Universiteit Utrecht

The role of competition and perspective in game-based learning for traffic rules education

Juan Antonio Fonseca Mendez
ICA-5814693

1. Supervisors:
dr. S.A. Sosnovsky
Faculty of Science
Department of Information and Computing Sciences
Utrecht University
prof. dr. R.C Veltkamp
Faculty of Science
Department of Information and Computing Sciences
Utrecht University

M.Sc Game and Media Technology Department of Information and Computing Sciences Name
Faculty of Science
Netherlands
April 2019

Abstract

Computer games as a tool for education have showed improvements in certain domains. Different game design elements have effects that can improve to different extents the quality of applications used in this game-based learning process. The present thesis examined the effect that two of these design elements, competition and visual perspective, have in the use of an application intended to be used in game-based learning. Driving education, in particular the set of rules that control the situation of two cars meeting at an intersection, provided a natural domain to experiment with these two elements in particular. Using a prototype game where two players represent each car involved, analyse a static scene depicting the situation and choose the correct action to take, with the player, these effects can be examined. The scenes used are shown from three different perspectives, each one putting one of the cars as the focus or the situation presented from a bird-eye view. A single player version of the game provides a control group for the competition element, while providing more data on the differences in visual perspective. After the experiment, the data shows that the player's performance is hindered by views that require them to view themselves from the perspective of the other car. It also shows that the game with competition elements motivates the player to give answers faster, without this increase in speed impacting their ability to answer correctly. This in turn could possibly mean that they are more immersed in the dynamic, a desired quality in educational games according to previous literature, although further work is needed to confirm this. These effects could be used to further tune applications in the same domain or other game-based learning applications.

Acknowledgements

First, I would like to thank my supervisors Dr. Sergey Sosnovsky and Prof. dr. Remco Veltkamp for their support, patience, and help during all the stages of the present work, patience. Their guidance was vital for the completion of this project. I would also like to thank Utrecht University for the opportunity to be part of this Master's program, which has given me a much broader perspective in the possibilities that games have in their world, and how important for those is the work behind the scenes.

Second I would like to express my very profound gratitude to my parents and family for giving me the tools to get so far and their complete support in all aspects in this adventure of studying abroad, so far from home. It would not have been possible without them.

Finally, I would like to thank Guillermo and all my friends and colleagues for being there and sharing this journey, their ideas, interest, sometimes much needed advice and their invaluable friendship. My special thanks to Claudia for being there to cheer me up, help and give that push when I most needed it.

Contents

List of Tables

List of Figures

Chapter 1

Introduction

Playing games and learning have a close relationship in human culture[20]. The use of games to aid teaching and the learning process has been present in classrooms for a long time. From early childhood [14] to higher and adult education [38][6], the effects of games and play as a learning tool have been studied and tested many times[29], with many positive outcomes.

Since their introduction and through the years, computer games (colloquially referred to as ”videogames”) have risen as one of the main entertainment industries (with revenues calculated around $108.4bn USD in 2017[22]). These games, and all related media created around them, have demonstrated to be highly engaging and entertaining activities. Traditional teaching methods could be seen as boring, creating disinterest, and making the learning experience less effective for the students. This means that there is a permanent search for activities that help these students and trainees to be more engaged in the topic they are learning, which in turn motivates them to continue their study. Educators and researchers have turned part of their attention and efforts to the use of computer games as tools to bring this motivation and engagement to the education process. However, not every game is suitable to be used as an educational tool. Serious games need to be created for this purpose. Charsky (2010) defines serious games as “games using instructional and videogame elements for nonentertainment purposes”. Systematic literature reviews on serious games, such as the one performed in [11], indicate that most empirical research on gamebased learning approaches show they have significant impact, with mostly positive outcomes, in performance, knowledge acquisition aspects and the attitude of the student. In [11], they also claim that there is still plenty to do in the domain of educational serious games. The research shows that different game elements have been identified that improve motivation and engagement. Limited results have been collected to determine if this translates in actual learning. This thesis will then explore some aspects of an educational serious game interface with the intention of finding out if the use of certain design elements fosters a better learning experience and better learning outcomes.

1.1 Definition of the problem

From [7], we know that many design elements can alter and improve the benefits brought to the learning process by serious games. Elements such as uncertainty, cooperation, challenge, competition, feedback, flow, among others. Thus, some of these have been used and studied by different authors (e.g. [31], [5], and [4]). However, not everything about how this outcome is influenced is fully known yet. This motivates the exploration of implementing different design elements, related to how the player perceives and interacts with the game, and how they affect the learning goals of a particular gamebased application.

One domain that presents an interesting setting for this interface experimentation in the context of an educational serious game is driving education. Driving already provides a rich environment for interactive tools, shown by the fact that driving simulators have existed for a long time, starting in the arcade era with *Pole Position (Namco 1982)*, with different levels of success. There are simulators for many kind of vehicles from racing cars, to emergency vehicles, and even trucks. Many of them are used purely for entertainment purposes, while others are used for training or they become substantial in many different areas of research, like drug testing. One example can be found inside the Utrecht Institute of Pharmaceutical Sciences, where they use a simulator to study physiological responses involved in driving under the influence of certain pharmaceutical drugs [39].

Regarding driving education, the idea of the inclusion of serious games as part of the teaching process being suitable and beneficial for the domain is based on a number of reasons: the learning process of driving is interactive by itself; driving requires different types of skills and knowledge, it presents different type of situations for both the student, the environment and other people in it, etc. These characteristics allow us to explore different design elements in gamebased learning applications for this domain.

More specific, traffic education presents an interesting problem within the driving education domain. Learning to follow the traffic rules and correctly behave on the road is a fundamental part of the driving learning process. Considering that preservation of human lives and safety concerns in general are involved, it becomes one of utmost importance. This translates in government institutions requiring new drivers to pass not only practical exams concerning the applicant's driving skills, but also theoretical exams that comprise questions about the regulations applicable to cars and their expected behaviour on the road. Most of these traffic rules govern the way drivers should act in relation with their environment, but some of them also involve interactions between drivers. This interactions between driving agents naturally creates an opportunity to test interface and game design features that involve more than one player, such as cooperation, competition, perspectives, or social gaming. In particular, the present thesis will focus on the rules that govern the rightofway and traffic prioritisation at intersections where two vehicles meet, and both must decide who goes first, and who yields. Sufficient knowledge of these rules is expected from a driver to avoid being at fault on the road, creating conflicts with other drivers and even possibly causing harm to themselves or to others. Creating effective methods to ensure that new drivers effectively learn those rules is then desirable. A gamebased learning environment that evaluates that knowledge and could possibly improve the learning process of said rules. Thus, the learning of these rules will drive the efforts of this thesis and its interest in investigating if interface and design elements that involve more than one player would help in the learning of the rightofway rules that manage intersections.

1.2 Approach

It is not clear what design elements, mechanics and characteristics would make such an application the most efficient and effective possible. In order to gain insight about them, the present thesis will examine two design characteristics by implementing them into a serious game. To frame the learning activity, this game will be based only on the analysis of static scenes. The outcomes to be tested are both the user's performance when interacting with the application, and how the user perceives the game as a learning tool.

The first concern I will explore is the identification of oneself and the others when a decision has to be taken. This will be explored through the use of visual perspective as a way to identify the agents at play in a particular setting. The setting in this case is the situation that arises when two cars come at an intersection at the same time from two different streets. These interactions are governed by a set of predefined rules that establish who has the priority to go.

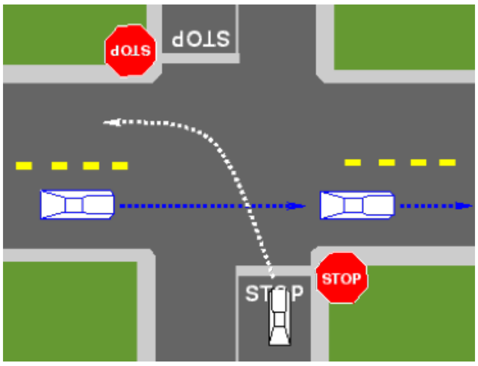


Figure 1.1: Example diagram of a behaviour that must be observed in a certain situation regarding two cars in conflict in an intersection

The traditional method to learn these rules usually involve the usage of images similar to the one displayed in Figure 1.1. Although not very realistic, this representation is used because it is the simplest way of depicting the situation at hand. Another type of representation is the one seen in figure 1.2. This creates a more realistic view of the elements and agents at play. Both approaches have their own strengths and weaknesses. Our proposal is that the use of a modern game engine would make it easier to generate different perspectives using the same framework, assembling procedure and assets. This could bridge the differences between the two approaches, creating a middle ground that combines their positive aspects, with the possibility to quickly try different perspectives. This new perspectives might capture the present situation in a better way and could give the student better cues to identify the correct behaviour.

Figure 1.2: Example of photography used for practising the theory exam for driving required in the Netherlands. Image obtained online from [36]

The second concern that I would like to evaluate is how the presence of an element of competition in the game changes the effectiveness of this type of game-based learning application. Given that the traffic priority rules apply in situations that involve two separate parties, a twoplayer game is a natural design element to consider. But there are many ways to implement the interaction between multiple players. Since this situation brings an element of disagreement between the two parts, competition in this case is a more intuitive answer than collaboration.

The initial concept of this research project involved the creation of an educational simulation, where two players are involved. The agent that each player represent should be clearly identified, and presented in the scene in such a way that leads to a natural selfidentification. Assigning roles, execution and results of the game are to be controlled by a central server, while the users will use a personal client. They are put in a series of competitions where scenes are presented to them and after a signal, they must decide, based on their knowledge of the rules and the analysis of the situation, whose vehicle could hypothetically "go", and who must "yield" in favour of the other. After both the correctness of the choice and the time it took them to reach the decision is combined in a score and the player with the higher score wins. This game involves both the design elements explained before, and it is hypothesised that the including them would make the learning process of the priority traffic rules that should be observed at intersections.

However, at the time there was not enough information about the literature on the topic, if anything like the present work has been done before. To formulate precise and concrete research questions, a literature review must be carried out to determine what are the conclusions of related research, what methods they use, and what concerns are raised.

This will be done in the next section, focusing on three main aspects: serious games, competition and visual perspective

Chapter 2

Related work

2.1 Serious games

Education is one of many applications of serious games. We recall the definition of serious game from [9]: "Serious games use instructional and video game elements for non-entertainment purposes". While this does not necessarily mean that all serious games are educational, they form a large segment of the work produced in this group. Several reviews compile many research pieces that explore the effects of serious games and gaming applications in education settings [11] [35][15][13]. Many of these works have identified benefits in knowledge acquisition and content understanding when games and gamified applications are applied to educational activities. There are also reported improvements in motivation of students, both intrinsic and extrinsic [24], although most researchers focus on intrinsic motivation, or the internal will to perform and excel at a task, as a more positive type of motivation for students. This in turn transforms in enhanced learning outcomes. The desired learning outcomes when creating a game can be unclear, even though some broad classifications have been proposed, such as the one in [27], a paper that proposes "families of cognitive demands" such as content understanding, problem solving, collaboration, communication and self regulation. [41] proposes a similar model that recognizes knowledge and cognitive skills as the main, but also motor, affective and communicative skills as part of the game-based learning goal. Moreover, [11] points out that while some learning outcomes are hard to define and categorise in many experimental and implementation papers, and most approaches rely more on qualitative rather than quantitative measures. Nonetheless, the existing findings point in a positive direction that will need further work towards it, and more research on the matter is being conducted every year all over the world.

The range of domains to which these games have been applied is wide. From general education, both basic and higher education[21], to more specific fields like military training[34], and medical education and surgical skills development [19]. However, not all the fields and domains are an interest for the present work. For our domains of interest, driving education, and more specifically, traffic education, there is previous research work too. Back in 1989, Renaud and Suisse[30] evaluated the use of simulation games to teach traffic safety to kinder-garden children. Measuring attitude behaviour and transfer of learning, the intervention group showed better performance than the control groups in all three measuring instruments. Although their experiment confirm past claims that simulation games provide good transfer of learning, their results only apply to 5 year-old children. However as they state, it appears that "simulation games using triggering elements may serve as an effective educational strategy in modifying attitudes and behaviour concerning traffic safety". More recently, Backlund et. al. have performed a number of steps towards the creation of an efficient driving simulator for leaning. First, in [1], they test whether or not previous experience with computer games has a positive effect on driving performance and attitude, finding that experienced players are rated better by driver instructors, while they do not show signs of a worse attitude towards other drivers. Next, in [3] they performed an experiment that showed "clear, positive individual learning effects". In [2], they focused on testing how the feedback system can be designed to increase the self-efficacy, understood as the effect that people beliefs in their capabilities can affect their driving. results again indicate an improvement on the self-reported presence of self-efficacy. However, it is also worth noticing that their findings also state that this increase in self-efficacy does not correlate with better performances from the learners. Finally, in [4], using a real car as a controller, they perform an updated user study with the driving simulator test, using similar measures than their previous work. One important change in [4], is the introduction of a game task in the simulator, hypothesised to be a method to enhance learning. For this updated study, the participant's perception of the simulator as a learning tool was also qualitatively evaluated using a survey.

Other efforts are being made in this domain, but their results were not found with the terms used for the present related work review. A further, more extensive literature review on the domain of driving education and the interactive tools would be an interesting addition to the future work.

[9] mentions that for them to create instructionally sound, effective learning tools, both instructional designers and video game designers must be aware of how the game characteristics (e.g. goals, challenge, competition, etc.) influence and facilitate both motivation and learning. This is one important concern for the academic community, where many papers and books try to explore different elements and elaborate on them. There are different ways to classify the game design elements. [16]. Further down we will focus our efforts in the competition and visual perspective elements.

2.2 Competition

Another active area of research relevant to this thesis is the impact of competition elements in game-based learning environments. There are many possible ways in which competition can be present in a game-based environment. Thus is important to make an important distinction when talking about where is the main focus in an educational activity that involves a competition. For [5], the difference is clear: there is Competition-based learning (CnBL), which is a methodology where learning is achieved using a competition as a medium, but making the learning absolutely independent from the outcome of the competition; and there is Competitive-based learning makes the learning dependant from the outcome of the competition itself.

We only intend to make use of the natural adversarial setting that right-of-way traffic rules present to include a competitive element. Therefore, competition will only be used as a vehicle to foster interest and engagement in the learning activity and its results are not part of the goals of the activity itself. Therefore, this section only requires to focus on examples and instances of CnBL.

There are many instances of the aforementioned CnBL in research literature. For example, Cagitlay, Ozcelik and Ozcelik (2015) test in [7] a serious game used to learn database concepts, in which competition is the main mechanic. They do a qualitative assessment using control groups that play a version of the same game were competition is not involved, and experimental groups that play the version with the competition element. When comparing the performance of both groups in a post-test, they conclude that the competition motivates the participants to achieve better performances and in turn, helps the learning outcomes. Similar results were in 2014 by [40], [8] and of course, [5]. In particular, Worm et al. report that competition increases the overall participation. This seems to be consistent with a similar claim made in [5] by Burguillo, when he says that the improvement in the learning experience is most likely a result of the students dedicating more time to study the subject, motivated by the competition.

Since my research considers situations where two agents take part, there is one particular competition format that becomes interesting for this thesis: 1 vs 1 competition. This type of competition is explored in [18]. Here, Foster, Esper and Griswold proclaim that competitive 1 vs 1 games, such as chess and StarCraft II, contain elements that make them more attractive than single player games, and provide an analysis of the features involved. These competition games, they argue, provide diversity, as in comprising an extensive number of activities related to the domain to learn; and sustainability, which means that the learning process can be prolonged for more time that it the content designed, keeling the players engaged. These are the qualities that make them popular, durable games, even though they have a learning curve, they say. Finally, they suggest that by designing games that imitate as closely as possible those characteristics, they state, it is possible to create effective educational games. They put this claim in practice by producing and testing a game to educate intermediate users of the programming language Java, which is deemed both sustainable and diverse, "inspiring high levels of content coverage, engagement, and meta-cognition".

It is important to keep in mind possible drawbacks in CnBL. For example, Cantador (2010) [8] warns about the need to keep the educational goals as a centre, and warns about how a bad game design or a game that is "too simple" can impact negatively, and even negate the improvements the competition introduced. Additionally, when talking about competition one concern that may arise is the balance when pairing players. [10] argues that while competition acts as a motivation enhancer in the classrooms, it can be soon dominated by the differences in the skills and capabilities of the students, frustrating those that are left behind by the most able students and losing sight of the real goal: learning. They then develop a mechanism to balance the pairings and give all students the same opportunities, allowing the learning process to become more uniform.

Some of these drawbacks could be addressed using a proxy agent, as it is suggested and explored in [33]. Sjöden et. al. use an educational serious game designed to teach mathematical concepts to students in the 10-11 year-old bracket. They collected behavioural data from the interaction between the children and the game. With the competition being an element inherent to the game by design, they used the data from these interactions to find possible effects and influence associated with the social motivations introduced by the use of a Teachable Agent (TA). They found that the presence of an ego-protective buffer, such as a TA, not only exploits the motivation from winning, but also motivates the students to respond productively to failure.

Note that not all studies on the matter of competition in educational serious games are positive. In [37], they find that competition is not significantly related to student's learning gains and it is barely related to motivation. They report that even when the students are instructed to play in a gaming environment, the activity is still perceived as a learning environment. The existence of these contradicting findings suggests that competition-based learning might not be suitable for all cases, and shows the dire need to differentiate the domains for which the competition-based approach is useful.

There are other outcomes that are desirable when using game-based learning as well. Ke discusses these in [25] alone, and with Grabowsky in [26]. [25] finds that when exposed at different group structures (competitive, collaborative and alternative), students from 5th grade using computer math games showed no significant difference in math tests performance, the collaborative games provided noticeably better attitudes. While the focus of this study will not be collaboration, it is important to be aware of the existence of these elements and have them in mind for the the design of the game.

2.3 Visual perspective

Visual perspective plays a role in cognition and the mental process of understanding and processing information. Estallo mentions in [17] that computer game players have an important advantage in their senso-motor development, through factors such as spatiality and visual perspective. On the same topic, [28] tells us that a more direct perception of Virtual Reality games offers a reduction in the mental load that the cognitive interpretation of the world requires. This unambiguous and direct perspective allows the brain to allocate more resources to do problem-solving and the mental representation of other concepts. Finally, [12] explore the neural representations of the self and others in a ball toss game, using two critical processes: perspective taking and agency. Analysing the brain cortex activity during these processes, they conclude that self-consciousness is independent from perspective taking and the projection into agents, even though they are related. These ideas give us a sense of how important visual perspective is for the cognitive activity on the brain.

There are a couple of interesting findings on visual perspective as a tool instead of a goal. First, Scoresby and Shelton(2009) study in [32] the effect visual perspective has on presence and flow within virtual learning environments. This follows previous research that states that reaching a state of flow has a noticeable positive influence on the learning outcomes of a game-based learning activity, as they report it. With three different visual perspectives, first person view, third-person view and text-based games, they do an exploration into the nature of flow, which is defined as being absorbed by an activity, "the 'sense of being there'"[32]. After executing the study, the analysis of the results shows that while the players that achieved a state of flow had better learning performance, that state of flow was much more influenced by emergent categories *content, emotion, motivation, and engagement*, than it was by the visual perspective of the game.

Finally, very recently the medical field is developing protocols to study the training of novice surgeons on laparoscopic procedures, such as the one described in [31]. They propose using serious game elements and exploring the positive influence of using the "surgeon's real perspective" instead of regular laparoscopy views. The results of this study could provide useful information in the future. Unfortunately, at the time of the creation of this document, this remains to be only a proposed protocol. However, it shows the interest of other fields in research that involves visual perspective as a defining element for game-based learning tools.

Chapter 3

Methodology

3.1 Research questions

After the literature review, and with the context previously defined and the findings of previous work in mind, the objectives of this thesis can be formulated in a better way. The present work aims to explore how these two design elements affect the performance of players analysing situations that involve them and taking decisions about their next action. This would be a first step into producing a more effective learning process, in the future.

In particular, this thesis will look into how efficient the players can be at this task. This efficiency will be measured on how quickly they can select the correct next action to perform in a situation, making time and accuracy the two main variables. This situations will be depicted using static scenes, created outside of the game, as a preventive measure to remove the effect that movement could have during the task, and allow for a more focused analysis of the important variables. This scenes will depict the situations where two cars meet at an intersection at the same time and one of them has to yield to the other, from different visual perspectives.

This can be condensed into the following two research questions:

RQ1: *Do different visual perspectives have an effect on how effective is the player in a static-scene analysis task?*

RQ2: *Does competition, as a game design element, have an effect on how effective is the player in a static-scene analysis task?*

3.2 Methodology

The first step towards addressing these questions, is the creation of a game-based learning system that presents the elements stated in the research questions: competition and different visual perspectives. Then, perform one or more experiments using this game to gather data that could show effects related to those two design elements, if they exist. This section presents the details of both phases. First, it describes the design and creation of the main material required for the game: the scenes depicting the situations involving two cars meeting at road intersections. Next, a description of the main elements and mechanics of the game, along with their desired goals. Finally, the chapter closes with the description of the experiment setup and execution.

3.2.1 Materials design

Traffic rules

To create scenes that represent situations in which traffic rules are applicable, the first step is to define which rules are to be used. The list used here was mainly based on the rules applicable in the Netherlands. The rules of giving way are compiled in sections 2.3, 2.4 and 2.7 of the Road Traffic Signs and Regulations in the Netherlands [23]. It is important to notice that only the rules that put two cars at stakes are considered. For example, interaction with a tram, or pedestrians, while valid and applicable, would be out of the scope and impossible to include, as it only concerns one driver and another external road agent. Rules concerning traffic signs do not use any specific wording, just showing the signs in Appendix 1B, and thus are interpreted and described here for the sake of completion. Finally, while there are other rules that might be applicable, to maintain the experiments manageable in terms of time, considering the amount of scenes per rule, the final set is reduced to only these 7; even though that could make the set incomplete in a global sense, these rules are still representative of the many situations that can be found on the streets.

The final list of traffic rules used for the experiments is:

1. At road junctions, drivers must give priority to traffic approaching from the right.

2. At an intersection marked by a stop sign, you must stop completely at the intersection before crossing, thus yielding to any other drivers.

3. At an intersection marked by a yield sign, you must yield to any car coming at the intersection on either side.

4. Drivers and riders intending to turn must give way to all oncoming drivers and riders and to all drivers and riders on their left,right and coming up closely behind them

5. Drivers and riders intending to turn left must give way to oncoming drivers and riders intending to turn right at the same road junction.

6. All cars entering the road from any other driveway (parking lots, garage, etc) must give way to drivers already on the road.

7. A driver who enters a traffic circle or rotary must yield the right-of-way to drivers already in the circle.

Scenes

Once the rules are established, the next step was the creation of the scenes depicting situations where these rules are applicable. We established before that the goal was to create something between the simplicity of hand made drawings and the complexity and difficulty of real-life photography, maintaining a certain degree of fidelity with real life. Thus, the approach taken was to recreate the situations in a three-dimensional model, to later quickly create views from many different perspectives to evaluate them.

All the scenes were created using the game engine Unity™ (version 5.6.3), developed by Unity Technologies. There are several reasons to choose this tool to create the scenes. The main reason is that it provides many features to ensemble and manipulate three-dimensional environments. Also, Unity is compatible with many formats for three dimensional models and images used by the game art community, who provided many of the royalty-free models and art used during the implementation. Another reason is that, while created separately, the scenes are ready to be easily integrated into the game if the same engine is used for both. Finally, it is freely available, easy to use, well documented and supported by a large community of developers and artists, with all these characteristics allowing for faster development.

For every rule, there are different situations that use the same rule to regulate the actions to take. This was exploited in order to create the widest variety of situations possible, within a count limit.

- Rule 1 - Situation 1: Two cars meet at a one way intersection, both intend to continue straight forward.
- Rule 2 - Situation 1: Two cars meet at a one way intersection. One street has a stop sign, the other is marked as a priority road
- Rule 3 - Situation 1: Two cars meet at an intersection. One is marked as priority at the intersection, the other one presents a yield sign.
- Rule 3 - Situation 2: Two cars meet at a curved intersection. The main road follows the curve, while the lesser road intersects it.
- Rule 4 - Situation 1: Two cars meet at a two-way intersection. Both cars are turning right and thus does not enter in conflict with each other.
- Rule 4 - Situation 2: Two cars meet at a two way intersection, facing each other. One car intends to turn left, while the other one desires to go to the left.
- Rule 4 - Situation 3: Two cars meet at a T-shaped intersection. One car intends to go straight forward, and the other tries to turn left.
- Rule 5 - Situation 1: Two cars meet at a two-way intersection. One car intends to turn right, and the other intends to turn left into the same side of the same street.
- Rule 6 - Situation 1: Two cars meet at the exit of a parking lot. One of them is coming out from the lot, the other car is going along the street.

(a) Aerial, or bird-eye, view. (b) First person view (c) Third person view

Figure 3.1: Initial three views. Each view contains the same necessary elements to reach a decision, such as turning lights, traffic signs, etc. The elements are adapted to the context of each view.

- Rule 7 - Situation 1: Two cars meet at a roundabout. One of them is already on the circle, and the other one intends to enter it.
- Rule 7 - Situation 2: Two cars meet at a roundabout. One of them is trying to exit the circle, while the other car is trying to enter. No conflict exists in this situation.

The creation of the scenes was iterative. During the first iterations, the goal was to determine which of the proposed views, if any, was useful enough to be used in further experiments. The first set of scenes produced was used with the pilot for the game. To make the comparison meaningful, all views were required to present the same amount of information for the player, albeit adapted to their own context. Three were tested: a bird-eye view, presenting the two cars and the surrounding elements, which is more in accordance with the traditional materials used to demonstrate and teach right-of-way traffic rules; a first person view, displaying the elements as they would be viewed from a driver inside the car; and a third person view, from a few meters behind the car and slightly above the vehicle, usually used in entertainment videogames to facilitate control during driving.

The scenes always show the two main cars involved, the intersection, and any traffic sign or light that is needed for the situation. All the situations are set in an urban environment. The main cars can be identified by their colours, one blue, and one red. The player is always represented by the red car, and must make a decision accordingly. The red car always appears in the lower part of the image in the bird-eye view, and it is at the centre of the scene in the first-person and third-person views.

Examples of these scenes can be seen in figure 3.1. Here, all three views present the same information about the car turning to the right. In the case of the bird-eye view, the turning light is represented as an icon above the car; for the first person view, it is represented by the turning indicators that are common in the dashboard of many car models; finally, for the third person view, the turning lights are part of the 3D model of the car, and are enhanced by floating icons that allow for better visualisation.

Now, every situation presents two cases: the first case is when the player represents the car that must yield; the second when the player represents the car that can continue its way. In the first situation for rule 4, since both cases present exactly the same problem, with only slight changes in the environment. Due to this, one

Figure 3.2: Icons used to identify the two different players involved in the competition-based game

of them has been eliminated in order to prevent the player to feel like they have already solved that problem before.

Scenes were created for all two cases per situation, and three views per case, making **6** the number of the scenes derived from each of the 12 situations, minus 3 from the case eliminated. This brings the total count of images to evaluate to 69. The scenes were created in a resolution of 1280x720 pixels using the screen capture capabilities of the Unity game engine. This resolution was chosen because it is easy to scale and fits the screen of most modern devices without significant distortion. Also, the scenes were created, bundled and stored in such a way that allows to plug any set of scenes into the game with minimal changes to the configuration files and no changes whatsoever in the code.

After conducting an pilot run of the game using the scenes previously described, it was determined that not all the views proposed were effective, mostly based on feedback given by the users. Thus, the creation of a new set of scenes was necessary. The situations were maintained, except for Rule 1 - Situation 2, as it was identified to be too similar to Rule 4 - Situation 3. Since the new set was going to be used for the competition experiments, it was important that now both players were aware of which car they were representing at all times, regardless of perspective. The approach taken was using icons to identify each player. These icons were printed on all visible sides of each vehicle, with the intention of making them easily identifiable from as many different viewpoints as possible. Two icons were used, with minimalist designs of animals. They are presented in figure 3.2. The first symbol depicts a gorilla with a green background, the other an eagle with a red background. Each icon was given a very strong colour hue to contrast well with the colour of the cars and making them easier to see. To further make the contrast significant, the main cars were given a white colour.

The main change in this new set of images is the use of only two views. For the new set only the bird-eye perspective and the third-person view, as the first person view was perceived as limiting and occlusive during the pilot. Now, as there would be two players involved, there are two third-person view images, one from the perspective of each car. Examples of the second set of scenes can be seen in figure 3.3.

Each situation continues to have 6 different scenes, three views for each one of two different positions of both players. The purpose of switching is to test the ability of the player to recognise the differences in the same situation that would make the

(a) Aerial, or bird-eye, view. (b) Third person view for one player (c) Third person view for another player

Figure 3.3: Example of the second set of scenes. Three perspectives but only two different views. Each player has one image from its own third person perspective. All views preserve the same information about the situation.

correct answer to change. Thus, the two situations that do not present any conflict don't require the players to switch positions. This reduces the total of images used to **60**, 10 situations with 6 scenes and 2 situations with 3. A complete list of all the scenes is compiled in appendix A.

Once created, the scenes are named following a code that identifies. The identification helps both the designer to identify the scenes quickly; and the internal engine of the game, that uses the names and its codification to load and evaluate the scenes, and register results. The name of each scenes contains three parts. The first one is the rule and situation depicted, correct action for each car, using only one letter "G" for "keep going" and "Y" for "yield to the other car. The first letter corresponds to the car with the green icon, and the second letter corresponds to the car with the red icon. Finally, a letter identifying the view used for the scene: "B" for the bird-eye view, "G" for the third person view from the perspective of the green-icon car, and "E" for the third-person view from the perspective of the red-icon car. Thus, an image named "T011_GY_B" identifies the scene for the Rule 1 - Situation 1, the case where the green-icon car is in the position to go, and the red-icon car is in the position to yield, from the bird-eye perspective. As the previous statements proves, this is an efficient way to shortly encode a long description, useful both for the game system, and for anyone reviewing the scenes.

3.2.2 Game design and implementation

The design of the game incorporated the main requirements for the experiments. The game has to present scenes, input for the player to submit their choices, the choices should be timed, evaluated, and feedback should be given back to the player on the correctness of their decision. A competition element should be included in one version as well.

The game was designed and implemented in iterations. The goal for the first iteration was to provide feedback on the usability of the game from real users , and validating the scenes. The goal for the next version was to add the element of competition, use the final scenes, and polish the design and distribution of the user interface. In the second version, a single-player version of the game was created too, to provide comparable data to the competition version during the experimental part.

Figure 3.4: Main screen of the game. This corresponds to the single player version, where the player only plays against time.

The single-player version of the game contains all of the main game elements. First, a main menu screen is shown to the player. The main menu presents instructions of what will happen next for the players to be informed before participating. It also has a button to start the main gameplay.

When the game starts, the main screen is showed. An example of the interface used in the main screen is shown in figure 3.4. The main activity, which is done in this screen, consist on four steps performed for every scene:

1. A scene is shown to the player

2. The player observes the image for the amount of time they need to make a decision.

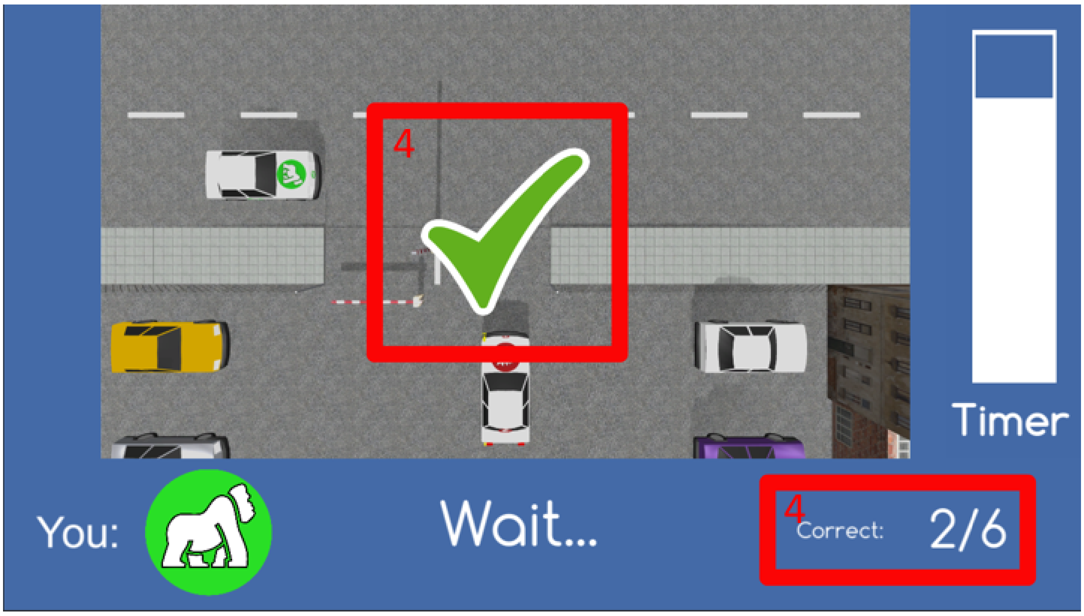
3. The player decides whether it is correct to continue or to yield to the other car, and submits said choice.

4. The game evaluates if their answer is correct, and gives feedback to the player on the decision.

When the player has reviewed all the scenes, a final score is given. The score is accumulative and awarded for every scene. The score rewards the player for making consecutive correct decisions, and penalises slightly for every second that passes. The mathematical expression used is $70 * bonus + (31/timer) - 1$. However, the purpose of the score at the moment of the experiment is only to create a gamified environment. This score would be useful for subsequent uses of the game by the same player and the implementation of leader boards. That remains an open line for a possible future iterations of the game.

The game interface consists on four main elements; each one corresponding to the requirements described at the beginning of this section. A screen-shot from the

(a) 1.Scene Panel 2.Timer 3.Control Panel



(b) 4. Feedback elements

Figure 3.5: Main screen of the game. The interface is divided into its main components.

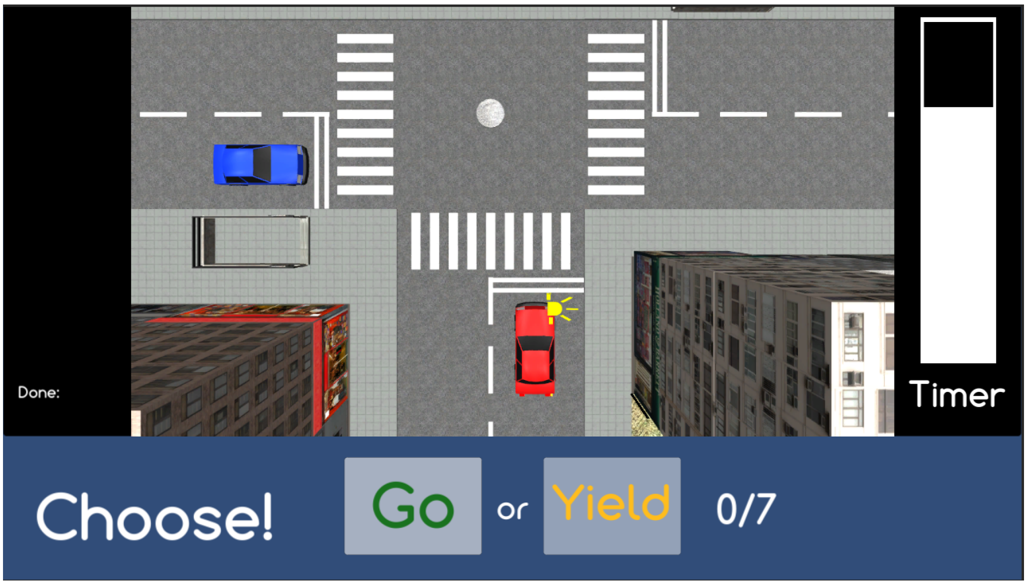


Figure 3.6: Early version of the game, presented in the pilot.

game can be seen in figure 3.4. All four main elements are outlined in figure 3.5. The numbers between {}correspond to the numbers in this figure. The first one is the scene panel{1}, which frames the scenes presented to the player. To create a smooth transition and giving the player time to think without overwhelming them, each scene fades in and out from a black screen. The timer{2} informs the player of how much time they have left to answer. Although in the interface the timer depletes to zero, the game records the time starting from 0 and increasing. On the lower part of the screen is the control panel{3}. This panel contains the button for the player to interact with the game. There are two buttons, one for each possible action the car could take in every situation. The button labeled **Go** corresponds to the action of continue driving, knowing the car has the right-of-way. The button labeled **Yield** corresponds with the action of yielding to the other car. Also in this panel is the icon that works as an *"avatar"* of the player. This icon exists to remind the player at all times which car they represent. The feedback for the player is presented in two forms: the first is the counter of how many of the scenes the player answered correctly compared with the total number of scenes the player has seen. This feedback is present at all times, and it is updated whenever an answer is evaluated at the end of the main cycle. This lets the player see how they are performing in general. The second element is an overlay on the scene panel{1}, that shows either a tick when the player is correct, or a cross, when the player's answer is wrong. This informs the player of their immediate results in each scene. The overlay remains while the scene is fading away. These two elements can be seen in figure 3.5b.

The game was built using the game engine Unity (version 5.6.3), the same engine used to assemble, capture and produce the scenes. It was compiled into a WebGL application, using the native deployment capabilities of Unity. All versions of the game were hosted in a web server, for easy access at all times. While available in any device with a WebGL compatible internet browser, the use with a computer is highly encouraged, and it was the only version properly debugged. Throughout all versions of the game, the player only interacts with the game using buttons present

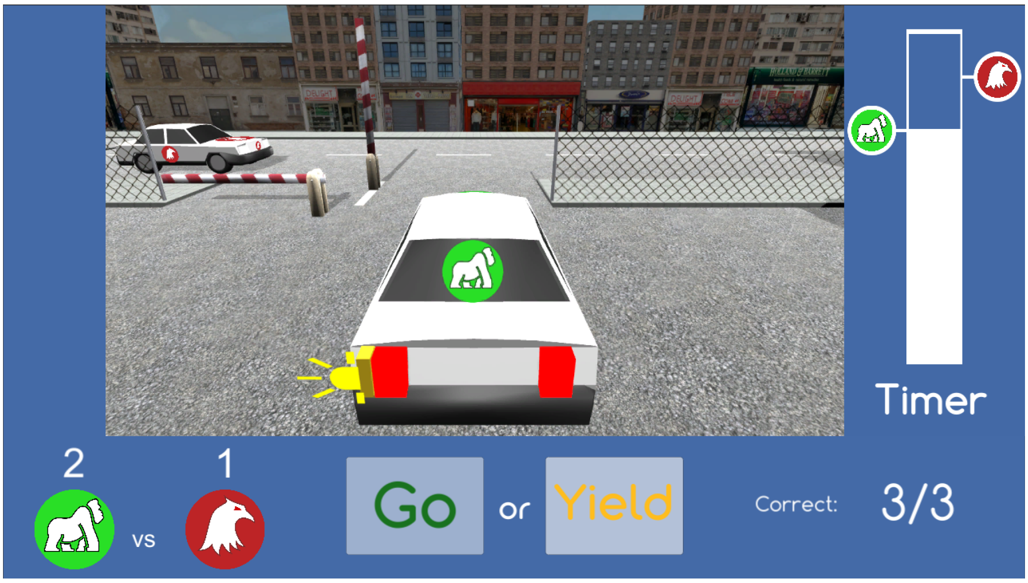


Figure 3.7: Main screen of the multi-player version of the game. The changes from the single-player version's interface are mainly to accommodate information about both players participating.

on the screen, with the help of a computer mouse. The game was implemented with as much modularity as possible, making it possible to change which scenes it should use and different parameters such as the time limit for each scene or the source of the images. All these changes are possible without altering the code of the game, and can be done at any moment.

A second iteration of the game can be seen in figure 3.4. The version presented during the pilot is shown in figure 3.6. While the main elements are maintained, the distribution is slightly different. The main change between versions was the inclusion of the player's "avatar" icon. This change was important to ensure that the player has the information about the car they represent. In the first game, since the scenes used only colours to distinguish between cars and always presented the player's car at the centre of the bottom of the screen, such information was not needed. However, this makes the images much more rigid and repetitive. This motivated the change to differentiate the cars using icons, which allows for a wider variation of positions and framing, while still having the possibility of clearly identifying both cars at all times.

The multi-player version of the game, and the main focus of the present work, follows similar directives to the single player version previously described. This version presents more mechanics than the single-player game, adding the element of competition that the present work wishes to explore. The competition against another player is both about a competition of time and a competition about correctness. The main loop consists on similar steps, with elements of competition:

1. First, a scene is shown to the both players. The timer starts running for both at the same time.

2. The players observe the image for the amount of time they need to make a decision.

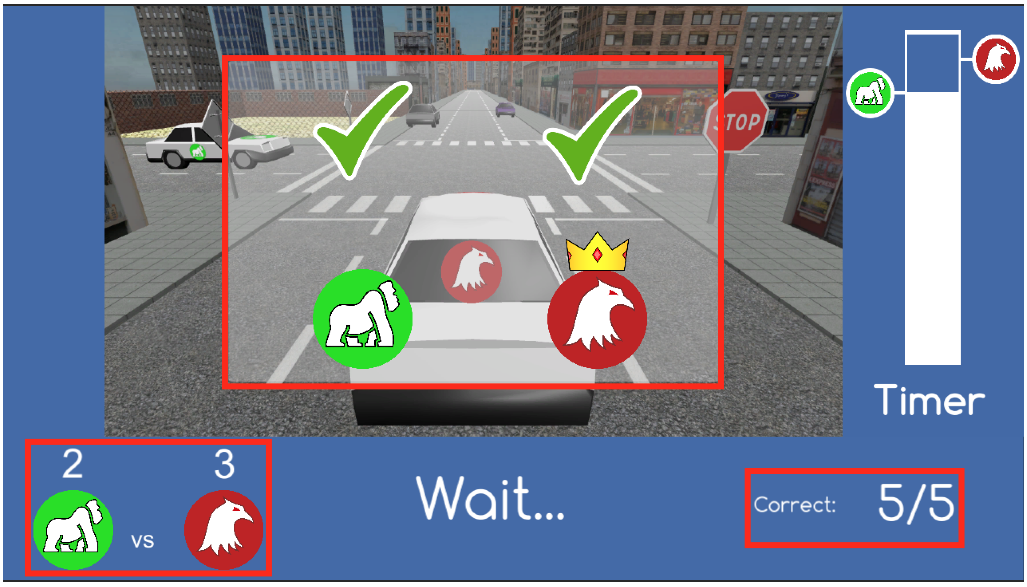


Figure 3.8: Feedback elements of the multi-player version of the game.

3. The players submit their answers whenever they are ready. When they submit an answer, the timer stops for that player. The waiting period lasts until both players have submitted an answer.

4. The game evaluates if either one or both answers are correct, determines who wins the round, informs its decisions to the players, both about the general correctness and the winner.

The winner is determined considering first correctness, and then speed. If only one player answers correctly, that player is considered the winner. If both are correct, the player who took less time to answer is the winner. This policy is motivated by the final learning goals and the nature of the domain. These rules are intended to regulate how cars are to behave on the road to reduce risks. Considering this, it is much more important for the governing entities that these rules are applied correctly, even if it takes slightly more time. Therefore that should be more important to the player as well. Although small differences in time are not crucial on the road, in the game comparing times allows to decide a winner in most of the cases. Speed is an adequate tie-breaker, since the situations we are dealing with require taking decisions quickly to not interrupt the transit, and motivating faster decision times is desirable.

The interaction with the game is very similar to the previous version. The main screen again presents the three areas, scene, timer, and control panel. This version present some changes: for a start, there are now two player icons, showing the two participants in the game; the timer is adapted to show the timing of both players; finally, the feedback for the player is increased in complexity, which we will discuss next.

Now that there is a competition in the game, the interface needs to reflect its new component. This can be seen in figure 3.8. The correct answer counter is maintained. Its use is still valid, because a player has an individual goal of being correct as many times as possible. A new form of feedback is added to show at all times how many victories each player has. This again, informs the player of their overall performance during the session, and hopefully motivates them as well. The timer now has two markers, as mentioned, and the moment a player has submitted an answer, their marker on the timer stops to let know the other player that they are at a disadvantage. Finally, the feedback at the end of each iteration of the main loop is expanded, now to include marks to show if the answer of each player was correct, as well as a crown on top of the player to show that the system has determined they are the winner of the round.

For the current implementation of the game, and given the design of the experiments, an AI agent is included as the second player. The main goal of this agent is that it is unrecognisable from a real, human player. While written directly inside Unity, this agent is designed to be plugged as an external element, that uses the system in the same way a human player would. Since an AI would make immediate decisions, the times and answers given are simulated using the game engine, where the agent "waits" for a number of seconds before submitting its answer. To bring these times closer to a real person's behaviour, the data from the pilot was used as a base. For each scene in the pilot, there were taken three data: the mean time people playing the pilot took to answer the scene, the standard deviation, and the percentage of players that answered correctly to that scene. Using these, the answer is artificially created using the percentage of people that answered correctly as the probability of someone to be correct when answering the scene, and the time the PC waits is distributed around the mean uniformly, with a limit below and above this mean. In order to not overwhelm the player with answers that are two fast, the distribution is biased towards slower answers. The limits are set to $[mean - 0.3\sigma, mean + 0.7\sigma]$. This means that a scene which mean time is 3.5 and standard deviation is 1 s, the uniform distribution will be between [3.2,4.2].

For all versions of the game, data about the actions of the players is saved and uploaded to a database for posterior review and analysis. A database is created to store the data. The database consists on 2 tables for each version. The first table, "Player" stores identifying data for each player. For both versions, an 8-character random string that serves as primary key, player name and identifier to protect privacy during the experiments. This player ID string is scored along with the total amount of correct answers the player gave, and the final score that they achieved in the game. For the multi-player version of the game, the number of rounds the player won is included in this first table. The second table, named "Results", records each occurrence of the main game action. An identification of the scene at play, using the encoded name of the image, as discussed at the end of section 3.2.1; an identification of the player, using the same id from the "Player"; last is recorded the time taken, and correctness of the answer. For the multi-player version the same information is recorded about the other player as well, along with the winner of the round for easy analysis at glance.

3.2.3 Experiment

The experiments were designed with two purposes. The first and most important was to test effects of competition and perspective, not only through hard data from the game, but also through the perception of the participants. A secondary purpose was to verify the usability of the tool. This was recorded through a number of questions answered by each one of the participants. These questions are also helpful to approximate the benefits to learning that may escape the scope of the data recorded by the game, but are not lost in the player's experience.

The experiment consists of three stages: first, participants filling a pre-activity questionnaire. This pre-activity questionnaire contains demographic questions that collect information about the participant that is relevant for the activity of learning traffic rules, such as age, country of residence, whether or not they already have a driver's license, country where they are licensed to drive and for how many years they have done it. This first part of the questionnaire consists of 8 questions (Q1-Q8). The second stage is the main game activity, where participants play one complete round of the game. This means that the player will be presented with all 60 different scenes and is evaluated in the knowledge of the rules applicable to each one of the 60 different images in the game, while both information about the time taken answering and the accuracy of their answers for each single scene are recorded, completely transparent to the player. To complete the experiment, the participant fills in a post-activity survey. The post-activity survey gathers the participant's opinion on the usability of the game and their perception of the variables to study. At the end there is an open question for the participants to voice their opinion on anything involving the experiment in a more free manner.

To test the competition element of the game, it is necessary to split the participants in two groups. Each group played a different version of the game. The first group (from here on Group A) plays the single-player version of the game described above, where the only objective is to answer correctly in a timely manner, and the only adversary is time itself. The second group (Group B) played the two player version, also described above. In this version, the participant plays against both time and the other player. As discussed previously, for this experiment the other player consist on an automatic agent and not a real player. However, the automatic agent behaviour is modeled after real players, and this version of the game does not let the players know that and it is designed to give the impression that they are actually playing against another human. Given both conditions, the results will be subject to the assumption that the player's reactions and interaction with the game are the same they would be if they were playing against another human player. The variable of player perspective is present across all participants, since all of them are presented all 60 scenes, including all three visual perspectives in them. This variable is tested within both groups separately, and not between groups.

Both groups in the experiment are independent from each other, with no crossover in subjects between them. Since both groups experienced a different game with different conditions, the post-activity surveys are also slightly different. For both Group A and B, there are four general questions about the user experience (*Q9-Q12*), and four more questions about player perspective and identification (*Q13-Q16*). For Group B only, three more questions regarding the competition element are added (*Q17-Q19*). These questions were presented as a series of statements with a Likert-type scale to answer, with the options being Strongly Agree, Agree, Neutral, Disagree and Strongly Disagree.

Different online tools were used for the execution of the experiment. The surveys were hosted on the Google Forms service for easy access throughout the experiment and posterior analysis. To perform the experiment, the surveys were distributed using Amazon Mechanical Turk platform. This platform allows people from many different backgrounds perform short tasks, for a small economic compensation. The main appeal is the wide distribution of populations, from different backgrounds and levels of experience in both traffic education and videogames. To add even more diversity to the pool, an additional number of responses was gathered by distributing the surveys through social media among Dutch-based groups with expatriate and local presence.

It is pertinent to mention here that the experiment design was tested with a prototype version of the single player game played by Group A during a pilot run. The data gathered from said pilot was used to refine the protocol of the experiment, to test the interface of the game and how people interacted with it, and familiarising with the online tools used for the main experiment and how they work, creating a more steady work-flow. The AI agent used in the multiplayer version of the game was modeled using the time and correctness data gathered in this pilot, averaging the results that were obtained and treating such as an average player, making the AI as close to a human player as possible, including a short window to account for human error and small differences in speed.

The following section will present and discuss the analysis of the results obtained from the execution of the experiment.

Chapter 4

Results and Data Analysis

To provide answers for the research questions presented in the beginning of Section 3.1, the data gathered from both groups, A and B, who played the single-player and the multi-player version respectively, was analysed. The results of the analysis are presented below.

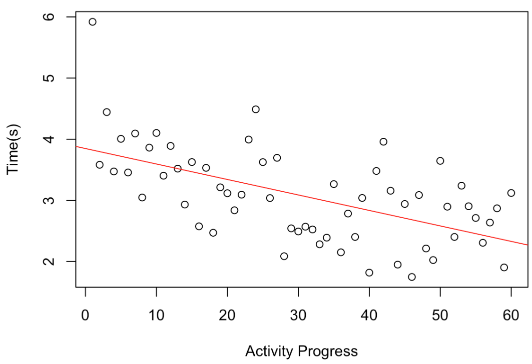
4.1 Overview

Group A was composed of 42 subjects (64% females) from 8 countries. A majority of subjects (79%) were from US. All subjects had driving licenses and 88% of them indicated that they drive regularly. Only 5 participants reported less than 10 years of driving experience, making this a group we would expect had ample knowledge of the driving rules involved in intersections.

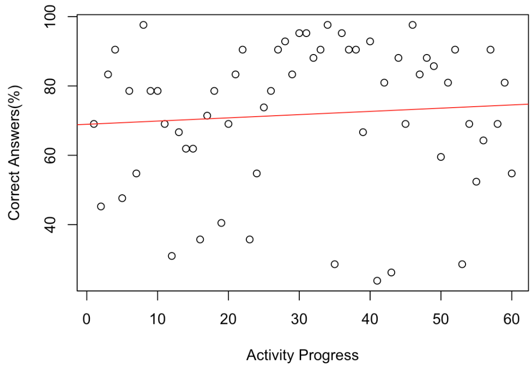
Group B was similar. It consisted of 43 subjects (51% females). This group included people from 7 countries with the majority from US (53%). 7 participants from this group did not have a driving license, and 10 more said they do not drive regularly. 39% participants had more than 10 years of driving experience, with 44% ranging from 1 to 5 years of experience.

An overview of the answers to the post-activity survey provide some insight into the usability and the interaction between the participants and the experiment tool. About the user-experience questions (*Q9-Q12*), almost all members of Group A (92%) considered that the task to perform was clear at all times (*Q9*), with only 3 participants disagreeing with such statement. In Group B only 67% of the participants found the task to be clear, while the rest did not. The response on the usability of the application was very positive, with 83.5% participants having the opinion that the application itself was intuitive and easy to use (*Q10*).

Q11 and *Q12* asked the participants about their perception on the quality of the scenes. When asked whether or not they agreed the elements present, such as traffic signs lines in the pavement, etc., were clear and easy to see (*Q11*), 12% of the participants disagreed with this statement, most of them from group B (72% of the participants that disagreed); neutral answers were almost as numerous(11%). 57% of the participants of both groups agreed in these elements being sufficient to make an informed decision (*Q12*), while another 18% thought they were not.



(a) Average response times for different points of progress in the activity for Group A



(b) Percentage of correct answers for different points of progress in the activity for Group A

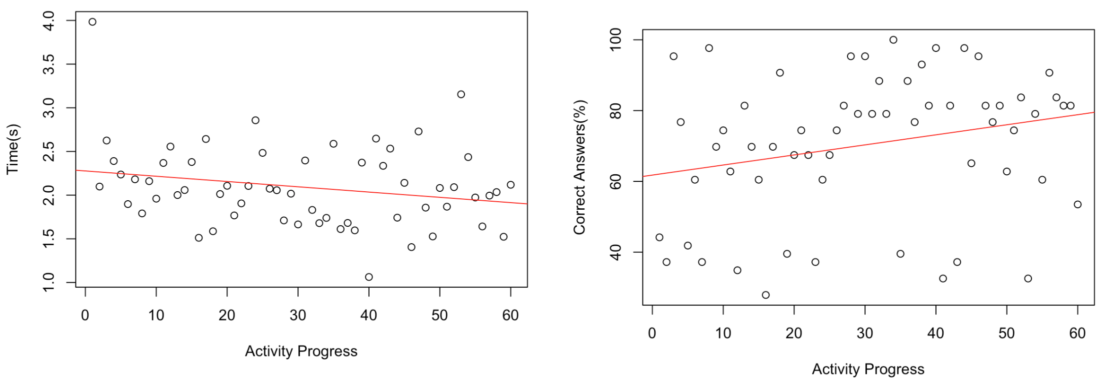
Figure 4.1: Behaviour of response times and percentage of correct answer for each scene of the game as the players in Group A progresses through them.

These results are overall optimistic, because they point towards the choices of game and interface design being the correct ones. It also signals that the scenes are mostly correctly assembled, even though they can be improved with more and clearer information for some users.

To test the effects of interest in this thesis, the game measured two main variables: (i)the time it takes the participant to answer and (ii) whether the given answer was correct or not. This was recorded for all 60 scenes, for all participants.

Observing of how the variables behave as the progress through the activity on can be useful to compare with other findings. It is important to notice here that the order of the scenes presented was randomised before the players were. This randomisation has two purposes: the first being to avoid as much as possible to bore the player because the game is repetitive; the second is to encourage the player to analyse each image for separated instead of relying on the order, both regarding their knowledge of the rules and the perspective from which they are looking at the situation. This randomisation is made once during the game production and after that, the order for all participants is exactly the same. For Group A, these variations can be seen in Figure 4.1. A linear model was fit using these points, which shows that as the player progresses through the activity, the time it takes for them to answer goes down; this is confirmed as significant by the regression model: F(1,58) = 28.35, p-value = $1.712e^{-6}$. While the model shows that the accuracy of the player seems to go up as the game goes on, impossible to know from this analysis if that change is related to the progression in the game, since the fitted linear model is not significant at a $p<0.05$ level; F(1,58) = 0.3544, p-value = 0.554.

Group B presents less changes overall than those of Group A. While the fitted models suggest the same differences are present, average response time decreasing as the player advances through the game and correctness increasing, these models fail to reach significance a a $p<0.05$: neither for time F(1,58) = 28.35, p-value = $1.712e^{-6}$; nor for correct answers F(1,58) = 3.759, p-value = 0.05738. However given the values for the accuracy case, it is possible that the players's accuracy in terms of correct answers indeed increases with the progress along the multiplayer game.



(a) Average response times for different points of progress in the activity for Group B

(b) Percentage of correct answers for different points of progress in the activity for Group B

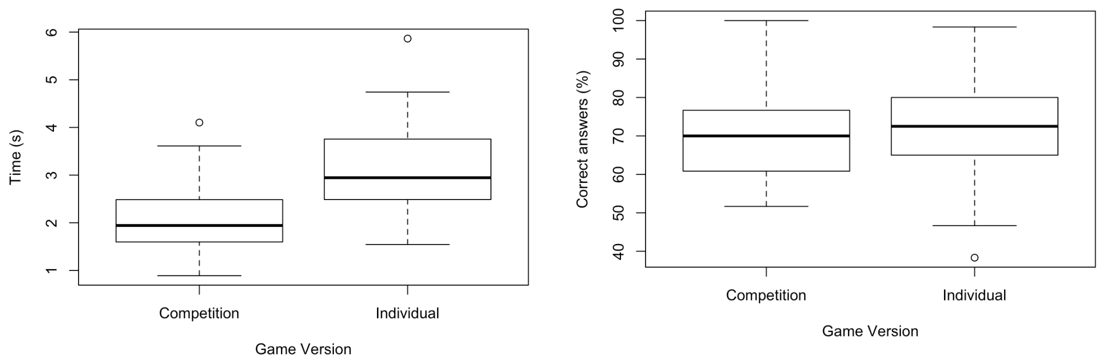
Figure 4.2: Behaviour of response times and percentage of correct answer for each scene of the game as the players in Group B progress through them.

4.2 Competitive element

To answer *RQ2*, a competition design element was introduced in the version of the game played by Group B. Comparing the two variables recorded, time and correctness, some differences appear between the two groups. This differences can be seen in Figure 4.3. The main difference between the two groups is the significantly faster response time between the game with a competition element (M=2.0930, SD=0.7610) and the game without it (M=3.076, SD=0.9609), confirmed by a t-test to be statistically significant as well at a $p<0.05$ level; t = -5.22, p=1.4e^{-6}. While seemingly small, this is a 33.33% speed up. Also noticeable is that this significant speed up in the participants' response time does not represent a significant difference in the accuracy of the answers. While the single-player version (M=0.76, SD=0.1224) version obtained a higher percentage of correct answers than the multiplayer game(M=0.7046, SD=0.1224), a t-test reveals that this difference is not significant at a level of $p<0.05$; t=-0.5003, p = 0.6182. This means that while the players felt compelled to and accomplished completing the task faster, their accuracy did not receive a significantly negative impact.

These results are consistent with the opinions gathered from the participants in Group B during the post-activity survey. 72% of the participants agreed that the competition element motivated them to answer faster (*Q17*), while 23% disagreed. 65% did not find the competition particularly stressful (*Q18*), but 23% reported they did. For 20%, the timer that showed the time elapsed for the two players distracted them from their task (*Q19*). Finally, when asked if they felt the activity helped them learning the traffic rules involved or refreshed their previous knowledge on them, more than half the group replied positively (60%), with another 20% having no opinion on the statement and 20% disagreeing with it altogether.

Another line of interest is investigating how is the player's success, referring to the player winning against the AI player for a particular scene, behaves as the activity progresses from scene 1 to 60. This can only be tested for Group B, as they are the only group that played the multiplayer version of the game. The reader



(a) Average response time per game version (b) Percentage of correct answers per game version

Figure 4.3: Differences between the two recorded variables in the two versions of the game. The time was reduced significantly, while the accuracy was preserved.

can see this behaviour in Fig 4.4. Here it can be seen that as the player completes their tasks and progresses along the activity, they can beat the other player more often. The linear fitted model confirms this relationship; F(1,58) = 12.03, p-value = 0.0009953.

4.3 View and perspective

For *RQ1*, the effect that different viewpoints and perspectives may have in the way the participants perform in these tasks is explored. The main two variables to consider become again the response time of the participants as well as the correctness of their answers. As previously described in Section 3.2.1, the task consisted in analysing three different visual perspectives for every situation presented: the first one was a view from the top of the scene, (here coded AERIAL), a third-person view with the focus on the car the player represents (coded as PLAYER); and another third-person view, this time centred at the car not represented by the player (coded as ADVERSARY). As we observed in the previous analysis, the variables present significant differences between the two groups. This motivates the present work to do the analysis for each group separated from the other one, to remove any effects related to the different game types. The analysis of both groups will still be presented and compared side by side.

Part of the performance achieved by the participants presents differences when the data for the three perspectives are observed. In terms of response time, the average time taken to decide on an image from the *ADVERSARY* perspective (M = 2.1515, SD = 0.8464) is slightly slower than that from the *AERIAL* perspective (M = 2.0981, SD = 0.7880), and that from the *PLAYER* perspective (M=2.0292, SD=0.7566). However, a repeated-measures ANOVA analysis reveals that these differences are no statistically significant at $p<0.05$ [F(2,84) = 1.877, p=0.159]. This result is consistent with that obtained from Group A, where the *AERIAL* perspective (M=3.1699,SD=0.9927) view has an slightly slower average response time than the *ADVERSARY* perspective (M=3.0496,SD=0.9824) and the *PLAYER* perspective

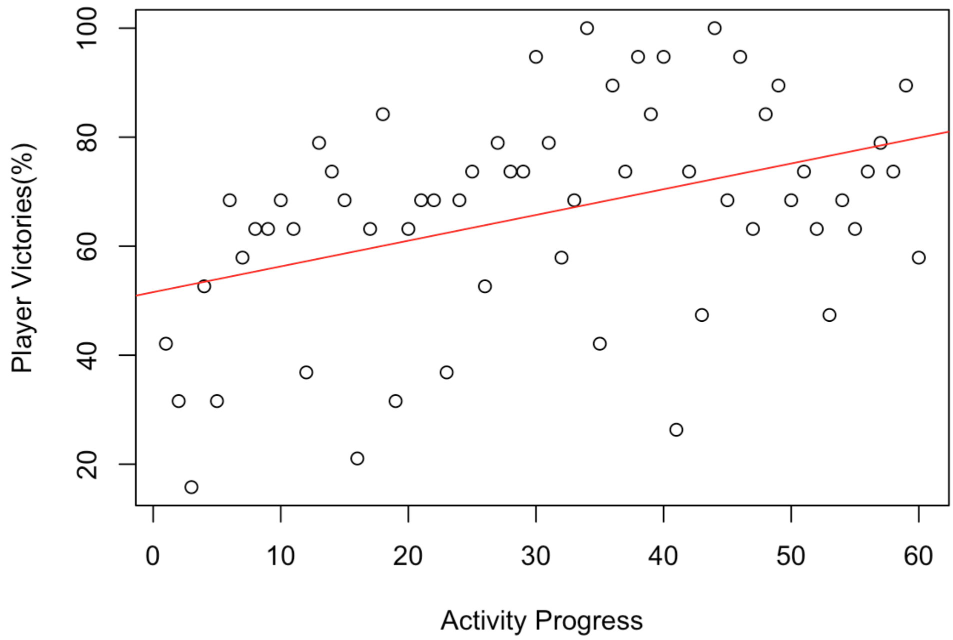
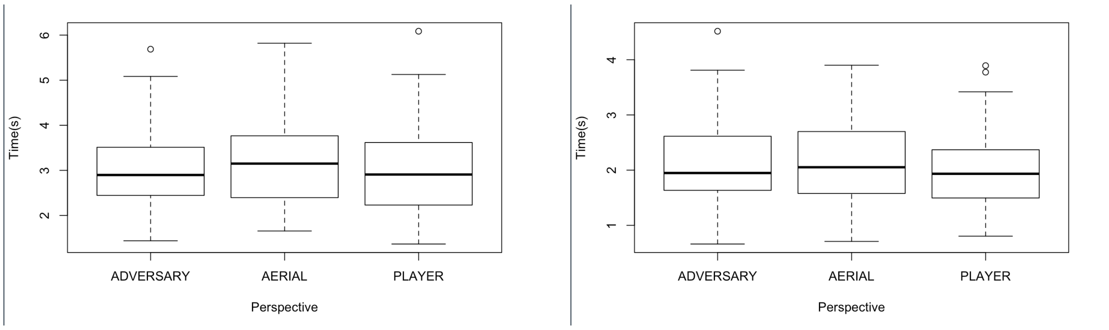


Figure 4.4: Percentage of victories related to progress in the game for the multiplayer version played by Group B

(M = 3.0085, SD = 1.0301), but again, these differences have no statistical significance at $p<0.05$ reported by the same analysis [F(2,82) = 2.4426, p = 0.09324]. The distribution of the average response times for all views can be seen in figure 4.5

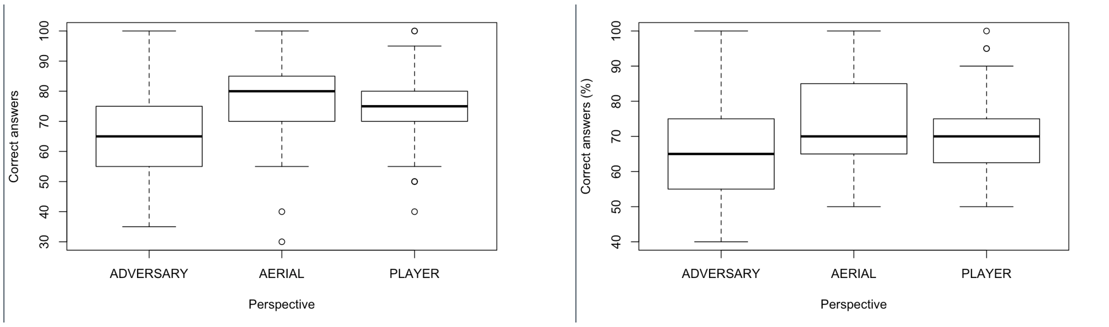
The correctness of the answer was the parameter that presented the most significant findings in this analysis. This variable shows that the *ADVERSARY* view is noticeably harder to answer correctly, both for Group A (M=12.95, SD=2.82) and GROUP B (M=13.37, SD=2.89). The values for this view are well below those for *AERIAL*(M=15.21, SD=2.66) and (M=14.86,SD=2.83) and *PLAYER*(M=14.04, SD=2.44) and (M=14.9047, SD=2.7122). A new repeated measures ANOVA analysis confirms this difference as statistically significant for the multiplayer game played by Group B [F(2,84) = 10.811, p = $6.636e^{-5}$]; while a non-parametric Friedman test does so for the Single-Player version played by Group A [$\chi^2(2) = 29.554$, p = $3.823e^{-7}$], where the distribution does not satisfy the conditions for ANOVA. This distributions can be seen in figure 4.6.

The perception of the participants on the different perspectives presented to them contains some notable data. In general, Group A and Group B found easy to identify which car was represented by the player (*Q13*) (76% of the total of both groups). However there was a 27% of the participants that did not find this information easy to understand. For both groups the AERIAL view was the highest rated with only 3 participants (4%) reporting it as confusing and difficult to answer (*Q14*). The other two visual perspectives received less positive ratings, with 20% of the total considering the third-person view from the perspective of the player (PLAYER) was confusing and difficult to answer(*Q15*). A higher 34% had the same opinion of confusion and difficulty to answer about the third-person view from the perspective of the other driver (ADVERSARY) (*Q16*), 60% of them from Group A. This pairing of group-perspective is the only one where people that rates the ADVERSARY



(a) Average response time per visual perspective for Group A (b) Average response time per visual perspective for Group B

Figure 4.5: Distribution of the average response time among the three different visual perspectives. The three groups present no significant differences.



(a) Percentage of correct answers per visual perspective for Group A (b) Percentage of correct answers per visual perspective for Group B

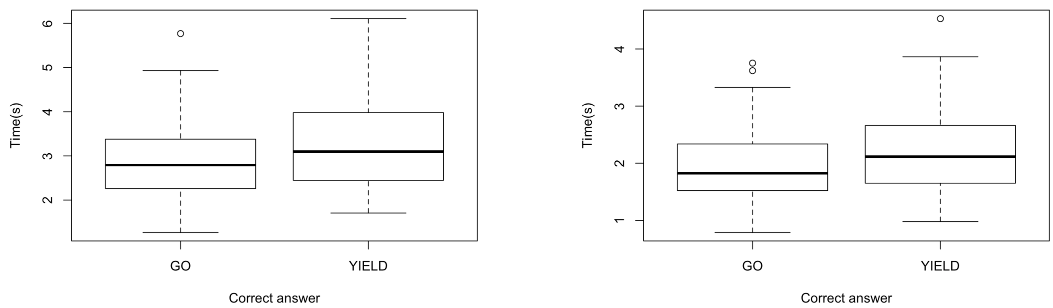
Figure 4.6: Distribution of the percentage of correct answers among the three different visual perspectives. Differences are significant between the three groups

perspective confusing and difficult to answer (*Q15*), outnumber those who rate it positively and disagree with the statement (45% and 35%, respectively). For all the other pairings, the positive opinions are more numerous than the negative.

With the intention of gaining more information on these differences, some interactions between visual perspective and the other variables present in the experiment can be interesting. The following Subsections present those interactions

4.3.1 Correct Answer and Perspective

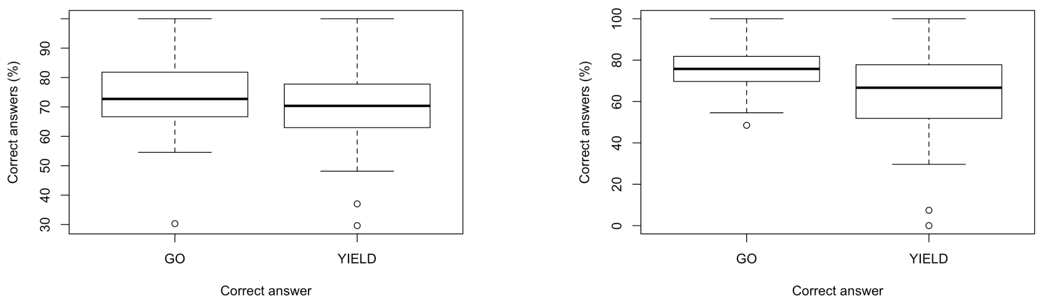
One of them is the relationship between the correct answer for the player in each scene and the perspective from which the scene presented. The player can only choose one of two actions, GO or YIELD, and only one of them is correct in each case. By themselves, these variables present differences. In Group A, both answers have a high percentage of accuracy, with GO (M = 0.7287, SD = 0.1208) being slightly higher than YIELD (M = 0.7045, SD = 0.1502). This differences, however, are not significant, after running a Wilcoxon signed-rank test on them; Z=-1.99, p = 0.1595. In terms of response time, players responded significantly faster when the correct answer was GO (M = 2.8914, SD = 0.9435) in relation with the case where



(a) Average response time per correct answer for Group A

(b) Average response time per correct answer for Group B

Figure 4.7: Distribution of the average response time when each of the two different answers is the correct one. Participants answered significantly faster when the correct answer was GO



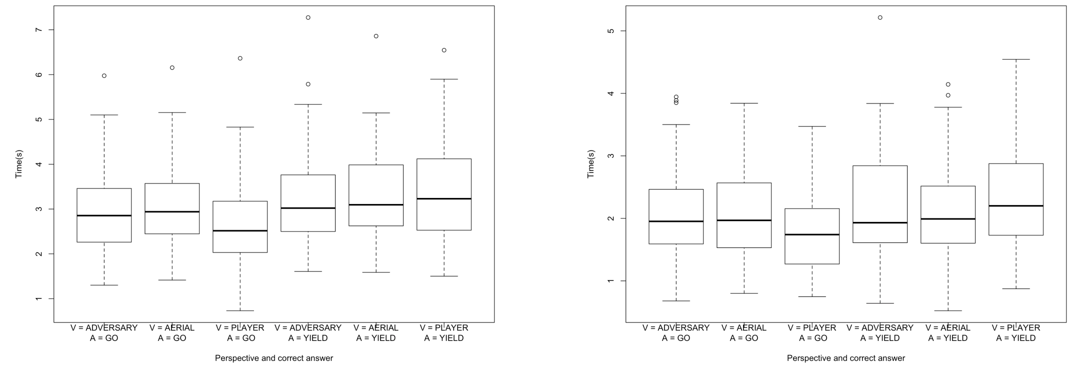
(a) Percentage of correct answers per correct answer for Group A

(b) Percentage of correct answers per correct answer for Group B

Figure 4.8: Distribution of the percentage of correct answers for the two different answers. No significant differences in accuracy

the correct answer was YIELD (M = 0.7045, SD = 0.1502), which is also confirmed by a Wilcoxon signed rank test; Z -9.55, $p<0.001$. This can be visualised in figures 4.7 and 4.8.

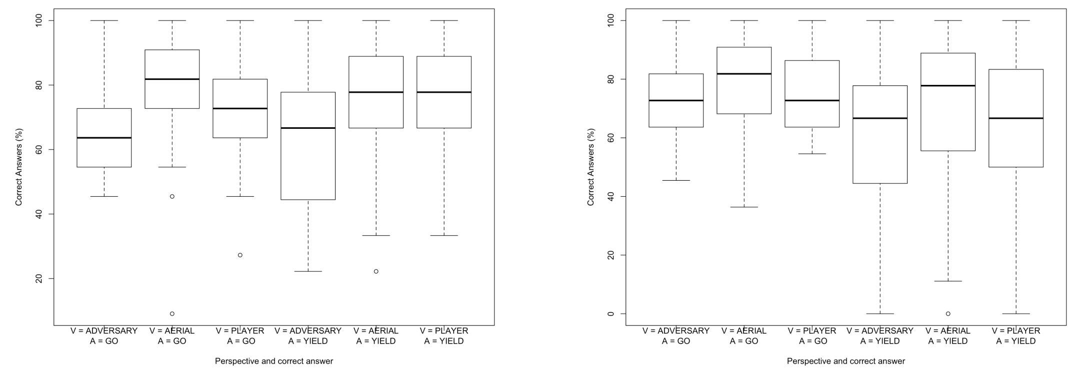
The next step is to analyse the interaction between the different visual perspectives and the correct answer for the scene. The distribution of each pairing for both groups can be seen in Figure 4.9 and 4.10. Interaction plots for the two variables are presented in Figures 4.11 and 4.12. A visual inspection of this plots indicates that the differences observed in the previous step are amplified when the visual perspective is taken into account, specially those differences in average response time. This suggest that participants take significantly more time to answer when the correct answer is YIELD and they are presented with a third-person view centred in their own car. After performing a two-way repeated-measures ANOVA test the interaction for the response time is confirmed as statistically significant for Group A [$F(2,82) = 6.2$, $p = 0.00311$] and for Group B [$F(2,84) = 12.65$, $p = 1.57e^{-5}$]. The main effects are consistent with those observed in previous analysis for both groups, with different perspectives making no significant difference in response time, and different answers creating significant differences in response time. In terms of



(a) Distribution of average time response for Group A

(b) Distribution of average time response for Group B

Figure 4.9: Distribution of average time response for each visual perspective/correct answer pairing. Differences are significant



(a) Distribution of percentages of correct answers for Group A

(b) Distribution of percentages of correct answers for Group B

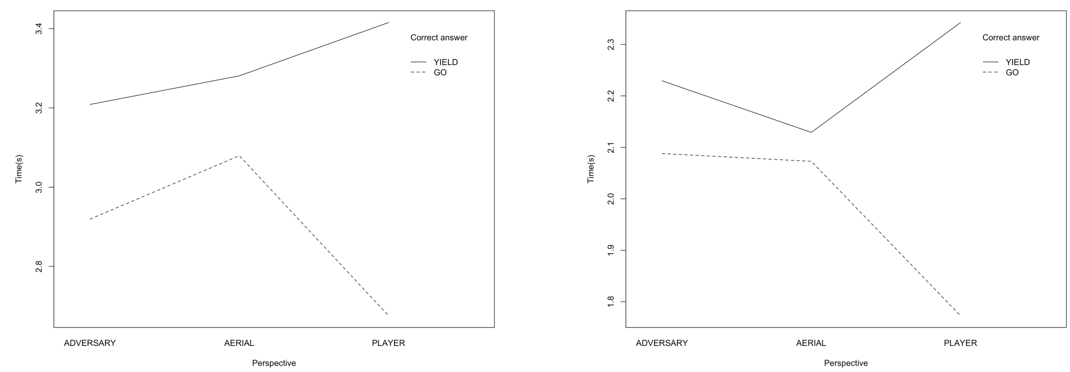
Figure 4.10: Distribution of the percentage of correct answers per each visual perspective/correct answer pairing. Differences are not significant

correctness, while there is an interaction suggested by the plot in Figure 4.12a, the ANOVA test shows that there is nothing significant at level $p < 0.05$ for Group A [$F(2,82) = 1.818$, $p = 0.169$], nor there is for Group B [$F(2,84) = 1.453$, $p = 0.24$f].

4.3.2 Demographic groups and visual perspective

In order to provide more information on the effects caused, the differences between different demographic groups were explored too. Three demographic groups that are easily separable and were considered relevant to be analysed are gender, country of issue of the driving license, and driving experience.

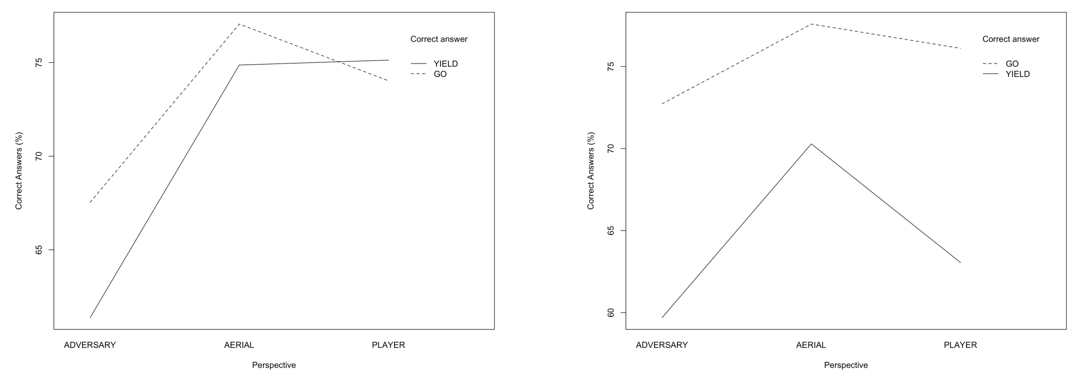
In terms of aggregation by gender, tendencies were similarly distributed as the general data, with the AERIAL and PLAYER view being similar and the ADVERSARY view requiring more time. ANOVA tests show that there are no major differences in terms of response time. In terms of accuracy in percentage of correct answers both games present interesting tendencies: the ADVERSARY view creates



(a) Interaction between visual perspective and correct answers for average response times in Group A

(b) Interaction between visual perspective and correct answers for average response times in Group B

Figure 4.11: Interaction plots for visual perspective and correct answers for average response times. It suggest the visual perspective amplifies the differences in response time for each correct answer



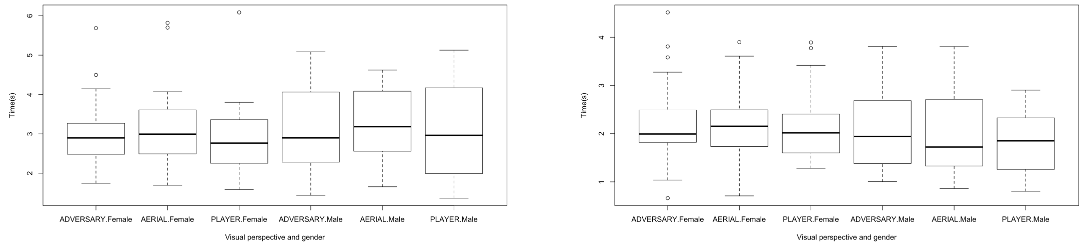
(a) Interaction between visual perspective and correct answers for percentage of correct answers in Group A

(b) Interaction between visual perspective and correct answers for percentage of correct answers in Group B

Figure 4.12: Interaction plots for visual perspective and correct answers for percentage of correct answers. Suggested interactions are not significant

more mistakes in females while they benefit slightly more from the AERIAL perspective than from the PLAYER view, the opposite being true for males. This holds true for both game types. However, an initial ANOVA shows that this differences are not statistically significant and view and gender do not interact with each other. The differences can be seen in figures 4.13 and 4.14. This will be discussed in the next chapter.

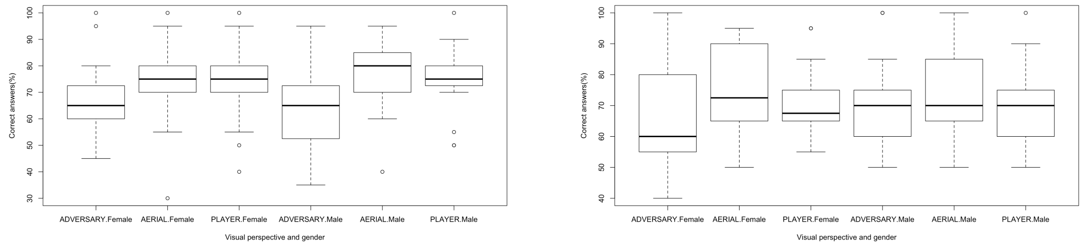
For the analysis of interactions existing between visual perspective and country of issue of the participant's driver license, the groups where divided in those whose driver's license was issued in the United States of America, and those who had a license from a different country. This grouping was made due to the low amount of participants for any other single country other than the USA. This analysis was deemed useful as it can show if a single country can create significant differences when contrasted against a pool of people from very different places, in this case the



(a) Distribution of average response time for Group A

(b) Distribution of average response time for Group B

Figure 4.13: Distribution of average response time for each gender-visual perspective pair



(a) Distribution of percentage of correct answer for Group A

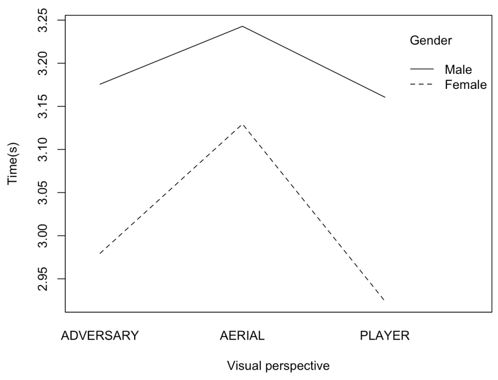
(b) Distribution of percentage of correct answer for Group B

Figure 4.14: Distribution of the percentage of correct answers for each gender-visual perspective pair

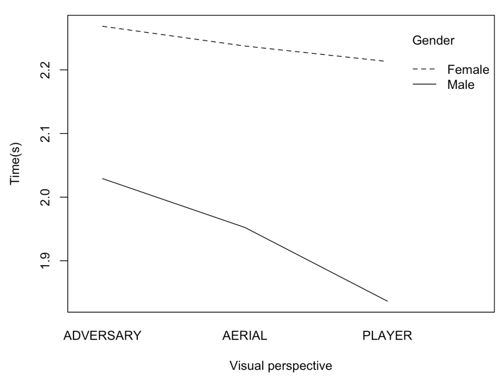
USA.

The results of the analysis are inconclusive. In the multiplayer version of the game, played by Group B, participants from countries that are not from the US have an important increase in percentage of correct answers across all visual perspectives, when compared against their American peers. The ANOVA analysis show these differences are significant at a $p < 0.05$ level; $F(1,34) = 29.3$, $p = 4.99e^{-6}$. However both sub-groups have the same tendency with the ADVERSARY view having the most errors, and the PLAYER and AERIAL perspectives having similar results. These distributions can be seen in Fig 4.18. The only interaction shown in this category appears in the response time in Group A. As the interaction plot in Fig. 4.19a shows, participants from the US answer much faster with both third-person views, AERIAL and PLAYER, while they are slower with the AERIAL view. For the participants with licenses issued elsewhere, the opposite is true: they are significantly slower with the third-person perspective, ADVERSARY and PLAYER than with the AERIAL perspective. This finding is confirmed by a two-way ANOVA analysis on the interaction; $F(2,80) = 3.45$, $p = 0.0365$. While the tendency is similar for the multiplayer version, as seen in 4.19b, the analysis showed that the differences are not significant like with the single-player version.

Finally, for the category of driving experience, no interactions arose in the data analysis. However it is notable that the expected tendency of more experienced drivers having better knowledge of the rules and performing better based on it are not present in the data. In Group A, people in the 3-5 years of driving experi-

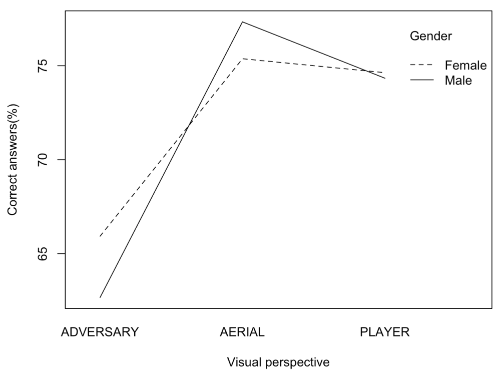


(a) Interactions in average response time for Group A

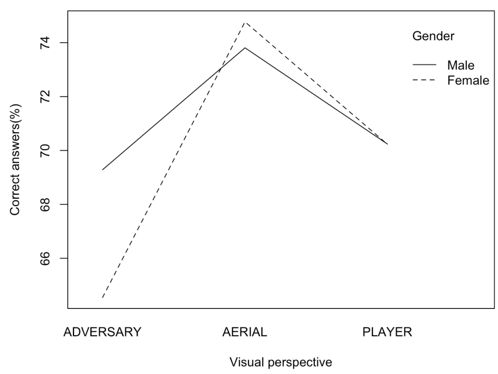


(b) Interactions in average response time for Group B

Figure 4.15: Interaction between gender and visual perspective for average response time



(a) Interactions in percentage of correct answer for Group A



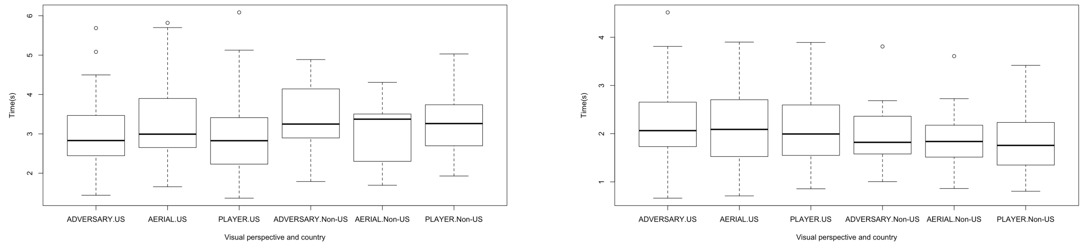
(b) Interactions in percentage of correct answer for Group B

Figure 4.16: Interaction between gender and visual perspective for percentage of correct answers

ence group took less time to answer than those in groups with more experience. In terms of correct answers, the best performing group was the 5-10 years of experience group. This distributions are shown in Fig. 4.21 for the average response time and Fig. 4.22 for the percentage of correct answers. However, despite these differences, ANOVA analysis of the groups aggregated by years of driving experience and visual perspective show that these differences are not statistically significant, with all groups performing similarly all around.

4.4 Difficulty of the scenes

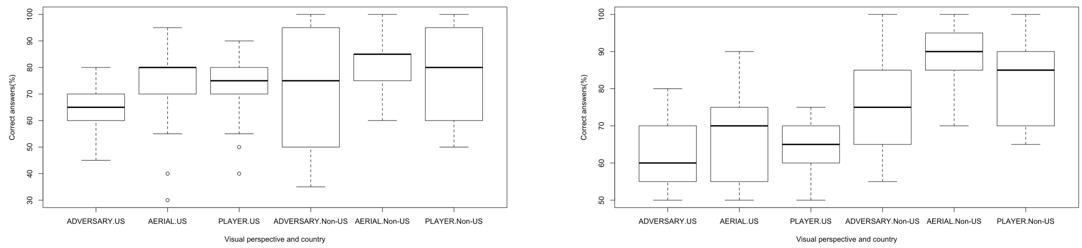
A different analysis that could further clarify why the differences seen so far appear is to test what differences are between the responses for each different rule and scenario, listed in section 3.2.1. We define a difficult task as one that takes a longer amount of time and has limited a number of correct answers. To rank them we



(a) Distribution of average response time for Group A

(b) Distribution of average response time for Group B

Figure 4.17: Distribution of average response time for each driver license's country of issue-visual perspective pair. Participants were grouped as US and Non-US for people from other countries



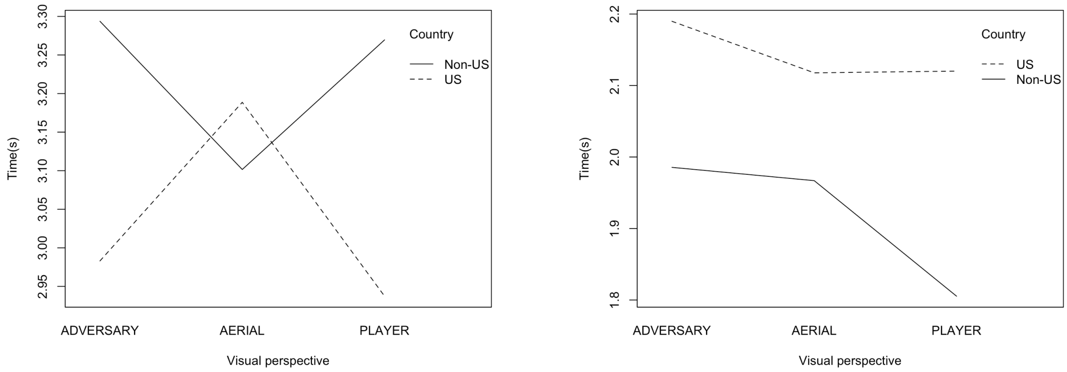
(a) Distribution of percentage of correct answer for Group A

(b) Distribution of percentage of correct answer for Group B

Figure 4.18: Distribution of the percentage of correct answers for each driver license's country of issue-visual perspective pair. Participants were grouped as US and Non-US for people from other countries

create a score by dividing the average response time by the percentage of correct answers, in decimal form, for each group; later this two results are added together to create the final score. This is consistent with the definition since the difficulty we are trying to measure is directly proportional to time and inversely proportional to the percentage of correct answers to it. Using this number we can observe which scenes are harder to answer. The data was collected in table 4.1.

In this case it is clear that T-shaped intersections have very high scores of difficulty with 15 (T043) and 8 (T021). A surprising result is that some tasks that intuition would suggest are easy, such as the first two which rely in respecting the car coming from the right (T011 and T021) and the situation where a road has a Yield sign (T031), resulted in subpar performance during the test, compared to other situations. Some other situations, such as roundabouts (T071 and T072), exiting a parking lot (T061) and following curved roads with intersections (T032) result very clear and intuitive for the participants to answer both fast and with a higher accuracy.



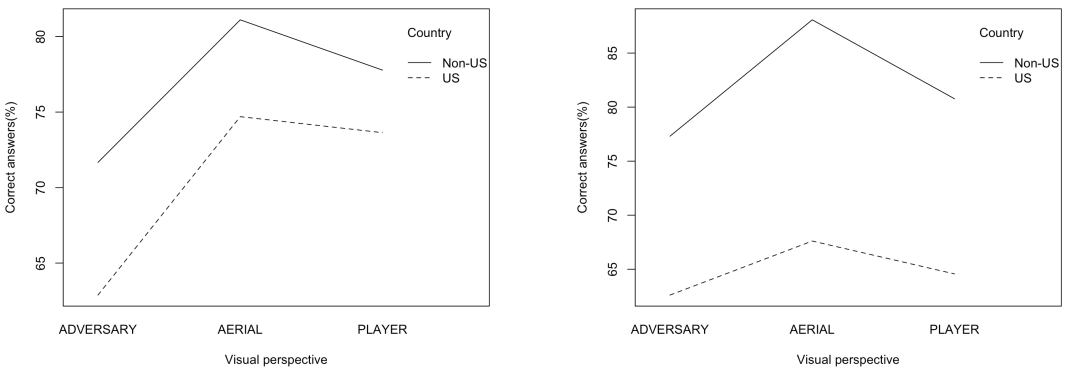
(a) Interactions in average response time for Group A

(b) Interactions in average response time for Group B

Figure 4.19: Interaction between driver license's country of issue and visual perspective for average response time. Participants were grouped as US and Non-US for people from any other country

Scene	Time(s)		Correct Answers(%)		Score
	Group A	Group B	Group A	Group B	
T011	3.738052	2.2674	69.44%	65.12%	8.8650
T021	3.375538	2.0914	67.06%	66.28%	8.1890
T031	3.912246	2.6107	53.57%	51.94%	12.3294
T032	2.417903	1.7941	88.49%	88.37%	4.7626
T041	3.192074	2.0422	91.26%	96.12%	5.6224
T042	3.111942	2.1581	77.77%	76.74%	6.8137
T043	3.266705	2.497	36.11%	41.86%	15.0117
T051	2.896659	2.1553	80.55%	73.64%	6.5229
T061	2.705098	1.8339	83.33%	81.39%	5.4995
T071	2.417497	1.6488	81.34%	79.46%	5.0471
T072	2.645388	1.7032	69.04%	63.56%	6.5113

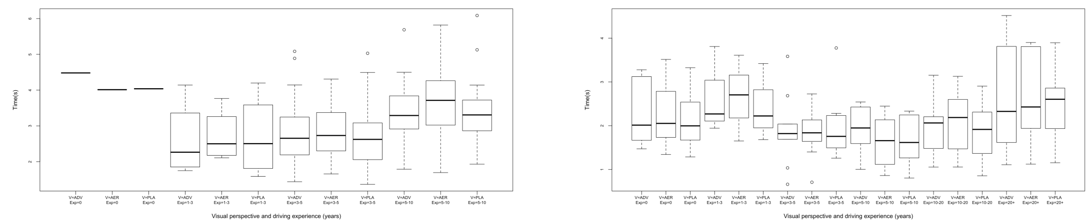
Table 4.1: Average response time and percentage of correct answers for each scene in the two groups



(a) Interactions in percentage of correct answer for Group A

(b) Interactions in percentage of correct answer for Group B

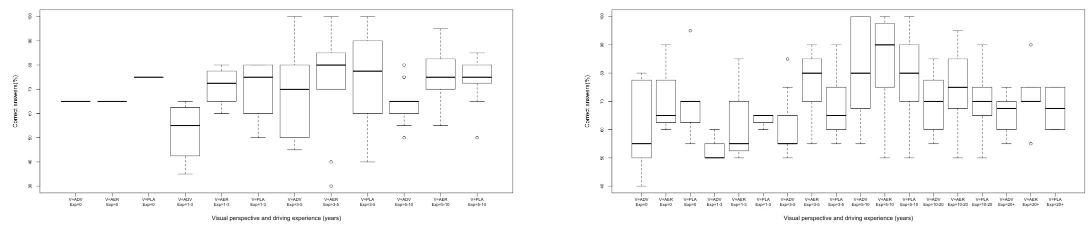
Figure 4.20: Interaction between gender and visual perspective for percentage of correct answers. Participants were grouped as US and Non-US for people from any other country



(a) Distribution of average response time for Group A

(b) Distribution of average response time for Group B

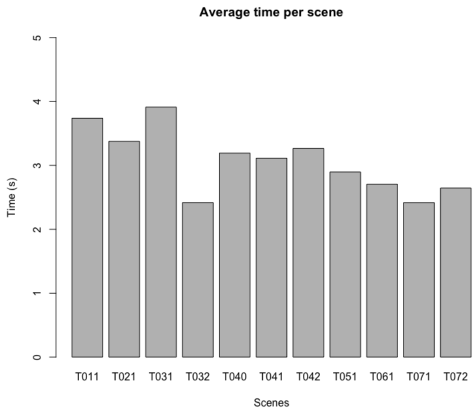
Figure 4.21: Distribution of average response time for each driving experience group-visual perspective pair. Driving experience is measured in years of driving



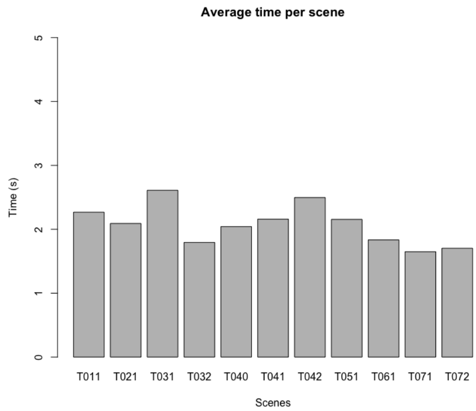
(a) Distribution of percentage of correct answer for Group A

(b) Distribution of percentage of correct answer for Group B

Figure 4.22: Distribution of the percentage of correct answers for each driving experience group-visual perspective pair. Driving experience is measured in years of driving

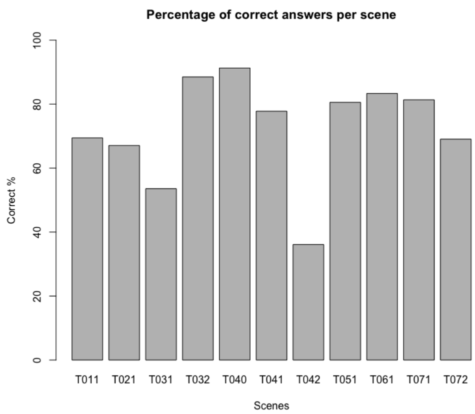


(a) Group A average time per scene

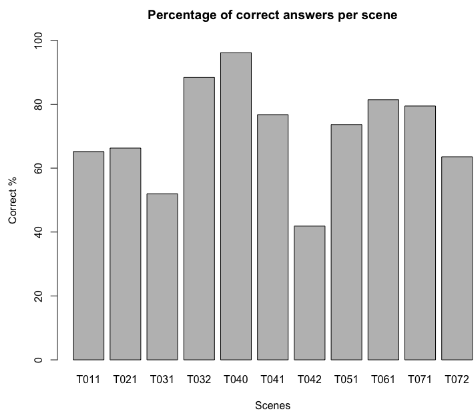


(b) Group B time per scene

Figure 4.23: Average time spent in each type of scene



(a) Group A correct answer percentage per scene



(b) Group B correct answer percentage per scene

Figure 4.24: Percentage of correct answers for both groups in each type of scene

Chapter 5

Discussion and conclusions

During the analysis of the results of the main experiment, some interesting effects came to light for all the different variables considered. This section will discuss how they relate to the two research questions (stated in section 3.1). The following section will suggest different directions for future work on this topic. The chapter ends with a summary of the conclusions of the present thesis.

5.1 Discussion

First, the effects different visual perspectives have on the effectiveness of the player during a static-scene analysis task were explored for RQ1. The data suggest that, in general, during this scene analysis players choose the correct answer more consistently with a perspective that either separates themselves from the action, like the AERIAL view, or with a perspective that put them (or their avatar in the game) in the centre. Participants have significantly less correct answers on scenes visualised from the adversary's viewpoint, which requires the player to put themselves in the position of another agent. Players seem to find it difficult to identify themselves and analyse their situation from an opposing agent's perspective. However, it is also true that any differences in response time between the three different visual perspectives are not significant. This suggest that players spend, in average, the same time looking at and analysing the scenes before deciding, even if they do not have the correct answer. There may be a number of reasons for this behaviour. The pressure of the timer, or the competition against another player could influence the time participants take before giving an answer. It can be a consequence of the players getting involved in the dynamic of the game itself, choosing to keep the pace even if this leads to more mistakes. It could be a combination of factors. Further research would be needed to gain more insights. On the qualitative side of the experiment, it is notable that the perception of the participants of the experiment did not find the ADVERSARY view particularly hard to analyse. This could be explained by the relative small times seen averaging around 2-5 seconds per scene. While a difference of one second is easily detected by the computer and significant in this context, it can be difficult to perceive by humans. Therefore it is understandable that people did not notice they were performing worse in the scenes with this perspective.

Some effects observed after separating different demographic groups are interesting. First, separating the groups by gender shows that the third-person view, focused on the opponent (the one named ADVERSARY view) has an increased effect on female players. This view, which has already been shown to be problematic for all users, causes more mistakes when presented to female users. This effect would be similar to those found in literature related to the topic like [44], which study the differences between genders in how spatial information is processed. While these differences were deemed not significant for the present work, a larger, more carefully selected pool of participants in future work could explore this tendency further. This could also point to a need of either create different scenes that help each gender better or tuning them in such a way that everyone can benefit the same and these differences are reduced or outright eliminated. Moving to a different demographic criteria, differences between drivers licensed in the US and those with licenses issued elsewhere were studied. The results suggest the need to further explore how to cater better to the requirements of particular countries regarding driving education. With the present tools it can be said that some significant differences seem to appear for this country only. A well distributed, larger set of participants with driver licenses from different countries would help solidify the idea that different countries create significantly differences in the analysis of this driving situations. Finally, the differences between groups with different driving experience can be surprising. Intuition would suggest that accuracy in the answers would go up for drivers with more experience, while response time would go down. This was not the case during this experiment. A guess could be ventured that this effect is a result of driving becoming a subconscious skill as experience grows, with some driving theoretical knowledge becoming internalised and being performed automatically, without conscious thought. This would be supported by the fact that the drivers that performed the best were drivers that learned to drive relatively recently (1-3 years) and this knowledge would be fresher in their minds. However, the present thesis lacks the scope to give any strong claims about this or any other reasons for these particular discrepancies in the expected behaviour of the variables and the actual result from the experiment, in terms of driving experience and its relationship with visual perspective during a static-scene analysis task. Further exploration would help clarify these findings.

For the effects that a competition as a design element may have during a static-scene analysis task (RQ2), the data provided by the experiment indicates clearly that introducing a competition between players in the game causes a significant reduction in response time, without any significant reduction on the accuracy of the answers. This is the most significant finding of the present thesis. It suggest that, when a competition against a second player is introduced, they become involved in said competition and feel more compelled to make decisions faster. Their ability to make accurate decisions is not affected by this element. Both behaviours are desired in an environment that requires fast reactions, but where failure could lead to dangerous situations. This is further supported by the linear growth observed in the player's victories against the AI adversary as they progress in the application. The combined effect suggests that, with time, these decisions consistently put the subject's performance above that from average players that were not presented with this competition design element. This "average player" comes from the fact that the AI agent was modeled after the averages of real people using the previous, noncompetitive version of the game, The effect becomes important because it could be interpreted as the players being more involved in the game itself, increasing their immersion, which several works define as an element that contributes to the learning experience. Further work into determining if this effects can be directly related with increased immersion should be performed.

Finally, the data on the difficulty of the scenes themselves shows unusual discoveries. Some of the data follows the intuitive idea that scenes with less ambiguous elements, such as coming out of a parking lot, or following a curve in a road that by size can be clearly seen as the main road, are easier to understand and make the decision easier. In turn, scenes with more unclear elements, such as T intersections and four way intersections increase the difficulty for players. Surprisingly some that the road regulations consider as basic and do not require many elements were still hard to analyse by the participants.

5.2 Future work

Regarding future work, the first improvement could be a much more carefully selected set of participants. This would be time consuming and potentially expensive, but if possible, would show much better how certain variables like the slight differences in driving in different countries or better distribution in terms of driving experience.

Another improvement would be the creation of many more scenes. However, the scenes that should be carefully balanced and distributed among participants, since simply giving them a much larger pool of static scenes to analyse could create other issues such as loss of interest, tiredness, boredom, etc. which would skew the results.

Another further extension of this thesis would be to increase the number of agents in the road. Driving situations often include more than two cars, with buses, trams, pedestrians, motorcycles and other motorised vehicles. Not all of these agents would be helpful to include as central agents that represent a player, but different sets could be helpful for new drivers. Extensions in this direction could be devised to enhance the capabilities of the game-based learning application.

5.3 Conclusions

The objective of this thesis was to explore the effect that competition and varying visual perspectives have as game elements for a game-based learning application. The domain used to test was driving education, in particular the learning of the traffic rules that govern intersections when two cars meet at them. After running an experiment an online based application to measure how players would perform during a scene analysis task in this domain, the data gathered on the variables measured contains some interesting results. This results can be considered positive, since some effects were indeed found and they point to benefits in the learning experience. This could lead to further our understanding of how they can benefit other applications in different educational domains.

One of the final objectives of this line of research is a collection of games that would help during the whole educational process for new drivers. The findings of this thesis could be used to evolve the application used for the experiment, reproduce some of its design elements and adapt them to other situations required during a driving learning course. The positive feedback on the design elements that were not the focus of this work, such as the User Interface, indicate that this tool could help driving schools and independent learners to learn, practice and study for any qualifications they are required to take. Further advances in this field could help educate better drivers and make roads safer for everyone.

Bibliography

[1] Per Backlund, Henrik Engström, and Mikael Johannesson. "Computer gaming and driving education". In: *Proceedings of the workshop Pedagogical Design of Educational Games affiliated to the 14th International Conference on Computers in Education (ICCE 2006)*. 2006, pp. 9–16.

[2] Per Backlund et al. "Designing for self-efficacy in a game based simulator: An experimental study and its implications for serious games design". In: *Visualisation, 2008 international conference*. IEEE. 2008, pp. 106–113.

[3] Per Backlund et al. "Games and traffic safety-an experimental study in a game-based simulation environment". In: *Information Visualization, 2007. IV0́7. 11th International Conference*. IEEE. 2007, pp. 908–916.

[4] Per Backlund et al. "Games for traffic education: An experimental study of a game-based driving simulator". In: *Simulation & gaming* 41.2 (2010), pp. 145–169.

[5] Juan C. Burguillo. "Using game theory and competition-based learning to stimulate student motivation and performance". In: *Computers & Education* 55.2 (2010), pp. 566–575.

[6] Jerome C. Bush. "The Impact of Classroom Games on the Acquisition of Second Language Grammar". In: *Language in Focus* 1.2 (2015).

[7] Nergiz Ercil Cagiltay, Erol Ozcelik, and Nese Sahin Ozcelik. "The effect of competition on learning in games". In: *Computers & Education* 87 (2015), pp. 35–41.

[8] Iván Cantador and José M Conde. "Effects of competition in education: A case study in an e-learning environment". In: *Proceedings of the IADIS International Conference on e-Learning. IADIS* (2010).

[9] Dennis Charsky. "From edutainment to serious games: A change in the use of game characteristics". In: *Games and culture* 5.2 (2010), pp. 177–198.

[10] Hercy NH Cheng et al. "Equal opportunity tactic: Redesigning and applying competition games in classrooms". In: *Computers & Education* 53.3 (2009), pp. 866–876.

[11] Thomas M Connolly et al. "A systematic literature review of empirical evidence on computer games and serious games". In: *Computers & Education* 59.2 (2012), pp. 661–686.

[12] Nicole David et al. "Neural representations of self versus other: visual-spatial perspective taking and agency in a virtual ball-tossing game". In: *Journal of cognitive neuroscience* 18.6 (2006), pp. 898–910.

[13] Sara De Freitas. “Learning in immersive worlds: A review of game-based learning”. In: (2006).

[14] Joseph C. Delquadri et al. “THE PEER TUTORING SPELLING GAME: A CLASSROOM PROCEDURE FOR INCREASING OPPORTUNITY TO RESPOND AND SPELLING PERFORMANCE”. In: *Education and Treatment of Children* 6.3 (1983), pp. 225–239. ISSN: 07488491, 19348924. URL: http://www.jstor.org/stable/42898779.

[15] Blaženka Divjak and Damir Tomić. “The impact of game-based learning on the achievement of learning goals and motivation for learning mathematics-literature review”. In: *Journal of Information and Organizational Sciences* 35.1 (2011), pp. 15–30.

[16] Mary Jo Dondlinger. “Educational video game design: A review of the literature”. In: *Journal of applied educational technology* 4.1 (2007), pp. 21–31.

[17] Juan Alberto Estallo. *Los videojuegos: Juicios y prejuicios:[Guía para padres]*. Planeta, 1995.

[18] Stephen R Foster, Sarah Esper, and William G Griswold. “From competition to metacognition: designing diverse, sustainable educational games”. In: *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*. ACM. 2013, pp. 99–108.

[19] Maurits Graafland, Jan M Schraagen, and Marlies P Schijven. “Systematic review of serious games for medical education and surgical skills training”. In: *British journal of surgery* 99.10 (2012), pp. 1322–1330.

[20] Johan Huizinga. *Homo ludens: A study of the play-element in our culture*. Routledge & Kegan Paul, 1949.

[21] Gwo-Jen Hwang and Po-Han Wu. “Advancements and trends in digital game-based learning research: a review of publications in selected journals from 2001 to 2010”. In: *British Journal of Educational Technology* 43.1 (2012), E6–E10.

[22] Superdata Research Inc. *Market Brief — 2017 Digital Games & Interactive Media Year in Review*. 2018. URL: https://www.superdataresearch.com/market-data/market-brief-year-in-review/.

[23] Ministry of Infrastructure and the Environment. *Road Traffic Signs and Regulations in the Netherlands*. 2014. URL: https://www.rijksoverheid.nl/binaries/rijksoverheid/documenten/brochures/2012/02/28/verkeersborden-en-verkeersregels-in-nederland-engels/i-m-rvv2014-eng.pdf.

[24] Karl M Kapp. *The gamification of learning and instruction: game-based methods and strategies for training and education*. John Wiley & Sons, 2012.

[25] Fengfeng Ke. “Alternative goal structures for computer game-based learning”. In: *International Journal of Computer-Supported Collaborative Learning* 3.4 (2008), p. 429.

[26] Fengfeng Ke and Barbara Grabowski. “Gameplaying for maths learning: cooperative or not?” In: *British Journal of Educational Technology* 38.2 (2007), pp. 249–259.

[27] Harold F O'Neil, Richard Wainess, and Eva L Baker. "Classification of learning outcomes: Evidence from the computer games literature". In: *The Cirriculum Journal* 16.4 (2005), pp. 455–474.

[28] Joseph Psotka. "Immersive training systems: Virtual reality and education and training". In: *Instructional science* 23.5-6 (1995), pp. 405–431.

[29] Josephine M. Randel et al. "The Effectiveness of Games for Educational Purposes: A Review of Recent Research". In: *Simulation & Gaming* 23.3 (1992), pp. 261–276.

[30] Lise Renaud and Samy Suissa. "Evaluation of the efficacy of simulation games in traffic safety education of kindergarten children." In: *American Journal of Public Health* 79.3 (1989), pp. 307–309.

[31] Mona Wanda Schmidt et al. "Learning from the surgeon's real perspective–First-person view versus laparoscopic view in e-learning for training of surgical skills? Study protocol for a randomized controlled trial". In: *International Journal of Surgery Protocols* 3 (2017), pp. 7–13.

[32] Jon Scoresby and Brett E Shelton. "Visual perspectives within educational computer games: effects on presence and flow within virtual immersive learning environments". In: *Instructional Science* 39.3 (2011), pp. 227–254.

[33] Björn Sjödén, Mats Lind, and Annika Silvervarg. "Can a Teachable Agent Influence How Students Respond to Competition in an Educational Game?" In: *International Conference on Artificial Intelligence in Education*. Springer. 2017, pp. 347–358.

[34] Roger Smith. "The long history of gaming in military training". In: *Simulation & Gaming* 41.1 (2010), pp. 6–19.

[35] Tarja Susi, Mikael Johannesson, and Per Backlund. *Serious games: An overview*. 2007.

[36] TheorieExamenOefenen.nl. *Gratis theorie examen oefenen*. Accessed: 2018-01-30. URL: https://www.theorieexamenoefenen.nl/theorie-examen-oefenen-gratis/auto%5C#.

[37] Sylke Vandercruysse et al. "Competition and students' perceptions in a game-based language learning environment". In: *Educational Technology Research and Development* 61.6 (2013), pp. 927–950.

[38] Dimitrios Vlachopoulos and Agoritsa Makri. "The effect of games and simulations on higher education: a systematic literature review". In: *International Journal of Educational Technology in Higher Education* 14.1 (July 2017).

[39] A.E. Wester et al. "Event-related potentials and secondary task performance during simulated driving". In: *Accident Analysis & Prevention* 40.1 (2008), pp. 1–7. ISSN: 0001-4575. DOI: https://doi.org/10.1016/j.aap.2007.02.014. URL: http://www.sciencedirect.com/science/article/pii/S0001457507000334.

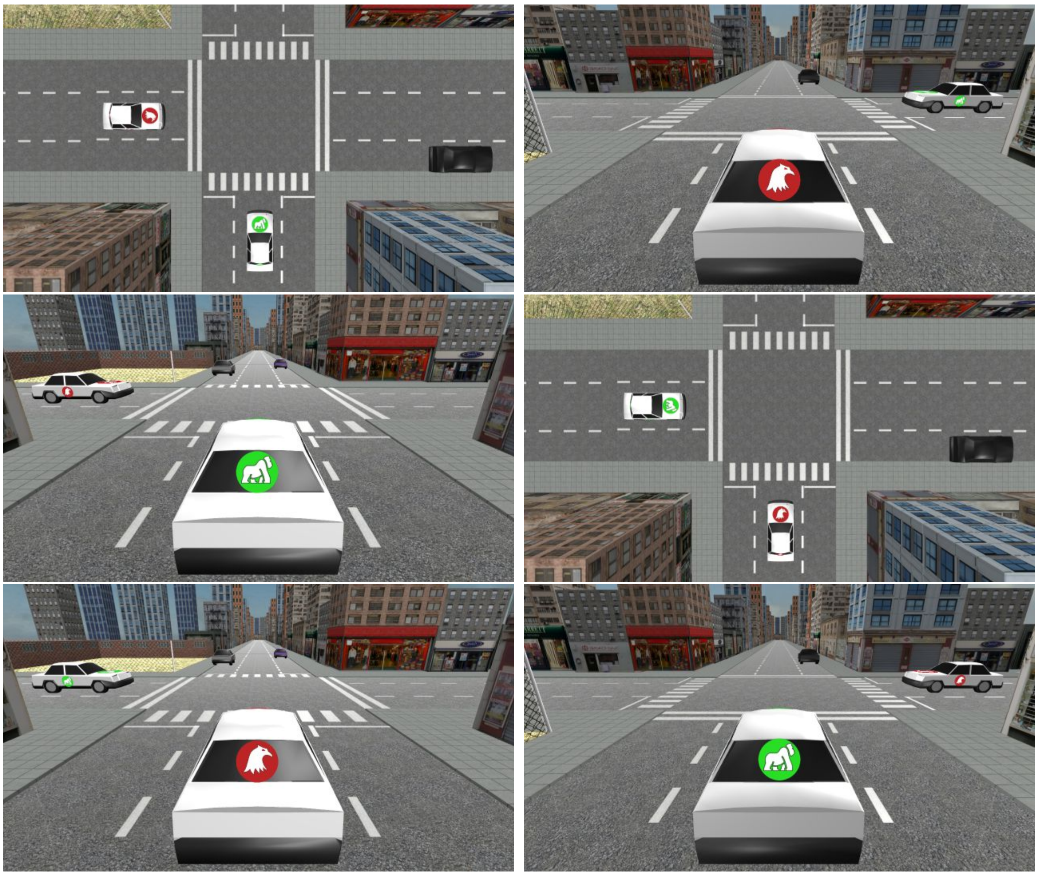
[40] Bjarne Skjødt Worm and Steen Vigh Buch. "Does competition work as a motivating factor in e-learning? A randomized controlled trial". In: *PloS one* 9.1 (2014), e85434.

[41] Pieter Wouters, Erik D Van der Spek, and Herre Van Oostendorp. "Current practices in serious game research: A review from a learning outcomes perspective". In: *Games-based learning advancements for multi-sensory human computer interfaces: techniques and effective practices*. IGI Global, 2009, pp. 232–250.

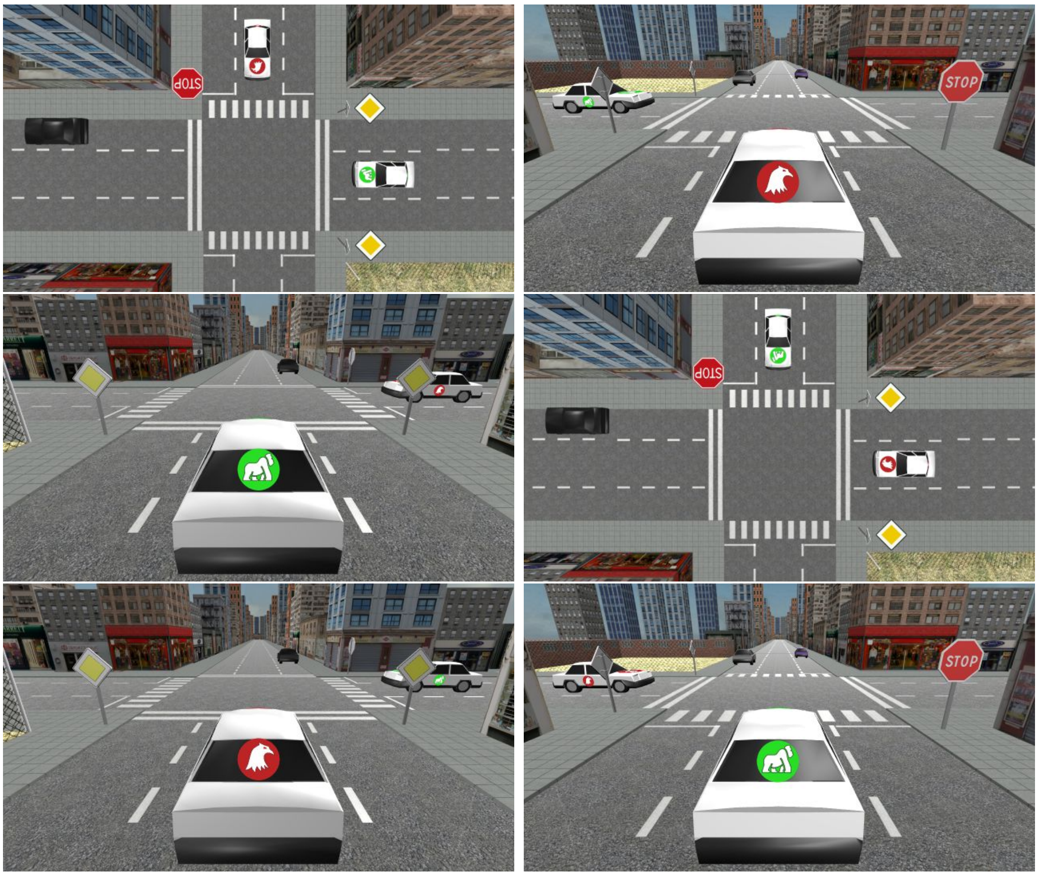
Appendix A

Scenes

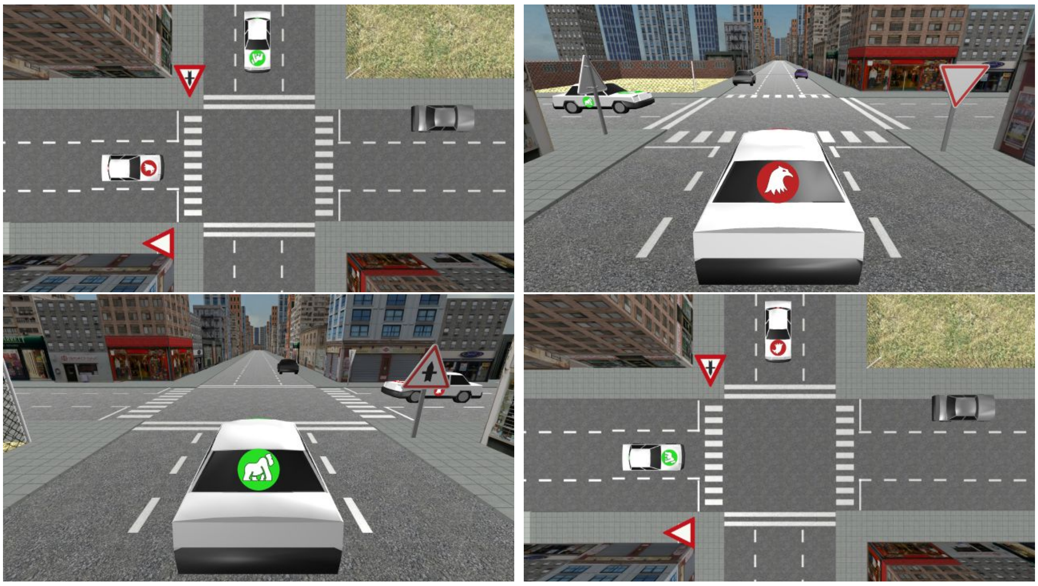
Rule 1 Situation 1: Two cars meet at a one way intersection, both intend to continue straight forward.

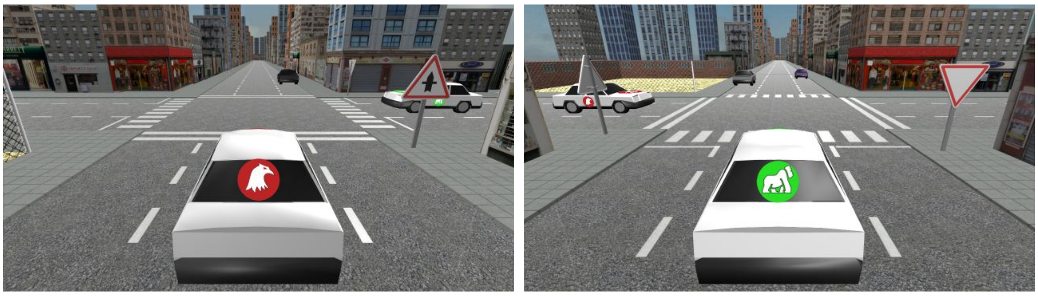


Rule 2 Situation 1: Two cars meet at a one way intersection. One street has a stop sign, the other is marked as a priority road.

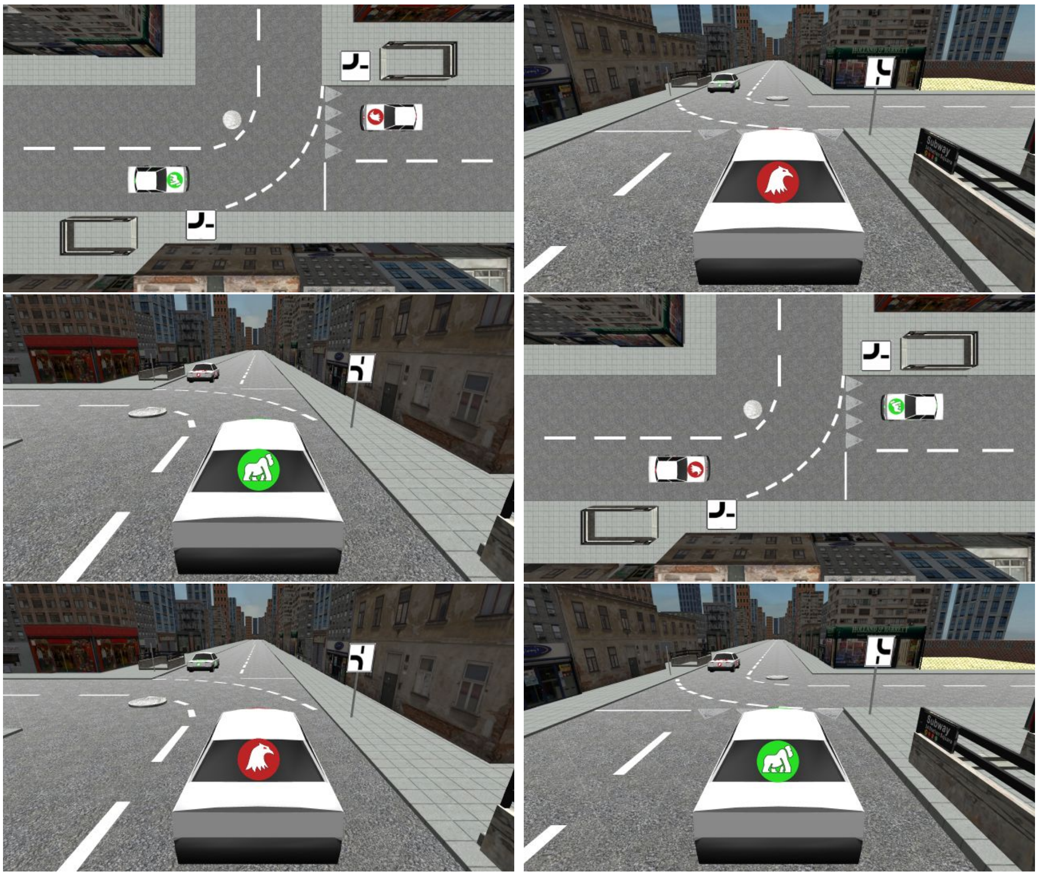


Rule 3 Situation 1: Two cars meet at an intersection. One is marked as priority at the intersection, the other one presents a yield sign.

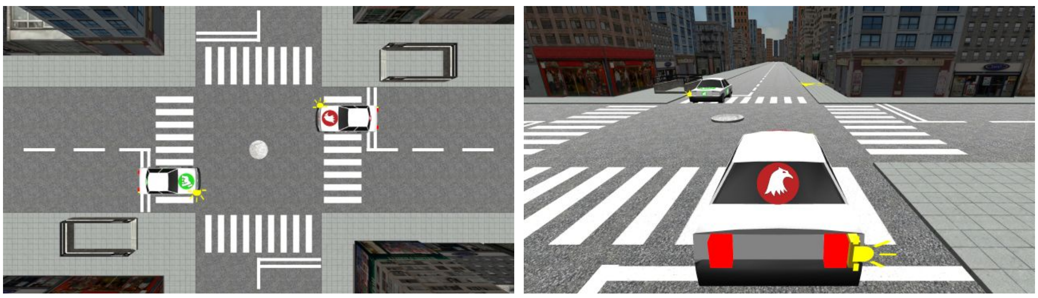


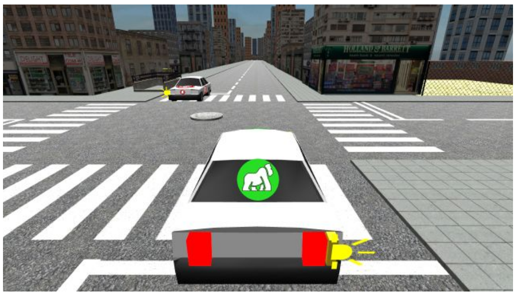


Rule 3 Situation 2: Two cars meet at a curved intersection. The main road follows the curve, while the lesser road intersects it.

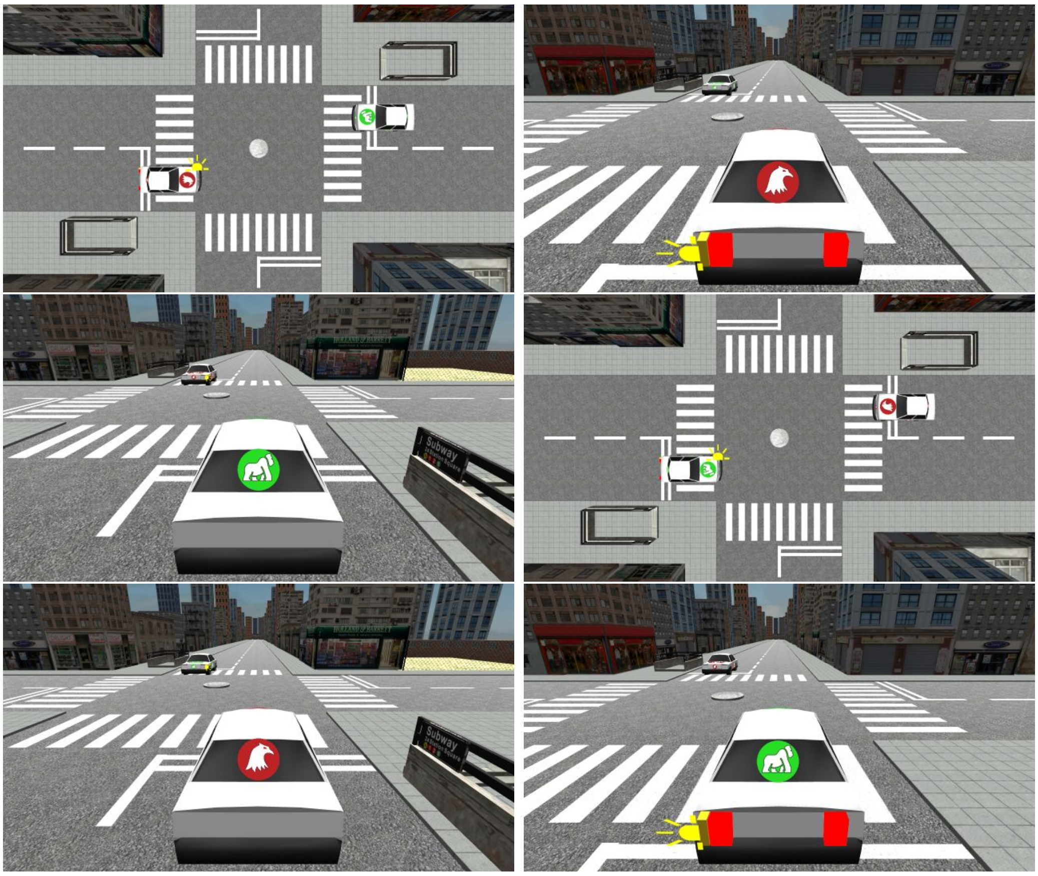


Rule 4 Situation 1: Two cars meet at a two-way intersection. Both cars are turning right and thus does not enter in conflict with each other.

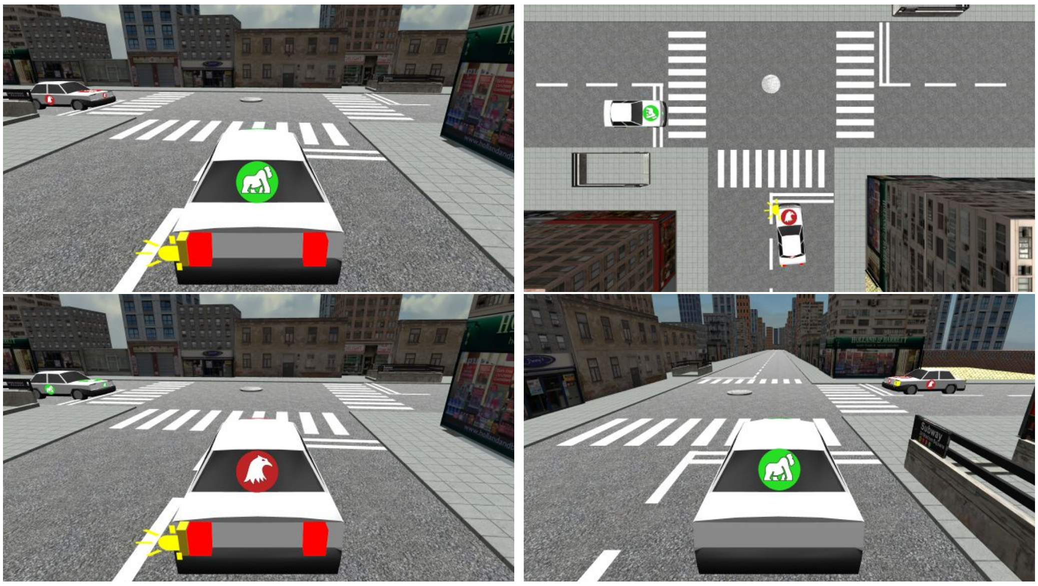




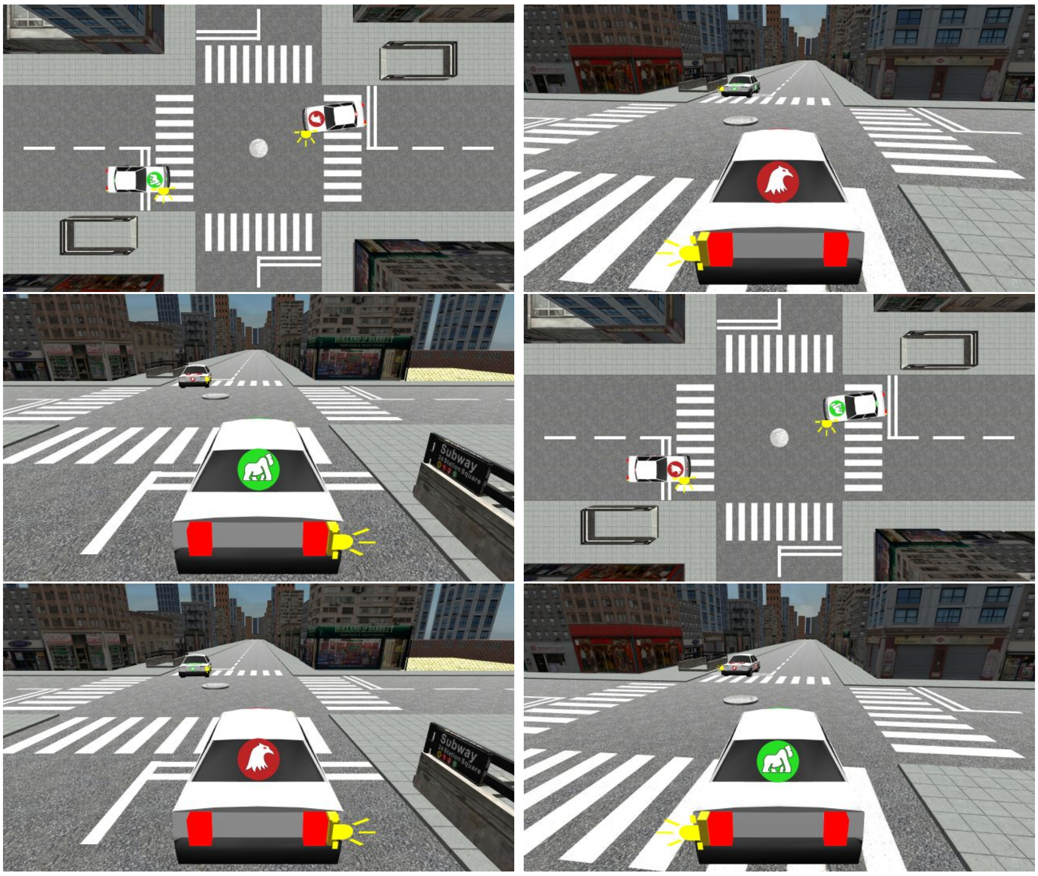
Rule 4 Situation 2: Two cars meet at a two way intersection, facing each other. One car intends to turn left, while the other one desires to go to the left.



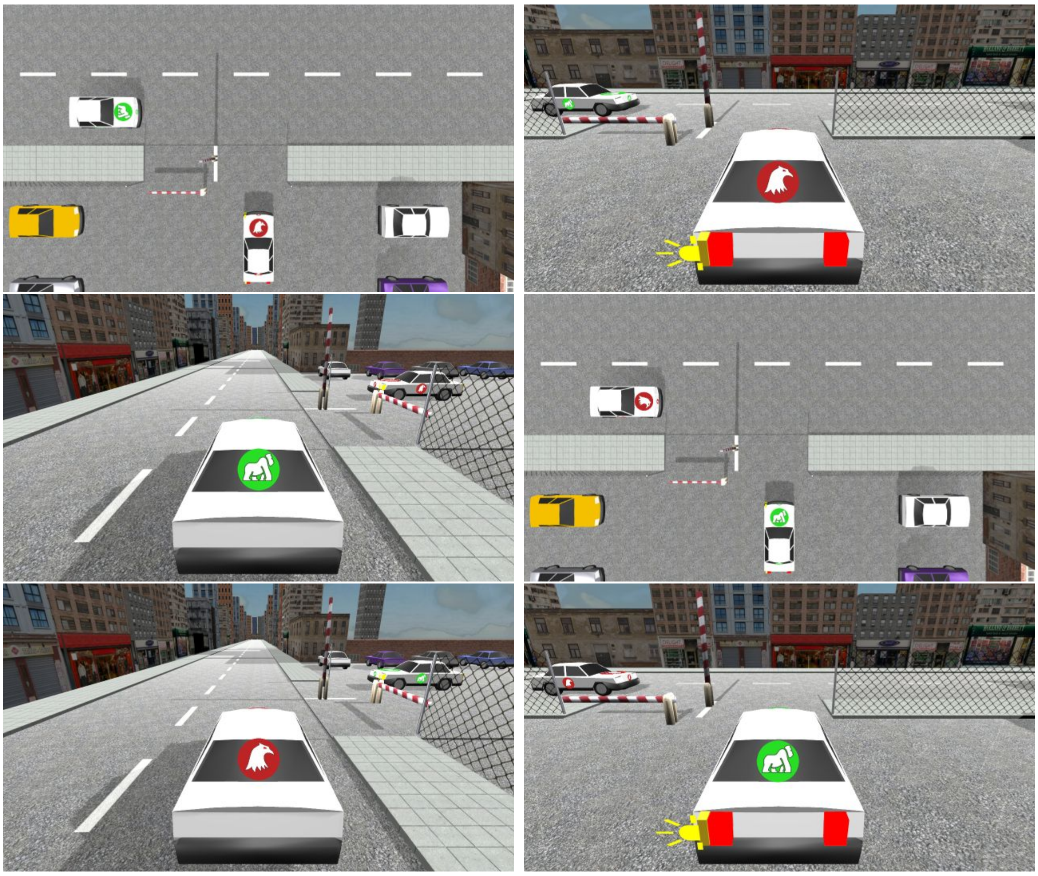
Rule 4 Situation 3: Two cars meet at a T-shaped intersection. One car intends to go straight forward, and the other tries to turn left.



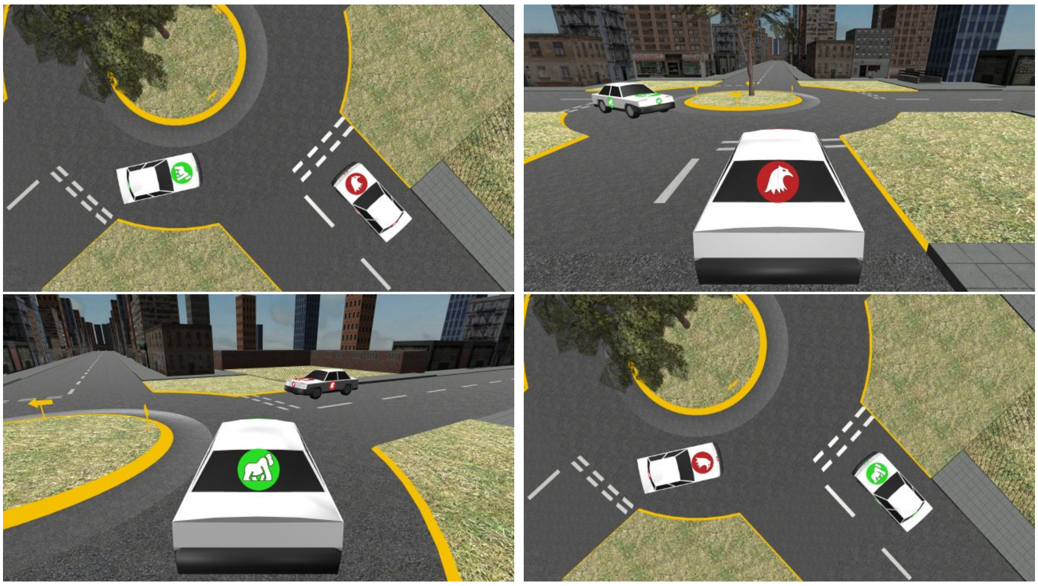
Rule 5 Situation 1: Two cars meet at a two-way intersection. One car intends to turn right, and the other intends to turn left into the same side of the same street.

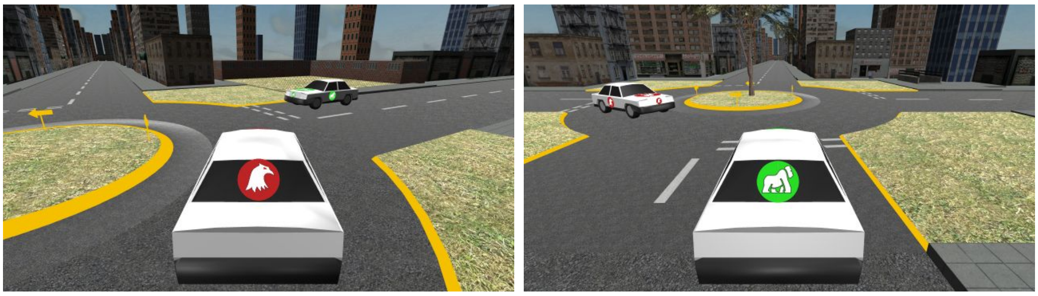


Rule 6 Situation 1: Two cars meet at the exit of a parking lot. One of them is coming out from the lot, the other car is going along the street.

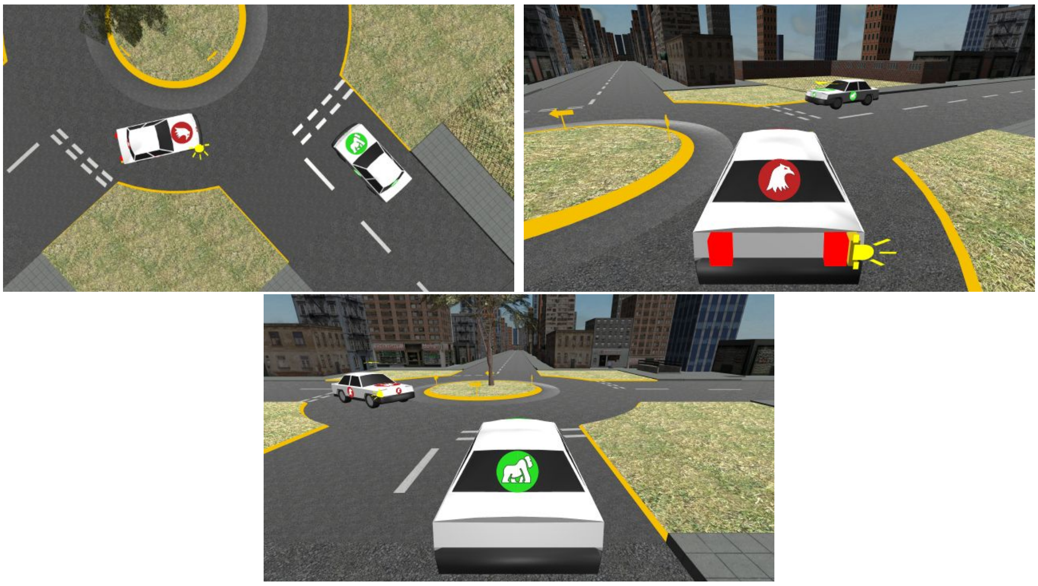


Rule 7 Situation 1: Two cars meet at a roundabout. One of them is already on the circle, and the other one intends to enter it.





Rule 7 Situation 2: Two cars meet at a roundabout. One of them is trying to exit the circle, while the other car is trying to enter. No conflict exists in this situation.



Appendix B

Survey

Q1: Age
Q2: Gender
Q3: Education level
Q4: Do you have a driver license?
Q5: Country of issue of your driver license
Q6: Do you drive regularly?
Q7: For how many years have you driven?
Q8: Have you played computer games before?
Q9: My task in each scene was clear (Likert)
Q10: The interface of the app was intuitive and easy to use (Likert)
Q11: The relevant elements in the environment were clear and easy to see (Likert)
Q12: Overall, the scenes provided enough details to make an informed decision (Likert)
Q13: It was clear at all times which car I was representing in the scenes (Likert)
Q14: The bird-eye view was confusing and difficult to answer(Likert)
Q15: The third-person view centred at my car was confusing (Likert)
Q16: The third-person view centred at another car was confusing and difficult to answer (Likert)
Q17: Competing against another player motivated

me to answer faster (Likert)
Q18: Competing against another player was stressful (Likert)
Q19: The timer was distracting (Likert)
Q20: The activity helped me learn/refresh my knowledge of traffic rules concerning road intersections (Likert)
Q20: Do you have any further feedback about the application?