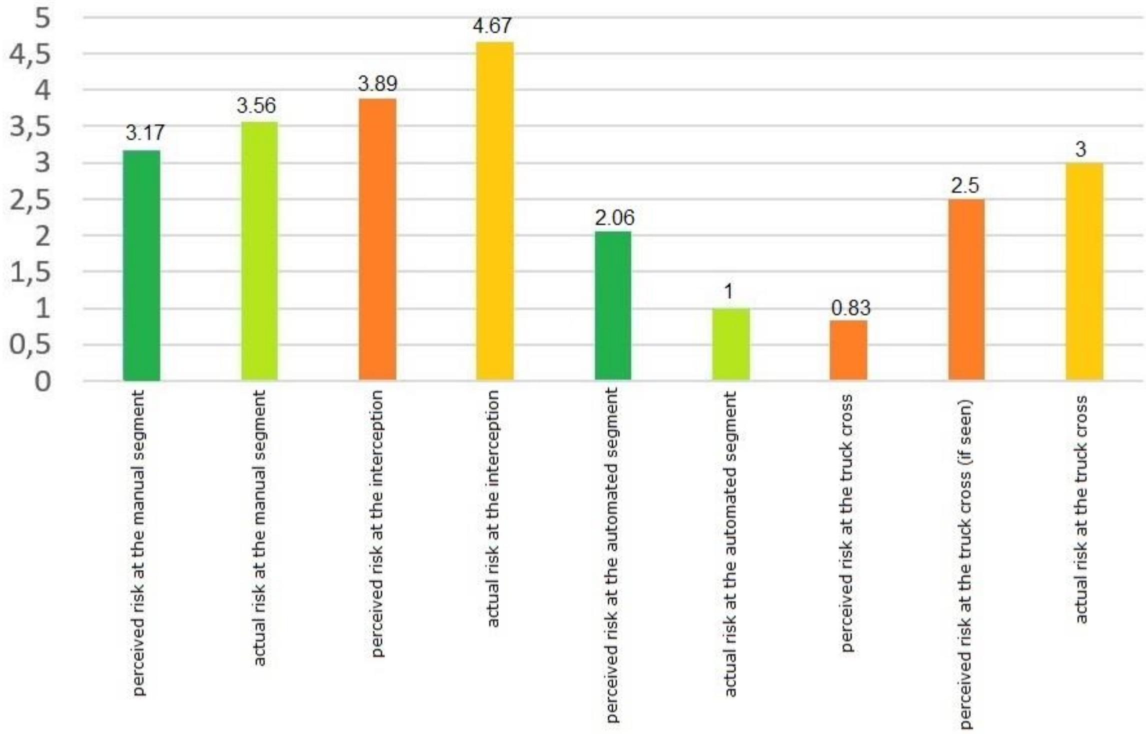

Figure 10 - Average risk

The figure 10 shows a relatively high-risk level faced by the participants in the manual driving segment and the intersection: respectively 3.56 and 4.67. The average perceived risk by the participants in those sections is slightly lower than the faced one: 3.17 for the manual segment and 3.89 for the intersection.

During the automated driving period the participants experienced a 50 km/h speed and no loss of control, for this reason the risk in that segment is assessed as 1. However, the participants in average rated that segment with a risk level of 2.06. Because of non-driving related task, 65% of the participants did not see truck crossing the road (figure 4); the perceived risk for those participants is set to 0. For this reason, the figure 10 shows two different bars: one plotting the average for all the participants (0.83) and one plotting the average for only the participants who saw the truck (2.5).

The table 10 focuses on the possible correlation between the actual risk of the whole manual driving segment, including the intersection, and the perceived one on the same path:

Table 10 – Correlation between actual and perceived risk

	Perceived risk at the manual segment	*Perceived risk at the intersection*
Actual risk at the manual segment	-0.03	0.29**
Actual risk at the intersection	-0.11	0.01

No significative correlation has been found, except between the driving performance on the manual segment and the perceived risk at the intersection.

The data highlighted a positive correlation of 0.45 between the performance at the manual segment and at the intersection.

Individual information about the participants was asked with the questionnaire before the beginning of the experiment. It is possible to integrate that data with the one about the risk presented above to find correlations, as shown in the table 11.

Table 11 – Correlation between the risk and individual background

	Driving experience	*Videogame usage*	*Racing games usage*	*Mobile games usage*
Perceived risk at the manual segment	-0.31**	0.17	0.16	-0.25*
Perceived risk at the intersection	-0.21*	0.10	0.11	-0.17
Perceived risk at the automated segment	-0.13	-0.32**	-0.04	-0.06
Perceived risk at the truck cross	-0.10	-0.22*	0.11	0.02
Actual risk at the manual segment	0.13	-0.34**	-0.32**	-0.53***
Actual risk at the intersection	-0.01	-0.27**	-0.37**	-0.09

The table 11 shows a negative correlation between the participants performance and their usage of videogames, racing games and mobile games, meaning that the more an individual is used to those forms of gaming, the lower is the risk faced while driving. In other words, more they played videogames, better was their performance (less speed and more control of the vehicle). No significant correlation was found between the driving experience and the performance.

A further analysis showed the r-squared values for the correlation between videogame, racing games and mobile games usage and the actual risk faced at the manual segment to be respectively 0.12, 0.11 and 0.28.

A negative correlation, with a r-squared value of 0.10, was also found between the usage of videogames and the risk assessment during the automated driving period, including the truck cross, meaning that people usually playing videogames rated the automated driving moment less risky than the others. This information gains value if it is taken into consideration that the participants, in average overrated the risk of the automated driving moment; meaning that the usual gamers provided a better evaluation of the automated driving moment.

6.3 Correct risk identification

The goal of this section is to analyse the correctness of the identification of the risk by the participants, including the personal information.

For each segment, it is computed the “risk identification error” as the absolute value of the difference between the perceived simulated risk and the observed one. The lower the risk identification error, the better the risk assessment. The figure 11 contains this value calculated for a sample of five participants, while the figure 12 contains the average for all the participants for the four driving segments.

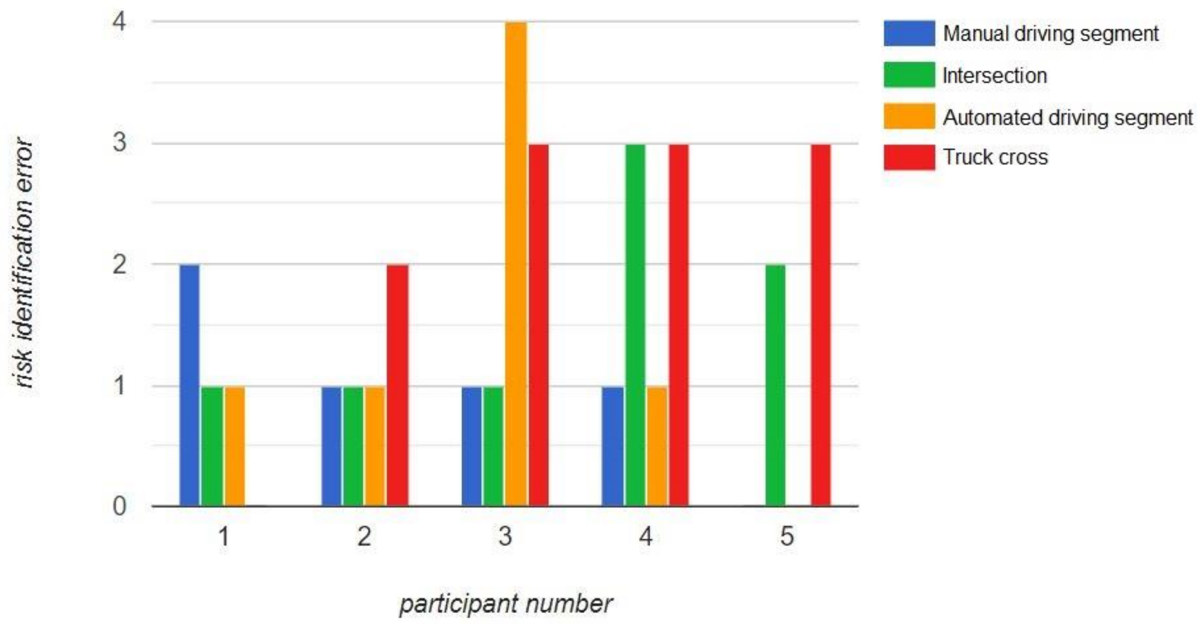

Figure 11 - Risk identification error

The participants, in average, made a mistake of 0.39 points while evaluating the faced risk in the manual driving segment. The risk identification error at the intersection was in average 0.78 while, in the automated driving segment, was 1.06. At the truck road cross the average risk identification error was 2.17. The data about the average risk identification error is shown in the figure 12.

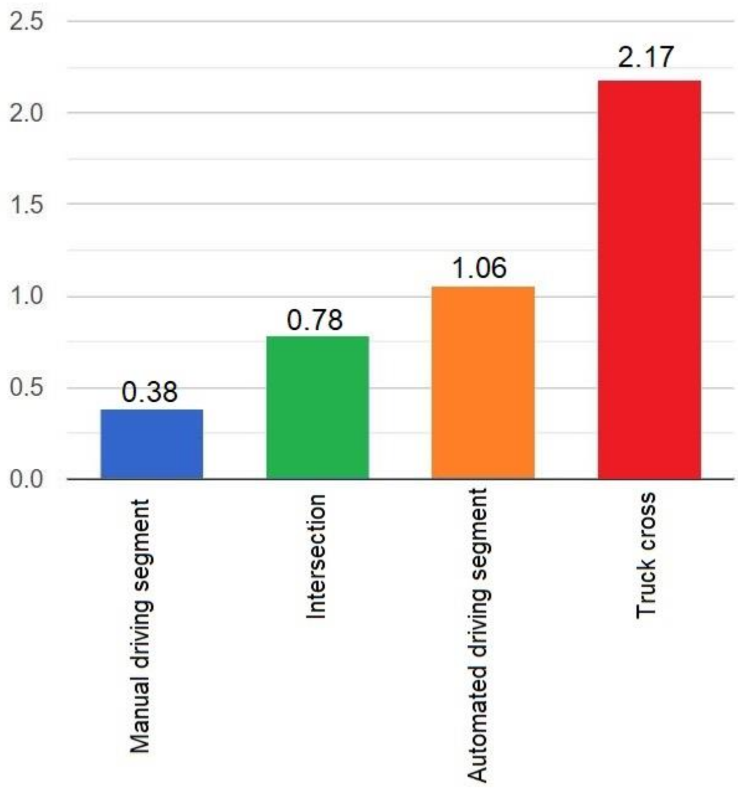

Figure 12 - Average risk identification error

The data on the risk identification error is then related with the personal information of the participants on their videogame usage, as shown in the table 12.

Table 12 - Correlation between the correct identification of the risk and the individual background

	Driving experience	*Videogame usage*	*Racing games usage*	*Mobile games usage*
Manual segment	0.16	-0.02	0.20*	-0.31**
Intersection	-0.13	-0.32**	-0.04	-0.06
Automated segment	0.10	0.22*	-0.11	-0.02
Truck cross	0.25*	0.08	0.01	0.01

The table 12 highlights a negative correlation between the mobile games usage and the manual driving segment (r-squared value of 0.10) meaning that, while manual driving, some categories of players assessed the observed risk in a more accurate way. It was not found any significant correlation among the participant information and the automated driving segment nevertheless denoting only a slight positive correlation, probably due to the absence of constant attention during the considered period. However, the correlation is not strong enough to potentially consider a cause-effect relation.

7 Conclusions

The purpose of this work was to evaluate the perception of the simulated risk faced by the participants in a low fidelity simulation in relation with the individual videogame usage. The context chosen for this study was the one of type-3 self-driving cars, partially autonomous vehicles which are able to control themselves for the most of the time and may ask the driver to take control of the car in case of specific situations.

The described objectives were done by making a low fidelity simulator, designing a risk assessment procedure and developing a simulation with simulated risk elements. The experiment was done with 18 participants, who were asked to drive and perform specific actions related to the context of the conditionally automated driving. Both the simulated risk faced by the participant while driving and the perceived one were calculated in four sections of the driving simulation through video observation and questionnaire. Personal information about the participant driving experience and videogame usage were also collected through questionnaire.

7.1 Discussion

While manual driving, the faced risk of the manual segment and the intersection was relatively high. As for the design of this risk scale, a driving behaviour can be considered safe only when the risk value is exactly 1. Instead, the performance of the participants shown in the figure 10 reflected an overall average risk higher than 3 in the manual driving sections. This is due to the average high driving speed (148 km/h) and the presence of partial or total losses of control. The high speed could be explained by the tendency of people to exceed the speed limit while driving in the simulator, an already known problem of the simulator on which the software used in this experiment is based on (Lebram, Engström & Gustavsson, 2006).

Moreover, the data found an asymmetry between the perceived risk and the faced one in a different way in the moments of the simulation. Overall, the participants rated less risky the moments in which they had the control of the car, while rating riskier the moment in which they did not having the control, as shown by the figure 10. It is not possible to say anything significative for the truck because of the little number of participants who saw it.

Overall, the analysis found a negative correlation between the participants usage of videogames and the faced risk, meaning that the more an individual was used to gaming, the lower was the risk faced while driving (less speed and more control of the vehicle). The more experienced participants in videogames also had a better identification of the risk. This result can be explained by the better perception of the car in the environment and a better orientation ability and speed management, agreeing with the findings of Schlickum et al. (2009) and Smith et al. (2009).

The background aspect that correlated the most with the performance is the videogame usage; this result highlights the limitation of the low-fidelity simulator. No correlation was found, instead, between the driving experience of the participant and the result of the experiment. The relation between the individual background and the result output may be explained by the low-fidelity of the simulator: the low-fidelity characteristics made the videogame component more valuable than the driving component because too many aspects of the driving are took away from the experiment context.

7.2 Future works

This study was designed with the idea of comparing the obtained results with the ones obtained it in the higher fidelity simulator of the University of Skövde: a higher fidelity simulator that differs in many aspects with the solution adopted in this study. A possible future work could be replicating this study in the University simulator to compare the data from the two different sources and explore the impact of the different fidelity levels.

It may be interesting to extend the questionnaire about the participants with more questions on the gaming and driving. A determined background can lead to specific kind of results and it may be fascinating to find correlations between the individual characteristics and the output of the experiment.

This work took under consideration a driving simulator and it may be useful to adapt the methodology of this study to other kind of simulators, not only driving ones.

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9 Figures

10 Tables

11 Appendix A – Introduction speech

Welcome to the study about self-driving cars. The study is about driving cars of type 3, autonomous vehicles that alternate moments of automated driving, in which the car drives by itself, to moments of manual driving, in which it is the human driver the controller. To give you a clearer idea, for example, Tesla cars may fall into this category. As you may guess, doing experiments on this type of car in a real road is dangerous because of many aspects; for this reason, it is mandatory to use a simulator to conduct the experiments.

This is our low fidelity driving simulator. You will be asked to drive on it. There is no need to be a proficient driver to conduct the experiment. This is the steering wheel, used to turn the car to left and right. Those are the pedals used to accelerate (the right one) and break (the middle one). The left one (the gear shift) is useless because the car has automatic gear shift. That button is the honk, you will need it during the experiment. No other button is needed.

During the simulated driving, you will have to perform some actions as displayed on screen. An image will appear on the screen, together with a sound, to warn you about the action to perform. They may be: “break”, “honk”, “accelerate”, “turn left” and so on. At one point, the car will switch from manual driving to automated driving; there is a countdown on the screen together with a sound like the one at the beginning of a race warning you about the context switch. During the automated driving (and only during that period) you have to play the non-driving related task, this smartphone game. At one point the drive will be switched again to manual with the same countdown as before.

All the actions are paired with noises, so don’t worry to miss one action, the sound is quite loud, and all the actions will be displayed on screen, so it will be easier to remember those things. I’m here to answer you any question.

12 Appendix B – Consent form

This informed consent form is for the participation to the study “risk perception during conditionally automated driving in low fidelity simulator” made by Carmine D’Alessandro, student of the University of Skövde.

Introduction

I am Carmine, student of the University of Skövde. I am doing research on the driving simulation of the Computer Science department regarding self-driving cars. I am going to give you information and invite you to be part of this research. You do not have to decide today whether you will participate in the research. Before you decide, you can talk to anyone you feel comfortable with about the research.

This consent form may contain words you do not understand. Please, feel free to stop as we go through the information to have time to explain. If you have questions later, you can ask me or other researchers.

Purpose of the research

Self-driving cars are becoming a reality. Because of problems involved in the experimentation, it is difficult to setup tests in a real road, so, a simulator must be used. This study focuses on type-3 self-driving cars: vehicles able to drive themselves autonomously, but that require human intervention in case of situations.

We want to learn more about how people interact with a type-3 self-driving car, studying the impact of a non-driving related task (a smartphone game) on the overall driving experience.

Type of research intervention

This research will involve your participation in playing a smartphone game, driving a car simulator, filling a questionnaire and attend an interview that will take about 20 minutes.

The experiment starts with playing a smartphone game, continues with practicing the driving simulator. After an explanation of the procedure, the core part of the experiment will take place. Later, a questionnaire and an interview will be done.

Voluntary participation

Your participation in this research is entirely voluntary. It is your choice whether to participate or not. You do not have to decide today whether you will participate in the research. Before you decide, you can talk to anyone you feel comfortable with about the research and postpone your decision. Feel free to ask questions to me or other researchers in case you feel uncomfortable for any reason.

You can stop your participation at any moment for any reason and without providing any explanation. If the study has already taken place, you can request the information provided by you not be used in the research study at any moment for any reason and without providing any explanation.

You may not answer questions that you do not wish to respond to.

Duration

The research takes place over 20 minutes. During that time, you will be asked to play a smartphone game, drive a car simulator and fill a questionnaire. The study will take place entirely in a room and you will be left alone. If you agree to take part, you can stop participating by exiting the room.

Risks

There is a percentage of risk to develop simulator sickness. Due to the spatial limitations imposed on the simulator, perceived discrepancies between the motion of the simulator and your one can occur and lead to simulator sickness. It is like motion sickness in many ways but occurs in simulated environments and can be induced without actual motion. Symptoms of simulator sickness include discomfort, apathy, drowsiness, disorientation, fatigue, and nausea.

Confidentiality

We will not be sharing information about you to anyone outside the research team. The information that we collect from this research project will be kept private. Any information about you will have a number on it instead of your name. Only the researchers will know your number.

To ensure privacy, all the multimedia content will be deleted before the end of the study.

13 Appendix C – Questionnaire

First part:

1. Do you have a driving license?
   Yes ☐

   No ☐
2. How long have you been driving? (in years)
   ____
3. How old are you?
   ____
4. Do you usually play videogames?

	1	2	3	4	5	6	
Not at all	☐	☐	☐	☐	☐	☐	Every day, multiple hours per day

5. Do you usually play racing games?

	1	2	3	4	5	6	
Not at all	☐	☐	☐	☐	☐	☐	Every day, multiple hours per day

6. Do you usually play mobile games?

	1	2	3	4	5	6	
Not at all	☐	☐	☐	☐	☐	☐	Every day, multiple hours per day

Second part:

1. How would you rate the risk while manual driving?

	1	2	3	4	5	6	
Very low	☐	☐	☐	☐	☐	☐	Extremely high

2. How would you rate the risk at the first intersection?

	1	2	3	4	5	6	
Very low	☐	☐	☐	☐	☐	☐	Extremely high

3. How would you rate the risk while automatically driving?

	1	2	3	4	5	6	
Very low	☐	☐	☐	☐	☐	☐	Extremely high

4. How would you rate the overall risk due by the monster truck?

	1	2	3	4	5	6	
Very low	☐	☐	☐	☐	☐	☐	Extremely high

14 Appendix D – Experiment data

14.1 Questionnaire

Participant number	Age	Driving license	Driving years	Videogames usage	Racing games usage	Mobile games usage	Risk manual driving	Risk at the intersection	Risk automated driving	Risk truck
1	21	Yes	0	1	1	1	4	6	2	4
2	21	Yes	2	2	2	1	2	5	2	3
3	21	Yes	3	2	2	3	4	3	2	3
4	22	Yes	3	5	2	5	2	4	1	3
5	19	Yes	4	2	2	4	2	3	2	2
6	21	Yes	5	1	1	1	4	4	1	3
7	24	Yes	2	6	2	3	4	6	1	5
8	23	Yes	4	1	1	2	2	5	4	5
9	24	Yes	2	4	3	4	5	3	2	4
10	28	Yes	10	2	1	3	2	4	2	1
11	23	Yes	2	1	1	1	4	4	2	3
12	21	Yes	3	5	5	4	2	5	2	3
13	22	Yes	1	1	1	3	3	3	5	3
14	21	Yes	1	3	2	5	3	2	2	2
15	21	Yes	4	3	1	6	2	4	1	3
16	25	Yes	6	3	1	1	3	1	2	3
17	24	Yes	3	3	2	1	4	4	1	4
18	24	Yes	4	6	4	4	5	4	3	3

14.2 Observation

Participant number	First segment mode speed (km/h)	First segment top speed (km/h)	Times other lane invasion	Times outside road	Crashed in the first segment	Intersection speed	Intersection crashed	Intersection outside road
1	120	140	0	0	No	95	Yes	Yes
2	220	230	2	1	No	230	Yes	Yes
3	170	175	0	0	No	150	No	No
4	140	170	0	0	No	120	No	No
5	120	150	0	0	No	110	No	Yes
6	180	200	2	1	No	170	Yes	Yes
7	200	220	2	0	No	200	Yes	Yes
8	160	180	0	0	No	150	No	No
9	180	190	0	0	No	190	Yes	Yes
10	150	170	0	1	No	140	Yes	No
11	120	140	4	1	Yes	80	Yes	Yes
12	150	160	0	0	No	130	No	No
13	140	170	1	0	No	110	Yes	No
14	110	120	0	0	No	100	No	Yes
15	180	190	1	0	No	180	Yes	Yes
16	160	180	0	0	No	150	No	Yes
17	70	130	0	0	No	30	No	No
18	100	120	0	0	No	80	No	No