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Designing a Collaborative Serious Game on Tabletops for Learning Traffic Rules

Master Thesis

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Author's declaration

I declare that, apart from work whose authors are clearly acknowledged, this document is the result of my own and original work. This thesis has not and is not being submitted for any other comparable academic award.

Abstract

This study aims to introduce a serious game design which facilitates collaborative learning on tabletops. The interface design enables mixed reality over tabletops to engage the players effectively in the learning activities. Additionally, the serious game scenario is created for students in driving schools to learn traffic rules and signs inside a city.

The Wizard of Oz methodology was employed to experiment the design. Both questionnaire and observation were adopted as data collection methods and the results from data analysis are reported qualitatively. In data collection and analysis, three perspectives of research are taken into account: supporting collaboration, facilitation of learning, and validation of design. To explore learning abilities of design, a pretest-posttest questionnaire was carried out, and for other design qualities both questionnaire and observation were applied.

The results of experiment suggest that the serious game design is highly effective in collaborative learning. It is shown that this serious game by implementing mixed reality over tabletops and supporting collaboration, is an effective way to learn the traffic rules. Moreover, the qualities of interface design and game scenario are explored during the experiment and suggestions for simplifying the design, and future research are presented.

Keywords: Collaborative learning, serious games, tabletops, mixed reality, learning traffic rules, Wizard of Oz.

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List of Abbreviations

CSCL = Computer Supported Collaborative Learning

D1 = Driver 1

D2 = Driver 2

SEGAREM = Serious Game and Mixed Reality

SG = Serious Games

SI = Sign Indicator

WOz = Wizard of Oz

Chapter 1. INTRODUCTION

1.1 Motivations

One of the important parts of education for citizens is to provide them with understanding of traffic rules and road signs. Education for understanding the rules of traffic in the city usually starts from the pre-school level. It is mandatory to learn more when individuals want to obtain a driving license. Some countries set obligations such as long hours of passing theory and practice courses to be able to attend the driving exam; and in many cases, the exam is very hard to pass. With all these efforts, every year many people die in car accidents, and most of the accidents happen because drivers do not respect the traffic rules. In driving schools, teaching and learning traffic rules and road signs are still done in a traditional way. Students go to usually boring theoretical lessons and they are required to spend normally twenty hours of lectures. This study aims to introduce a novel method for teaching traffic rules in driving schools that engage students in the process of learning by group collaboration.

The research is done to design a serious game to be played by two teams as competitors. Each team members are required to collaborate together in order to defeat the other team and win the game. During the collaboration, players learn about the traffic rules and road signs. The game is designed to be played over two digital tabletops that enable manipulation of objects; in this way players assign physical traffic signs and move tokens as physical cars.

The design is carried out to address three major qualifications: firstly, the design aims to create a serious game which has an attractive scenario and can be played in a group of people; secondly, the design facilitates collaborative learning; and Thirdly, the game interface is designed for utilizing mixed reality over tabletops. These three considerations are tightly interrelated since collaboration is facilitated by tabletops' features and serious game scenario. In the same way, game strategy and goal cover learning objectives that are strengthened by collaboration and manipulation of mixed reality objects.

1.2 Statement of the Problem

In the last decade, some video games are made like Bus Driver by SCS Software (Bus Driver, n.d.) and Urban Jungle (Urban Jungle, n.d.) that is an educational traffic simulator, ask players to drive and react to the traffic rules. There are also many online Flash games which just represent an attractive version of the road rules handbook while the teaching style follows the same traditional methods. This study aims to introduce a new learning method by designing a serious game for driving schools. Unlike the existing games which are played individually, this game is generated for group learning and suitable for classrooms.

Another justification for this research is to introduce the abilities of tabletops in learning traffic rules with a completely new approach. Various research papers show that tabletops have been used to simulate driving (Tonnis, 2007), or study the gestures of a virtual car toward physical objects on the tabletop (Leitner et al., 2008), however most of the educational models designed in CSCL for learning driving rules is designed for a single player by use of a normal computer. The thesis objective is to design a serious game that facilitates collaborative learning by employing mixed reality over tabletops. This project is done as part of a research internship in LIRIS lab at INSA de Lyon, and tries to follow the framework of the SEGAREM (SErious GAmes and Mixed Reality) project that aims to develop a prototype environment for the design of mixed reality serious games, as can be read on the project Website (SEGAREM, n.d.).

Based on the objectives of this study, the design of serious game follows principles of collaborative learning as well as tabletops' interactive design that enables mixed reality.

One of the key features of tabletops is to enable collaboration among a group of people. And using mixed reality over tabletops attracted many researchers to use these strong potential features in order to design collaborative learning scenarios for group learning. Additionally, tabletops are very efficient to support collaboration among a group of people since they provide face-to-face collaboration, as well as shared and individual environments at a time. For this reason, the study aims to adopt potential features of tabletops to design a collaborative learning serious game.

1.3 Research Questions

The following research questions are the focus points for the study:

- How does designing serious games on tabletops facilitate collaborative learning?
- How can collaborative learning design be assessed?

These two research questions intend to be solved by three major qualifications of the design: Supporting collaboration, facilitation of learning, and validation of design. The rationale behind the first question is to examine the design from collaboration and learning point of view. And the second question tries to find a method to assess the qualifications of design. To address the research questions, the thesis pursues the following order:

This introductory chapter provides an overview of research motivations, statement of problem and the objectives of design. Subsequently, the chapter contains of research questions and methodology. The second chapter explores the literature that has examined the concepts of collaboration and serious games then moves toward tabletops and mixed reality. The chapter explains the principles of collaboration design over tabletops and ends with an overview of research that has offered design models and tools.

The third chapter comprises the procedure of design from the beginning to the end to make the game ready for the experiment. Various design ideas with their advantages and drawbacks are explained and the full explanation of why the final design is selected is included. In this chapter the process of designing is finalized by carrying out several paper prototype tests and the simplified version of the design is introduced for the experiment.

Chapter four contains the whole process of experiment from organization and data collection to data analysis and results. In this chapter, the techniques used for the application of the WOz research methodology, as well as the sampling strategy and its limitations are included in the section of method; and background information of participants as well as major issues that are analyzed from the collected data to address the research questions are fully clarified in the results' section. Chapter five contains the conclusion. Themes related to the research questions are investigated with relation to the literature review focuses. Finally, conclusions are drawn, and significance of the study as well as topics for future research are suggested.

1.4 Methodology

This research employs an experimental method to design a collaborative learning serious game and the Wizard of Oz (WOz) prototyping approach to test the design. The data collection is via observation and recording the experiment and the data analysis is done qualitatively. To prepare the Wizard of Oz prototype, several tests are performed to make the design more complete as well as to define the interactive rules of the game. Salber & Coutaz (1993) clarify that the evaluation techniques and user observation improve the design of interactive interfaces; and define the Wizard of Oz as an experimental evaluation mechanism which can be extended to examine the multimodal interfaces.

The WOz methodology is well-known for exploring user interfaces for pervasive, ubiquitous, or mixed-reality systems that use complex technologies. Recent technologies provide many possibilities for user interaction and involve sophisticated hardware and software applications. Therefore, developing a complete prototype would be usually very costly and time-consuming if designers evaluate their assumptions through building the systems (Dow et al, 2005).

Wizard of Oz is a rapid-prototyping method in which human who is called Wizard act as a computer and simulates the system's intelligence to interact with the user via a real or mock computer interface. This method is very useful for testing the costly new technologies with innovative approaches to interface design (Maulsby, 1983).

In an iterative design process, there can be many cycles of brainstorming, prototyping, development, user studies, and assessment to be able to reach the final design. In this process using the WOz technology is helpful to remove one or two cycles as well as save time and investment, especially in computer vision technologies that require heavy programming. Höysniemi et al. (2004) explains that “Wizard of Oz tests are easy to arrange as field tests and the method is an invaluable tool for designing computer vision based action games” (p. 33).

The lack of time is the main reason for choosing the Wizard of Oz methodology since this research is defined in a Master thesis context with very limited time. In this regard, paper prototype of the design is prepared for each tabletop and a person as Wizard is considered to play the actions of the tabletop interface. As the WOz prototyping allows for a true interactive experience without traditional programming (Molin, 2004), it is advantageous to perform the serious game without technical bugs and potential hardware and software problems. Another factor of this methodology is to trigger an analysis of interaction which leads to development of the new design ideas (Molin, 2004). Since using tabletops for collaborative learning of traffic rules would be a new learning approach in driving schools, and developing the systems require having several tabletops with specific applications, the paper prototype would measure the usefulness of the design in education and might add new design ideas to modify the game. Molin (2004) claims that this type of prototyping would endorse collaboration and practical dialogue among users and designers and also considers the role of user as a stakeholder in the development process.

Chapter 2. LITERATURE REVIEW

At the beginning of the research, it is required to understand the collaboration design factors in general and also in tabletops. Acquiring the knowledge about the state-of-the-art is crucial to design a collaborative learning activity which is new in education and also offers new ideas for the collaborative learning tabletops.

This literature review presents a brief overview of significant issues regarding the objectives of the study. This chapter tries to cover issues of computer supported collaborative learning (CSCL) in domain of serious games on tabletops. In order to place this research in the context of CSCL, the literature structure follows a logical sequence from issues starting with a justification of Collaborative learning and significance of serious games; then moving on to the concepts of tabletops and mixed reality in educational contexts. Issues relevant to principles of collaborative learning design are explored and the most recent collaborative learning designs on tabletops are introduced. The strengths and drawbacks of tabletops have been considered to realize what aspect and tools of collaborative learning design need to be highlighted. It should be noted that covering some themes such as existing driving games that are either speed games or learning driving by simulation is redundant here as the serious game objectives are very different.

Studying various samples of collaborative learning over tabletops is a key to understand how tabletops are used for collaborative learning and what is left to do in the field of research. Finally, to narrow the focus of this study in the CSCL design on tabletops, design issues of a collaborative serious game to learn traffic rules along with the relevant existing literature are discussed.

2.1 Collaboration and Serious Games

Lehtinen (1999) claims that preparing the learners for participation in a knowledge society is inevitable for education in the future. CSCL is one of the revolutions of modern technology that enhance learning and teaching. “Collaborative or group learning refers to instructional methods whereby students are encouraged or required to work together on learning tasks.” (Lehtinen, 1999, p.3) Traditionally, the instructor is the distributor of knowledge and skills while in technology-aided learning environments there is no direct transfer model (Harasim, 1990).

To define the collaboration in a deep theoretical framework and use it correctly in design process, it is necessary to understand the distinction between cooperation and collaboration, because in each, the role and participation of users in an activity is different. “Cooperative work is accomplished by the division of labour among participants. It is an activity where each person is responsible for a portion of the problem solving, whereas collaboration involves the mutual engagement of participants in a coordinated effort to solve the problem together.” (Roschelle & Teasley, 1995, P. 70)

Shah (2008) brings various definitions of collaboration, and tries to define the differences among collaboration, communication, contribution, coordination and cooperation since using the right term is usually confusing in this research area. He states that even dictionaries do not clarify these terms very well and people usually use them interchangeably. Communication is a required part of collaboration for changing information. Contribution is an informal relationship to help people to get their individual goals. Coordination is bringing parties together for a shared activity and goal. Cooperation is the same as coordination while the parties follow some rules of interaction. And finally collaboration creates a solution that is more efficient than total parties’ contribution (Shah, 2008). Collaboration is defined in academic context as of “faculty collaboration is described as a cooperative endeavor that involves common goals, coordinated effort, and outcomes or products for which the collaborators share responsibility and credit."(Austin & Baldwin, 1991, P. 22)

Shah (2008) discusses about the kind of collaboration which is actively carried out among a group of people and suggests guidelines for a CIS environment to reach a successful level of collaboration: There should be a way that users can communicate with each other; there should be individual contributions to the collaborative environment; all the participants' actions and responses should be coordinated to reach an interactive collaboration; by discussing and negotiating in the process, users must reach a mutual agreement or follow a set of rules to have a productive collaboration; and the system should allow users to negotiate their roles and responsibilities and assign authority, as well as exploring their individual differences.

Serious games (SG) is one of the effective ways in fostering education. By emergence of technology and computers in the field of education, and more and more familiarity with computer games, serious games is becoming famous as an innovative generation of learning technology. Marfisi-Schottman et al. (2010) define serious games as pedagogical multimedia products that help players to improve their scientific skills.

SG production is a long process starting from a conception phase that a mock-up model is built by the experts in the relevant scientific or pedagogical field, then follows to the production phase which designers and programmers build the first version of the serious game which is called prototype. Afterward, the prototype needs to be tested on a representative test group. This phase can be very long and consist of several cycles in order to correct the errors (Marfisi-Schottman et al., 2009).

Educational games like any other games can be designed for one player or a group of people. Designing a game scenario for groups that enable collaboration for problem solving, would engage students in a shares activity which in they discuss and share information to reach a satisfactory result. Combining the features of serious games that arise students' motivation with supporting collaboration can result in a successful educational outcome. In the following section, tabletops and mixed reality are presented as beneficial means of technology to facilitate collaboration among a group of people.

2.2 Tabletops and Mixed Reality

Digital tabletops have been popular for their rich interactive and collaborative features. Their multi-touch interfaces and their abilities to engage users in the group verbal and face-to-face communication are their strong advantages; accordingly nowadays many scholars use them for educational purposes. Schubert et al. (2011) explain that there is still a need to investigate about tabletops' potential learning outcomes and their use in various situations. Studying diverse collaborative models by tabletops shows the potentials of this system to invent new approaches. For instance Schubert et al. (2011) compare tabletops and traditional paper & pencil tools for concept-maps' generation and conclude that the tabletop-environment effectively supports knowledge transfer.

An example of a game on tabletops that is played collaboratively is based on STARS platform which combines the powers of traditional board games and computer games (Magerkurth et al., 2004). In this game the participants share relevant information on a tangible interface that facilitates natural interaction. The game table is the main element of the platform and provides dynamic game boards to feel the same way as the interface of traditional board games. Magerkurth et al. (2004) claim that the virtual game components offer very interesting opportunities to the traditional game design and deliver richer game experience compared to the traditional media.

Moving toward the abilities of tabletops toward mixing the virtual and real environments, it is profitable to explain about mixed reality. Milgram & Kishino (1994) claim that the next generation of telecommunication technologies move toward a mixture of an ideal virtual space and reality essential for communication. They consider mixed reality as a subclass of virtual reality techniques which comprise merging of real and virtual environments. Coutrix & Nigay (2006) define mixed reality as "an interaction paradigm that seeks to smoothly link the physical and data processing (digital) environments" (Coutrix & Nigay, 2006, p.1).

Mixed reality applications have been used in many contexts such as games, education, and a variety of applications that uses computer vision, as well as virtual and augmented reality techniques. Augmented reality (AR) "means to integrate synthetic information into the real environment" (Bimber & Raskar, (2005), p.2).

A system designed for mixed reality lets real objects interact with virtual objects on a computer screen. Dong et al. (2008) design a mixed reality game in which virtual cars interact with the virtual and real objects that represent barriers and hips. The virtual car is physically modeled and affected by the real objects for instance, crashes when it hits a real obstacle. Although this research does not bring the technical concerns of the design and just aims to provide the design framework, it is useful to explain some principles of the practical work to understand how mixed reality works and can be implemented in the design. Dong et al. (2008) discuss some technical issues to design a mixed reality game. For instance, the accurate tracking of the real object is required in such system. In this regard, the camera position and recognition is important. Another factor is correct modeling of physical interactions between virtual and physical objects. To do so, the real object would have a virtual identity that is rendered to simulate the interaction in the virtual space.

IncreTable is a sample of a tabletop game that uses mixed reality where real and digital world merge to solve various puzzles in the game. Players use the real and virtual domino tiles as well as virtual cars, and find this mixture entertaining. The study shows that users like playing with tabletop interfaces that facilitate mixed reality, additionally the interface is perceived as responsive and intuitive (Leitner et al., 2008).

2.3 Design

This section intends to provide an overview on research that is done on various designs facilitating collaboration on tabletops. A variety of design models and frameworks are suggested by researchers, and tools are introduced to foster collaboration. Studying the related works is inspiring for the serious game design for choosing the appropriate tools in order to reach a high level of group collaboration.

2.3.1 Collaboration Design in Tabletops

A study by Whitaker (2006) illustrates the features of tabletops and describes that one of the key features of tabletops is collaboration that attracted many researchers. He explains that users' performances can be enhanced by modifying the interface and interaction methods on tabletops. It is essential to understand how users collaborate and interact with each other on tabletops, as collaboration on tabletops has some aspects that researchers try to consider while designing the collaborative environments.

Smeaton et al. (2006) describe some of these aspects in a study of using a tabletop interface to search for videos. This paper provides the design factors for a Collaborative Searching on a Tabletop interface. Three major elements explained by the paper include: Task allocation for each collaborator, the degree of group awareness, and the degree of coordination policy.

Regarding the first element, when the aim is to use a tabletop interface for collaboration, careful consideration of the way the overall tasks should be allocated to each collaborator is necessary. It is helpful to configure how a general task can be divided to several subtasks and assigned to every user so as to reach the best level of collaboration. Smeaton et al. (2006) examine some allocation schemes considering pair collaboration. The collaboration is styled in some ways: a task can be finished partly by one user and passed by to the next user; two users can conduct all the stages in parallel; a hybrid collaboration which both users work together to clarify the topic and reach an agreement then they can separately execute the tasks.

The second element stresses on the fact that users must be aware of each other's situation in collaboration regarding both remote and co-located settings. Thus the design should offer a user the tools and features to increase his awareness of what the other user is doing. In a co-located tabletop setting, being close together physically make it easier to be attentive. For instance watching gestural manipulations like dragging or hearing distinctive sound effects when an action is triggered would raise the awareness.

The degree of coordination policy would help the users' actions become less conflicting while they are working on a shared interface. Furthermore, the degree of coordination can be verbally defined by users as they naturally want to divide their workspaces. In fact, group awareness would lessen the conflicts and enrich a better coordination of their activities (Smeaton et al., 2006).

Some studies have been done on the role of partitioning and tabletop's territories in a collaboration setting. Scott et al. (2004) clarifies the role tabletop's territories play in the collaboration process and coordinating their interactions. He names the proximity of tabletop collaborators as a factor influencing the establishment of tabletop territories. In view of the spatial and functional features of tabletop territories, he suggests some design considerations for the development of digital tabletop workspaces. To design such spaces, one should provide visibility (an action is occurring) and transparency (an exact action is occurring) of action. There should be tools to monitor other group member's actions which are performed on the tabletop to increase the awareness. Another factor to be considered in design is providing an appropriate table space. The size of tabletop must be considered while designing the personal and shared spaces. If there is not enough physical space on the tabletop, it would have an undesirable effect on the collaboration. For instance if there is a need to divide activities on the table among several people, the size should facilitate the space for coordination.

The third factor is to provide functionality in the appropriate locality. Based on the functionality of the activities, a proper territory should be chosen. For instance, a personal territory is useful for reading and writing, and it should be easily accessible by appropriate tools. Allowing casual grouping of items and tools in the workspace is another factor of design. Piles of resources should be mobile and easily accessible by collaborators. By casual grouping of content and tools, users can organize and manage their work better (Malone, 1983).

Designing collaborative interfaces for tabletops requires deep understanding of how groups coordinate their acts over a tabletop. Tang et al. (2006) investigates collaborative coupling which is the way collaborators are involved in each other's work. "Very generally, coupling refers to the dependency of participants on one another" (Tang et al., 2006, p. 1182) on the other hand "participants can be loosely coupled, where relatively few interactions are required to make relatively significant progress, or tightly coupled, where participants need to interact frequently relative to the amount of work that needs to get done" (Salvador, 1996, p.54). Tang et al. (2006) show that the choice of coupling style in a collaboration is related to the preferred tools, physical arrangement, handling of interference, and fluidity of work.

In small working groups of two to five people, the collaborators can shift frequently between individual and shared activities during a work session which is called engaging in mixed-focus collaboration (Gutwin & Greenberg, 2002). This kind of collaboration increases the group awareness and creates the possibility of tight coupling. Tang et al. (2006) offer some implications for tabletop design in a mixed-focus collaboration. For instance, systems should support a flexible variety of coupling styles since mixed-focus collaboration on a dynamic tabletop display includes a variety of coupling style. He adds “A promising future direction may be the convergence of physical and digital media on tables as an alternative means for providing individual and group views” (Tang et al., 2006, p. 1189). Additionally, there should be fluid transitions between coupling styles. Users should have several views of the workspaces to see what others are doing and have the recognition of interference. In this way they can decide to transit dynamically between loosely coupled independent work and tightly coupled group work. Another implication is to provide mobile high resolution personal territories. Having distinct displays for personal work would reduce overlapping of working areas thus the reduction of interference. Moreover, a system should support easy-creation and modifying annotations. Annotations are helpful to generate and track the individual work and enhance sharing the work (Tang et al., 2006).

2.3.2 Design Models

Schneider et al. (2012) try to enhance learning of phylogenetics through interaction techniques that support collaborative processes. They also offer some design principles of learning environments that blends both multi-touch and tangible inputs to foster collaborative learning:

- Engagement: the learning experience should be engaging by a stimulating story and attractive interface and interaction techniques.

• Territoriality: the users' possession of both physical objects and spaces on a tabletop should be reinforced by a learning environment.

• Opportunities for reflection: "…our system needs to provide various "reflection stages" where users can step back and articulate their discoveries as formal concepts" (Schneider et al, 2012, p.3074).

• Autonomy: provides automatic feedback to the students and give them a sense of control.

Kharrufa et al. (2010) suggests design guidelines of collaborative tabletop learning applications based on the design experiment sessions. These include five guidelines:

1. Encouraging externalization makes ideas visible to others and generates discussions among students, also it would help the teacher to evaluate the students' interactions and activities.

2. A rich set of cognitive tools must be available. There must be all sorts of required tools for various representations of ideas.

3. Having a structure to the task. Structuring would be helpful in 'think back' moments and help the users evaluate their activity and detect their mistakes.

4. Design for different ability levels: the application should behave based on the users' performance levels.

5. It should support reflection. Discussing issues over the reflection stage improves users' performance.

2.3.3 Tools

Digital Mysteries is a study based on iterative design that validates a collaborative interaction and learning application for school pupils. The study shows that digital tabletops features in building collaborative learning tools are more efficient than paper or computer based tools (Kharrufa et al, 2010). In this design, externalization of thinking and reflection is encouraged by the use of application. A set of cognitive tools is developed in design to make groups, relations, and the way students think visible. These tools include a grouping tool, a relation tool, and a post-it note tool.

A study by Dimitracopoulou (2005) explores the collaborative systems and describes the systems' tools and functions which facilitate the collaborative learning. These high-level functions are: the appropriate means for dialogue and action; the functions for workspace awareness; the utilities for supporting students' self-regulation or guidance (it would be in a meta-cognitive level); the facilities related to teachers' assistance (are necessary for children's education); and the functions related to community level management.

Dimitracopoulou (2005) claims that one of the central features of work in CSCL is the concerns over design trade-offs. In design there are many possibilities and it is not possible to bring all the features into one design; so there is always a decision-making considering the design trade-offs. Some of these important trade-offs correlated to the utilities of CSCL systems in designing of collaborative environments include: the means of dialogue can be chosen between free and structured dialogue, parallel and embedded communication tools, or text-based and oral dialogue tools. Another trade-off that has an effect on the students' freedom is the coordination of action versus dialogue. Also there is a choice between meta-cognition support for self-regulation and teacher support. The last choice is between an action-based or text-based system which influences the main features of the system.

To support and enforce the interaction regulation in the collaborative learning design, mirroring and meta-cognitive tools are used in the study by Jermann & Dillenbourg (2007). Group mirrors are experimented in collaborative problem solving in this study, which the tools involve a graphical representation of actions that dynamically updated and collaborators can see the changes. In this study, the mirroring tool is a kind of bar chart that shows the amount of users' interaction and conversations during the collaboration. "Mirroring tools simply reflect the collaborators' actions through graphical visualizations and leave the diagnosis of the quality of the interaction to the collaborators themselves" (Jermann & Dillenbourg, 2007, p.293). The authors claims that the indicators of the mirroring tool must be understandable and when they show that they are linked to successful completion of the task, they would help the probability of successful action as well.

Jermann et al. (2001) review the systems that are characterized by the type of interaction data and their feedback they provide. They explain about the mirroring tool as a device that display basic actions to collaborators, and meta-cognitive tool that shows the state of interaction via a set of key indicators. Jermann (2002) has developed a tool that shows the participation rate to the collaborators to regulate the traffic light tuning in a traffic simulation. In this tool there are two indicators; one showing the amount of messages and the other demonstrates the number of problem-solving actions. He claims that this tool can have a positive effect on users' meta-cognitive activities and encourage them to discuss and regulate their interaction clearly, thus a better coordination and problem solving.

In the following chapter the applications of design models and tools are considered in the design process. A selection of tools which are introduced in the literature review is implemented in the serious game design and provided with justification.

Chapter 3. DESIGN

3.1 Design Process

During the design process, two approaches were experimented for designing a collaborative learning task. The first one is to design a collaborative environment without thinking about what kind of task is going to be done. In this process, the aim is to focus on perspectives of collaboration in a group by utilizing tabletops. Four is the maximum availability of number of tabletops, and the model should be designed to make use of individual and shared spaces to perform a task. This approach is helpful to understand how various perspectives of collaboration can be favored by different situated models of tabletops and virtual spaces.

For instance the following model (figure n.1) is designed to show collaboration between two tabletops while having a shared space among four. Each person has his own individual space while there are also two shared spaces. The shared space among four tabletops is to find and share information about the task especially in the beginning; and the second shared space between two tabletops is to execute the task collaboratively. This approach was not successful as it could not support and offer solutions in the real life situation; although it was a good practice in the beginning of the process to consider collaborative design issues while designing a task.

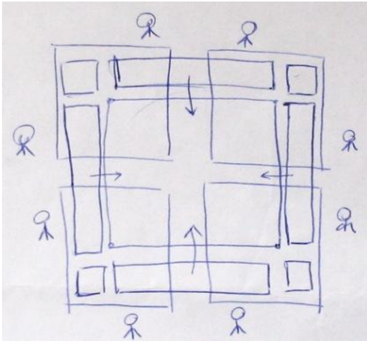


Figure 1. Individual and shared spaces in collaboration among four tabletops

Another approach is to think about a task or a subject to learn collaboratively at first, then design the tabletops' situation and spaces considering the task to reach the best model. The second approach was more of a success since having a goal as a subject makes the collaboration design more tangible. To come up with new ideas of collaboration design, it is tried to understand the features of tabletop which is profitable in collaboration and not obtainable by other means. It is also significant to recognize what sort of learning objective is reachable by means of tabletops.

One of the first ideas was to design a tabletop environment for collaborative learning of programming languages. But usage of tabletops is mostly appreciated for visual settings; it should be considered that tabletops cannot be suitable when heavy authoring is required. So we tried to think about areas that visual interaction has a main role like once users need to see a visual object and manipulate by hand. One of the areas that representation is important is education of traffic signs and how road signs regulate the traffic.

There are several advantages to take the idea of learning traffic rules as a serious game to design a collaborative model on tabletops:

- There is a potential for collaboration: people can learn traffic signs and practice them together; they can ask each other what a sign means and how to react toward a traffic or road sign. Thus, this kind of task can be considered in a collaborative problem solving environment. Also, designing a serious game would foster the users' motivation, therefore raising their collaboration.

- Designing a game which has a goal to learn traffic rules has been done for in various projects. The difference here is to offer a collaborative game in a classroom setting. The task of reacting to traffic rules perfectly matches with having it in the concept of serious games. Since people learn much better when they play because as they are engaged in an entertaining activity.

- Learning traffic rules requires visual and tactile reaction and perception. Also, tabletops' features are suitable for the designs that implement visual and kinesthetic learning.
- A combination of mixed reality and tabletops suits the game idea perfectly. This game considers moving a physical car on the tabletop as if the person drives it. This can engage the learners to move the car and the tabletop tracks the car in the virtual screen. Also traffic signs are physical tokens which users can situate them on the map and change them to regulate the traffic regarding the game goal.

3.1.1 Design Proposals

Here, various design proposals are described from the beginning to reach a satisfactory collaborative learning design. There has been sketch design for each proposal to be able to explore the strong points and drawbacks of each.

1. As can be seen on the sketch design (figure n.2), there are two tabletops, and one user on each tabletop (user 'A' and user 'B'). There is a map on each tabletop; also the small general view of the map on up-right corner. User 'A' task is to react to the signs that user 'B' selects for him; and user 'B' task is to assign the traffic and road signs correctly to the map. In case of any wrong action, both table screens will be locked and they are referred to a third interface to discuss and understand what the problem is. A multi-answer question would show up and ask them what the correct behavior in this situation is. The teacher monitors the situation on a forth interface and get the statistics of the students' answers. It will help to understand what the difficult subjects are so as to focus the teaching on.

   Aim of the game: Trying to have the least amount of mistakes during the actions and answering to the questions.

Advantages of this model: The idea of having signs and the car as physical tokens is very engaging (see section 2.2 Tabletops and Mixed Reality).

Problems of this model: The collaboration model is very weak; the game is more based on performing individual tasks than collaboration. There is no special need to have a third interface, as they can answer to the question on just a tabletop. Tabletops territories are not justified, on the other hand there is no justification to have two tabletops; it would be possible to perform over only one. Shared spaces are not considered as serious as private spaces. The game is designed just for two people with little collaboration.

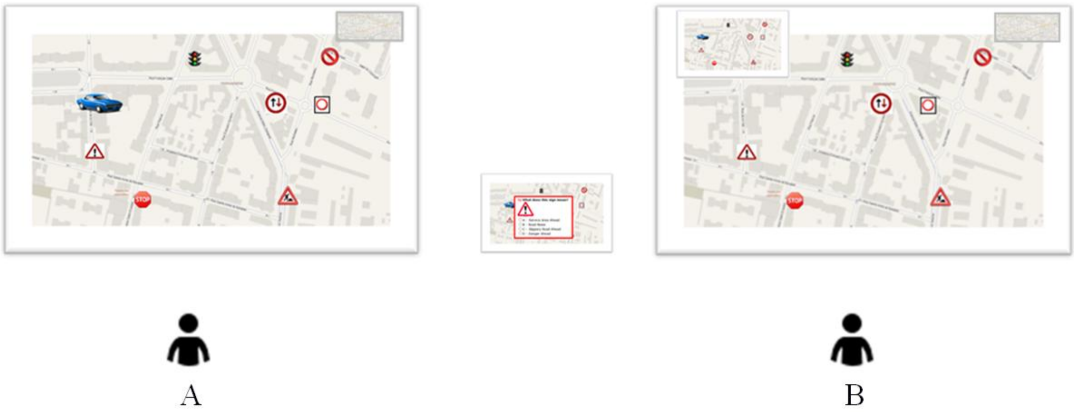


Figure 2. First design sketch

2. Based on the figure n.3, there are two tabletops and three users on each tabletop form a group (group 'A' and group 'B'). Each group performs their tasks collaboratively while they are competing with the other group. Group 'A' drives a car and reacts to the traffic and road signs which group 'B' assigns for them. The collaboration is to move the car and decide about its actions together. Each user has some buttons in front for handling the different actions (stop; accelerate to 30 or 50, turn left or right, U turn, etc.). To move the car properly regarding the signs, they must discuss and coordinate the specific actions; if they are not aware of each other's role and situation or do not get help from each other to react correctly, they will lose the game. Two or three people can fit in the group 'B', each managing a set of traffic signs. They must be aware of each other's actions and collaborate to assign the signs correctly to the map, otherwise they will lose.

Aim of the game: To make the least mistake (have the best result) in a limited amount of time.

Advantages of this model: There is a satisfactory level of collaboration in the game. Firstly, the team members must be aware of each other's capabilities and features; and secondly they all should behave coordinately. Like the previous model, physical tokens for the team 'B' are engaging for the users. There are both individual and shared spaces allocated for each user. Having two tabletops is reasonable since on each tabletop there is a different collaboration scheme and users would need a physical space to share their ideas and discuss far from their competitors. Including a competition as a goal to a game would motivate users to learn more and engage better to the learning environment.

Problems of this model: It is not justified how moving the physical tokens is integrated in the collaboration. It should be specified what exact features are to be considered in the game to enable correct reactions of the car (the buttons in front of each person).

Figure 3. Second design sketch

3. This design is more like a game with a competitive goal (see figure n.4). There are two tables including three users on each. Each user has a car and needs to follow the signs correctly to reach the goal of the game. The goal is to collect money from the banks of the city as much as possible. Both tables perform the same game and compete to collect more money than the other. The traffic and road signs are fixed but weather and light conditions, virtual traffic and the situation of pedestrians constantly change to examine the reaction of the drivers. On each table, there are

three cars that collaborate together to collect the most money possible. There is a time limit for the game, and that is the reason which forces players to react to the rules fast and try to understand and learn the rules via a dynamic collaboration. The cars are physical tokens to engage the users better in the game. Any mistake from the drivers would slow down their game by causing an accident or an intense traffic jam.

Aim of the game: To collect the most amount of money in a limited amount of time.

Advantages of this model: The goal of the game is attractive and engages the users in a tangible activity. The model of competition is clear and justifies assigning a table for each collaboration (based on the size of the tables and territory of shared activity). Changing the city conditions is an advantage for the players to experience more variety of rules. The factor of time is a good point and vital in driving since in real life situation, the driver must react fast to the road conditions.

Problems of this model: The personal space does not have a strong role in this design. The collaboration model is weak since they do not collaborate to perform a task (like the design n.2), but only coordination in collecting money and sharing their knowledge of traffic rules (see section 2.1 Collaboration and Serious Games).

Figure 4. Third design sketch

4. This design also illustrates a form of competition between two tabletops. Over each tabletop there are two users, each carries out a specific task (see figure n. 5). One has to move the car and react correctly to the rules; the other changes the current signs on the map to regulate the traffic faster and decrease the amount of accidents

in the city. The aim is to get to the destination with the least amount of accidents in the city. If the car does not react to the rules correctly, an accident will occur. There is also virtual traffic and pedestrians in the city like design n.3 as well as some accidents in the city at the beginning of the game. The role of the other player is to change the signs in a way that eliminates accidents. The other tabletop performs the same game and competes to get to the destination with the best result. To increase the awareness between two tables, it is better to design in a way that they know what the situation of the other is. So, there will be a space on the up-right corner showing the other table's interface.

Aim of the game: To get to the destination with the least amount of accidents in the city.

Advantages of this model: changing the traffic signs and rules considering the accident's elimination, is an innovative game feature. The user can practice the effects of road signs on the traffic regulation. There is a personal space that the users who handle the traffic signs, can browse the signs and look for their effects on traffic regulation. The collaboration is more about discussing in order to reach a satisfactory strategy to get to the destination.

Problems of this model: The collaboration over tabletops is not very strong; it is more of a cooperation than collaboration although they must agree to select a path which both spend their energy on; also they share information about the traffic rules.

Figure 5. Forth design sketch

5. The fifth model is to engage the users in urban planning, setting the location of the roads, bridges, and tunnels as well as regulation of the traffic by positioning the road signs. Users can practice the effects of traffic rules as part of urban planning. Following the figure n. 6, there are four tabletops, each tabletop for one user who is responsible for traffic regulation of one part of the city map. The traffic must be regulated based on the intensity of traffic and population in different parts of city. For example, there is more need for traffic solutions where the university is located on the map. Additionally, there is a virtual traffic and crowd that are visible on the map, and they will change based on the users' decision about the road signs and etc. The decisions must eliminate accidents and reduce the traffic jam. Collaborating is in the way that most of the decisions are made collaboratively since modifying traffic signs in one part of the city would affect the traffic in another place or all the parts. Thus, the users cannot perform a decision without receiving consent from their team members. In this way, there would be discussion, and they must be aware of what the situation is in the rest of the city. Many times it is mandatory to modify the rules in several locations at the same time to reach a satisfactory result. There is also a personal space for each user to try their plans on a test map and see the result of their action, this will be helpful to share more advanced plans with less defects in order to save time.

   Aim of the game: design a traffic model in the city collaboratively

   Advantages of this model: The game can be used in urban planning, also to modify the current traffic of a city to make the traffic smoother. The model has both personal and shared activity in a satisfactory level, and collaboration is expected to be dynamic. Research results of Jermann (2002) show that with a traffic simulator, co-occurrence of task and interaction regulation allow quicker problem solving, therefore better performance.

   Problems of this model: Traffic simulation and urban planning has been a study subject of many studies. For instance, Jermann (2002) explores a shared simulation that presents the traffic situation. The players need to tune a traffic-light simulation to diminish the cars' waiting time at intersections. Another study by Sugimoto (2004) presents a system that supports face-to-face collaboration in urban planning tasks. This system incorporates the personal and shared spaces by using PDAs for personal space and an augmented-reality sensing board for the shared one. So, using collaborative tabletops cannot be considered as a new area of research in urban planning. Additionally, the territory of the tabletops is questionable since the users standing on the north of the map would see the traffic signs upside down. If the location of the four tabletops is linear, the discussion and collaboration would be less dynamic; also increasing the awareness would be harder to achieve.

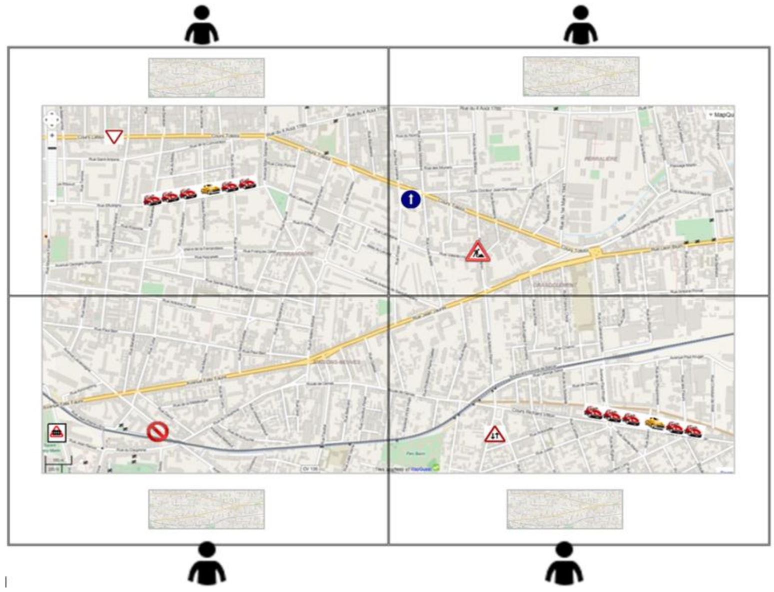


Figure 6. Fifth design sketch

3.1.2 Design Outcome

The ultimate model of collaborative learning game is a combination of three models above: second, third and fifth. Based on the advantages and drawbacks of each, the attempt is to adopt the positive features and make a more complete model. The collaboration model of the game is taken from the second design proposal since it provides a high level of collaboration. The game scenario is based on the third game competitive structure; because it would engage the users better to the game and motivate them to collaborate in order to reach the goal of the game. Territoriality of tabletops is taken from the fifth model; since utilizing four tabletops is considered as a better choice for our scenario. There are four groups over four tabletops; they cooperate two by two and each two compete with the other. In the picture (see figure n. 7), the group ‘A’ cooperates with group ‘B’, and it is the same for the groups ‘C’ and ‘D’. Additionally, team ‘1’ (including groups ‘A’ and ‘B’) competes with the team ‘2’ (including groups C and D). There are three people working collaboratively over each table of ‘A’ and ‘C’, and two people over the tables ‘B’ and ‘D’.

The scenario is the same for both teams, the goal is to collect the most money from the banks of the city in a limited amount of time and exceed the other team. On each map there is one car which has to respect the traffic rules and react to the road signs correctly to avoid accidents and collect the money very fast. Like the second design proposal, the way of collaboration is to move the car and use the features of the car (e.g. brake, accelerate, turn, and etc.) together. The group ‘B’ task is to help group ‘A’ by simplifying the traffic signs in the city and eliminating accident; at the same time they can change or add signs for the group ‘C’ and make their situation harder and more complicated. The interfaces of both groups ‘B’ and ‘D’ show the maps of ‘A’ and ‘C’; in this way they can modify, add, and change the signs of both teams. There should be some rules to decrease the interfering actions; for example, ‘B’ or ‘D’ cannot change the signs too close to ‘A’ or ‘C’ (while they are during the action). Moreover, when ‘B’ changes a sign, the new signs cannot be changed by any group under certain game’s rules.

Aim of the game: To beat the other team in collecting money in a limited amount of time.

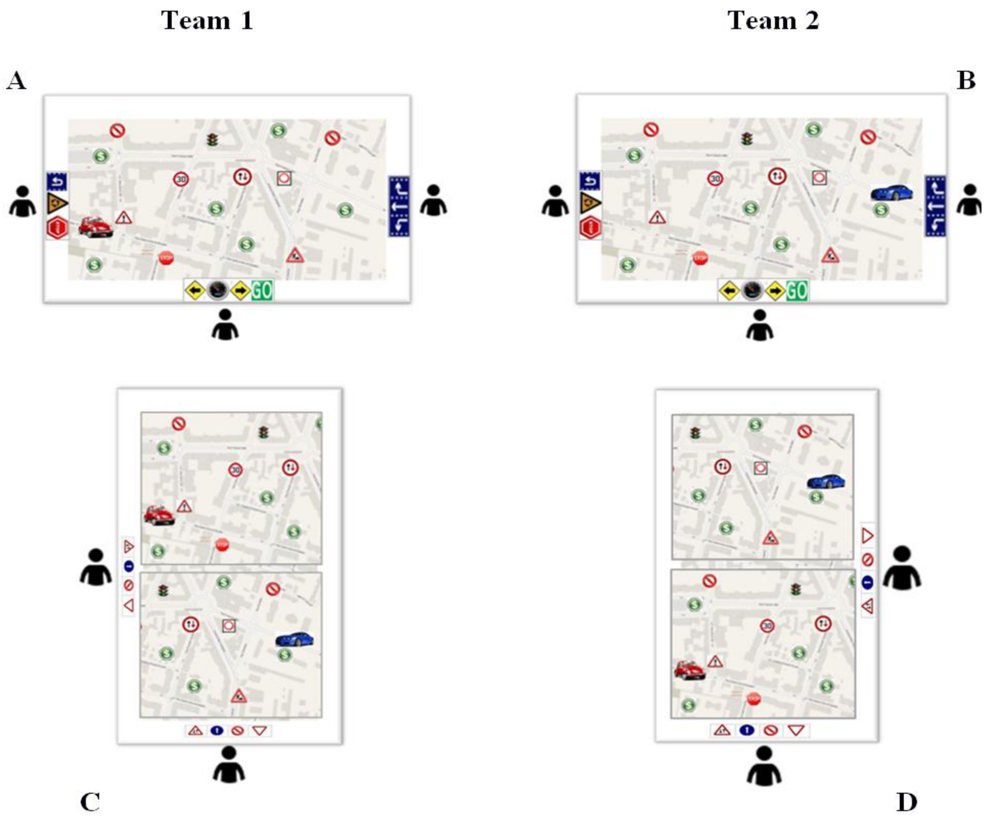


Figure 7. Final design sketch

3.1.3 Design Justification

The final proposal includes a good level of collaboration, an engaging scenario, and the territory of tabletops allows a good level of coordination among the groups. There are physical tokens to provide the features of mixed reality. Over ‘A’ and ‘C’ tabletops, the car would be a physical token and over ‘B’ and ‘D’, the signs.

Monitoring is possible for all users because there is enough visibility of actions over tabletops, and also they can see what kind of action is taking place so they have transparency of actions as well (Referring to section 2.3.1 Collaboration Design in Tabletops). Additionally, the personal space of each user is visible to his team members which raises the awareness, alternatively there is no private space which is not an issue in the goal of this game.

The size of the tabletop is: 46.2*61 cm; based on the amount of tasks to coordinate and divide, users will not run out of the working space. On the other hand, in a cooperative learning task small spaces are suitable for the group activities involving tightly coupled collaboration (see section 2.3.1 Collaboration Design in Tabletops). The amount of people assigned in each group on top of one table is well-thought-out based on the size of tabletops as well as the game coordination.

The system should provide a casual grouping tool or a simple management system to allow the users have an easy access to the piles of traffic signs, organize and utilize them on the map. The idea of casual grouping tool is inspired by Bauer et al. (2004) who has developed a pile management tool. In this design, participants are tightly coupled, since their actions are dependent on each other and they must interact frequently and dynamically to be able to react to the road signs. There is also mixed-focus collaboration involved to some extent because they have to switch between independent and shared activity although the independent activity here is not as intense as the shared one (for definition of mixed-focus collaboration see section 2.3.1 Collaboration Design in Tabletops). Independent activity here, includes browsing the signs or features and deciding what to choose.

The groups ‘C’ and ‘D’ have two shared views which they can see the shared interfaces of ‘A’ and ‘B’. Having several views on the table will enable them to have a tight coupling to their collaborator, and to interfere with their opponent. The game is mostly offering tight coupled group work rather than loosely coupled independent work. Users can search for indications of the signs in their personal space, but as they can share information and discuss, it is expected that they ask each other rather than searching for the information individually. There is danger of overlapping of working spaces between each two collaborative tables (e.g. Groups ‘A’ and ‘B’), design of the shared spaces must decrease the interference. For instance, if the car is close to a sign, that sign cannot be removed or changed by group ‘B’ or ‘D’.

3.2 Tools

The tools chosen for digital tabletops should eliminate the vague decisions of the users and help them to explain, discuss, and visualize their thoughts. For instance the grouping tool in Digital Mysteries (Kharrufa et al, 2010) asks precise information from the users. In a similar way for this design, by selection of this tool on the tabletop, a box would appear and all other interactions would be stopped to grab the attention of the users on one activity. In this way, when users decide to assign a sign on the map, the system appears a rectangular box and asks them to choose a category of signs at first and then assign the appropriate action (speed limit, danger, etc.). This box is to make sure if the user knows about the meaning of the sign or not. After the user chooses the category, he can put the physical sign on the map. In case the sign is not from the same category, the system would show an error. The error box appears also when the category is not well-chosen based on the location’s situation on the map. For instance, choosing category of speed in an intersection would show an error.

A warning box is necessary to explain users how they should move and behave in the game to eliminate the interference of the actions. For instance, assigning the signs on the map is not possible all the time; and players cannot change the signs close to the cars, because the users on tables ‘A’ and ‘C’ would be in the middle of discussion of how to react to the sign. So in case of an action to change it, a warning sign would show up to say that is not possible to change because it is too close to the Car! Also adding the sign is not possible in a location that a sign is just removed, as removing a sign is not possible when it is just added by another team. Also there must be the factor of time involved to inform them to wait some minutes in order to change the sign again.

Kharrufa et al. (2010) discuss that there should be some tools for the users to express all their decisions. Also to support reflection, there should be a tool to show the reflect from pushing a button by users on table 'A' or 'C' over the car. When the car moves to a sign, a user pushes a button to react to the sign for instance, pushing the stop button when reaching to the stop sign. To increase the awareness of others toward this action, a box will appear showing which user pushed the button by indicating a color; it shows also the feature of the button (stop), and the result: "correct, you can move" or "wrong, you cannot move for one minute!"

A post-it note tool exist for the users when they make a mistake and want to take notes of their mistake so as not to repeat it anymore; or when they make a decision but want to assign it later, they can use this tool. The tool is a small rectangle which has a keyboard and users can write notes or drag the virtual signs into it. The notes can be minimized or kept on sides of the map. "The post-it note tool aims to encourage students to record their thoughts for themselves and for others" (Kharrufa et al., 2010, p. 201).

As mentioned about the trade-offs in design (See section 2.3.3 Tools), based on Dimitracopoulou (2005) we decide to have the following selections for our design: the dialogue would be free, parallel as well as oral communication over and between the tabletops. The users spend time negotiating in free dialogue context and act based on their decisions. As the system is action-based as oppose to a text-based system, there is no means for a text-based communication.

The meta-cognition support is preferred here, as the system would show and gather all the users' responses and actions. The system shows the error and the reason the error happens; the students have an access to their action history, and improve their activity based on experiences and learning. The teacher's role (if the system is used in the context of a classroom) is to observe the results and stress on the problematic subjects for students in the theoretical and practical lessons.

As of the description about the group mirrors and meta-cognitive tools (See section 2.3.3 Tools), the visual representation on all of the tabletops change dynamically to update the collaborators. This design is inspired by the way Jermann & Dillenbourg (2007) measures interaction and collaboration with regard to the identifiability of individual performance; but in our design, this kind of tool is used to raise the awareness and motivate the users to collaborate better. In the design, there is a mirroring tool to show the users correct or wrong actions as a way of feedback (see figure n.8). Also the users can see how many actions are performed and how much money is collected. In this way, the collaborators can monitor their actions and their competitor's actions as well.

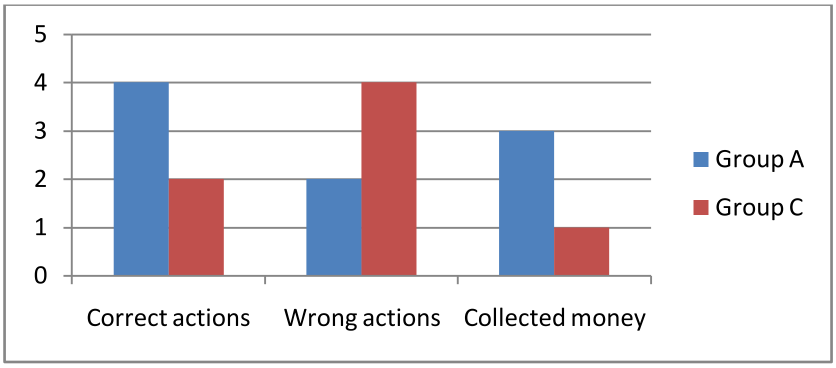


Figure 8. An example of mirroring tool based on the groups 'A' and 'C' actions.

In a kind of similar approach, the system collects the information about the groups 'B' and 'D' actions and relate them to the 'A' and 'C' decisions. This meta-cognitive tool would show how efficient the collaboration and problem solving decisions of groups 'B' and 'D' is. As it can be seen on the figure n.9, there are four groups of bars in the bar chart; the first shows the number of modifications that are done by each group 'B' and 'D' for their team members ('A' or 'C'), the second shows how well these modifications are treated by their collaborators ('A' and 'C'), the third shows the number of modifications that are done by 'B' and 'D' for their competitor team, and the last shows how challenging their signs was for their opponents ('A' and 'C'). The hypothesis for existence of this tool is that the representations inform the groups 'B' and 'D' how their activities are efficient, thus improve their decision-making and collaboration.

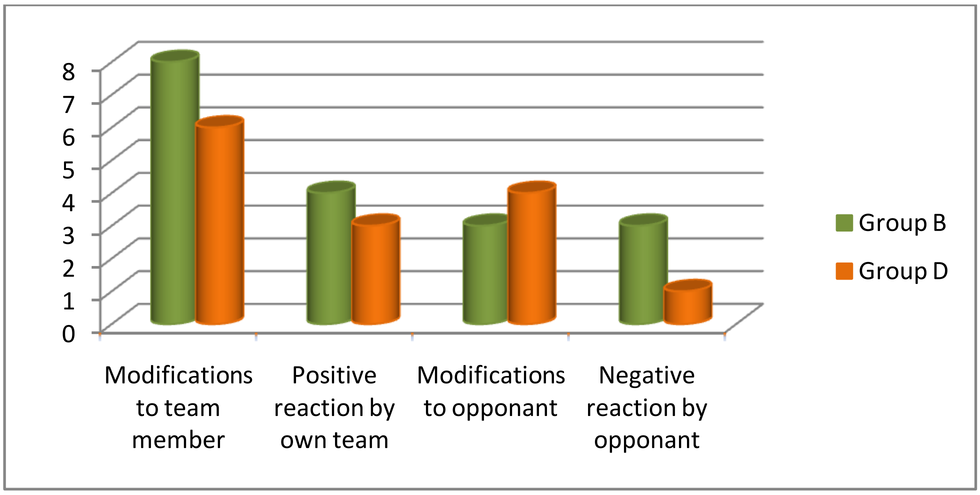


Figure 9. Meta-cognitive tool based on the groups B and D actions.

The difference between the first and second set of columns show how well or bad is the collaboration among the groups in a team.

3.3 Paper Prototyping and Design Tests

Before the main prototype experiment which involves many people, several design tests are done to identify the interface problems as well as the game rules to eliminate the overlapping of actions and interferences.

Figure 10. Design tests

The reflected rules are partly the rules of the game, but some rules are added to adopt the game to the paper version. For instance, as individuals play the role of the computer to test the prototype, factor of time is important. After each action, we need some time to synchronize each and every action to the other tabletops.

Another decision is to modify the game to a turn-based version. Since firstly, it is too complicated for users to know about each other's actions if there is no turn involved; and secondly, this way would give more time to users to think and discuss about their actions and learn from each other. It is also considered that in the future technical design, programming of a turn-based game is much easier than a real-time game.

In this prototype, the map is considered as an inside city map which 30 or 50 km/h are allowed as speed limitations. To be able to represent the speed and distance, the paper prototype uses a ruler to measure the distance a car moves while it is in speed of 30 and 50 km/h. The same tool also shows the distance users can put the signs on the map further from a car. In the digital game, there would be a physical car and a virtual car which is synchronized with the physical one; and the computer put a virtual barrier by measuring the distance the car can go, which here the ruler plays this role. After several design tests, the physical size of the ruler is identified to provide a balance in the game flow (6 cm).

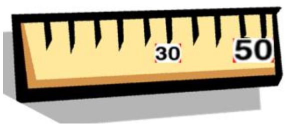


Figure 11. A ruler to measure the distance for 30 and 50 km/h speed.

It is revealed in the tests that distance measurement by users utilizing a ruler cannot be very precise. Especially when the car turns to various directions, measuring this distance is time-consuming and not very precise. This problem will be solved in the technical design since the computer's measurement would be accurate.

One of the difficulties is that many times when a sign is put on the map, it is not clear for which road it is assigned to, and in which direction on the road; so changing the signs to the smaller ones, and having wider roads would eliminate the problem. In the paper prototype test, the person who assigns the signs can explain about the exact location of the sign as well to lessen the complexity of the game. Since the participants are from France, the signs and rules in the game are based on the French traffic rules.

In the design tests, the efficiency of the various signs is tested and the most challenging ones are selected which needs the driver's reaction. Additionally, the selection is based on the signs that are applicable inside the city. There are two set of signs on the map, one is informing signs which are mainly used on the map before the game starts. The users should know about their definition but there is no necessary reaction toward them; like the signs to inform about the possible dangers. There are signs that users must react to them which are mainly kept for the users to assign them on the map. These signs are vital to help or impede the users to reach the aim of the game. A combination of fifteen signs is selected for the prototype experiment that includes a selection of direction, prohibition, and priority signs. In the real digital game, all the signs would be available but in the prototype version it is required to test a set of signs with clear rules for the computer to make the test feasible and eliminate the confusion.

A limited number of signs is considered for each team to simplify and reduce the time of the game, to eliminate the repetition of signs by users, and to make the game interesting and challenging. Testing the game before the experiment was very helpful to show how many of each sign is appropriate for the game. For each physical sign the exact replica is considered on the paper to show the virtual representation that will assign by the wizards. The chosen signs including their amount are shown in the following figure:

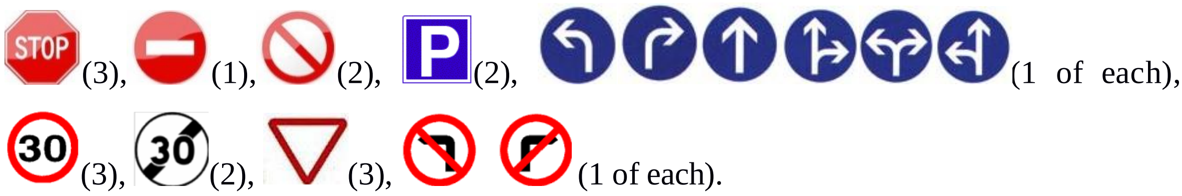


Figure 12. A selection of traffic signs for the game.

In the beginning these signs were considered: , but later they were taken out because if a user decides to put one of them in an intersection, he must put four of them at the same time on different sides of the intersection while in each turn putting just two signs is allowed. This sign 

is removed because the standard limitation is 50 km/h inside the city, so the sign would be redundant. During the design tests, the direction signs showed a lot of interest and challenge, as the user had to think and discuss where he put the sign in the intersections.

Some signs are chosen to put on the map before the game starts for the decoration and to show the users how the signs can be located; they are mostly warning signs that users do not need to do anything while passing them, or just slow down to be careful. Users cannot change these signs; if they try to do so, the computer will warn them.

In addition to find the most useful signs for performing the experiment, the relevant buttons to react to the signs are also defined. On each table there are eight buttons that are shared between the collaborators. These buttons are indicated in the following figure:

Figure 13. Buttons for car movement on the tabletops.

The ‘Slow down’ button is for the time that there is a possible danger or there is no priority for the user. There is no ‘Start’ button since the buttons for speed is considered as starting the car and moving in this precise speed. U-turn movement is considered to take one full turn in order to have a better flow in the game.

The banks should be considered as a drive-in kind of place since the cars must be in the same side of the bank to be able to drag the money. A simple way to represent dragging money from the bank to the car in the paper prototype is to represent the bank with Euro sign on the map, that user can just pull it down to his side with a finger point. When one table drags the money from a location, the same money on the other table vanishes.

The winner at the end of the game is the team with the most money and the least errors. To calculate the result of the game and identify the winner, each two errors would reduce one value from the money, and the winner would be the one who has the most money after the calculation.

There are two sets of game rules perceived from these tests; the one that computer must react based on (which will be programmed in the technical design) (see appendix 2), and the rules that users must know to be able to play the game correctly (see appendix 1). These rules will be printed and hand in to the users for the prototype test.

There will be a book of traffic rules in the day of experiment that users can find the information and rules they need. The book plays the role of individual space to search the information.

3.4 Simplifying the Design for Experiment

The tests which are done before the experiment, showed the complexity of paper prototyping and offered solutions for the experiment to modify the rules and simplify the design. Regarding the challenges experienced during the tests, it is tried to make the paper prototyping for a simplified version of the design. It is considered to build the paper prototype in a way that covers the main features of the game design and also it can be examined easily in the experiment. It will be explained in the section 4.1.2.1 Limitation of Sampling that the amount of people willing to participate in the experiment is very limited, which this is another reason for simplifying the design. For examining the original design, sixteen participants are needed while just nine appropriate samples can participate in the experiment. The paper prototype made for the experiment is considered for two tabletops rather than four, but performs the same aim as the original design while implementing less amount of people. Five banks is decided to be located on the map to make the game shorter, also teams cannot have equality for the amount of money.

In the experiment prototype, it is decided to have a mirroring tool and leave the meta-cognitive tool for the digital version of the game, since tracking the actions and calculate their reflection at the same time is too complicated in the context of paper prototyping. The mirroring tool here, is a simple bar chart that shows the amount of errors committed and money taken by each team. The mirroring tool is visible on the bottom-left corner of each tabletop (see figure n.14).

The following sketch (figure n. 14) shows the organization of tabletops and participants. Based on the original design, there are two groups that compete with each other. Each team's members collaborate together to reach the best result. There are three players and one wizard on every tabletop. 'D1' and 'D2' are drivers and SI is the sign indicator.

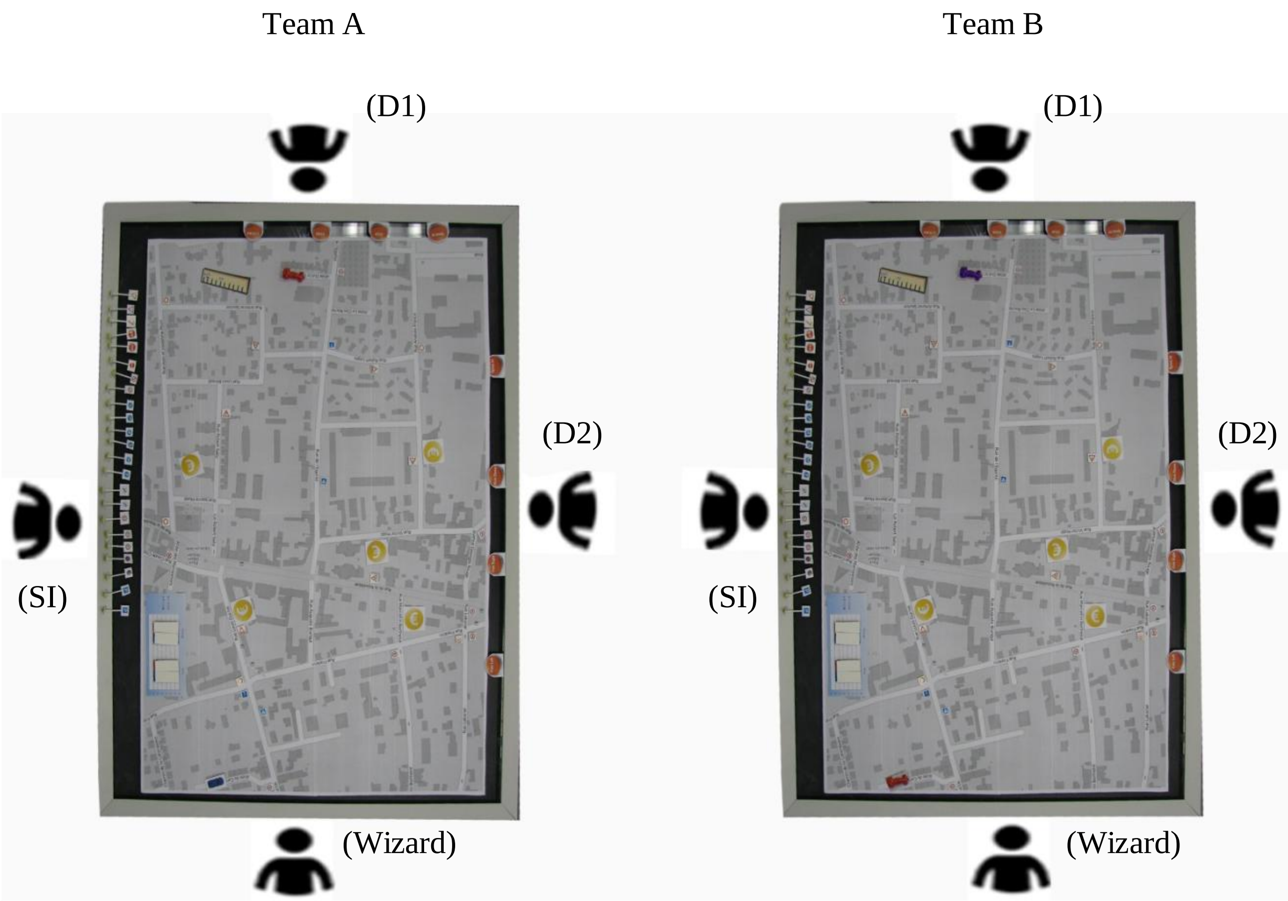


Figure 14. Final design sketch for the experiment

'D1' and 'D2' around each tabletop are responsible to move the car and react to the signs, and the 'SI'(sign indicator) is responsible to assign the signs on the tabletop. So the roles of tables 'A' and 'C' in the original design are merged here over one table. The forth participant is a wizard who must react as computers and reflect on players' actions.

As the experiment is done based on the Wizard of Oz methodology, the Wizards on each tabletop must be aware of all actions of tabletops, and that is quite complicated when human is involved instead of a machine. That is why the proposed design for the experiment includes two tabletops and just two wizards will be exchanging information about their players. One of the challenges revealed in the tests shows that it is very difficult for the Wizards to take care of all the actions over all the tables and change at the same time on its own table. Changing the game to turn-based is a huge help to give time and care to the Wizards; but still there is a possibility that they make mistakes and cannot see and change everything in the game. Another consideration is that the tables should be close to each other so that the Wizards can see the changes on the other table and change on their own. In the real game on digital tabletops, the location of the tabletops would be far from each other but for the paper prototype experiment, we have to arrange the tables in a way to reduce the complexity.

Chapter 4. EXPERIMENT

This chapter presents the methods of study, results from analysis of the data collected during the experiment, and discussion to summarize the results. The data analysis is organized to discuss topics of research questions. Regarding the aims of our serious game design, three major topics are extracted from the questionnaires, video records, and observation notes. The results from the experiment examine the hypothesis of this serious game design regarding supporting collaboration, facilitation of learning, and validation of design. Before exploring the results of experiment, this chapter begins with a brief overview on the method and participants of the experiment and how data is collected. Those background information of participants which are helpful in the analysis is described; additionally the players are coded by their role and team's name to be able to quote their statements in data analysis in order to support the main themes. The following pictures show the tabletops arrangement for the experiment (see figure n.15), the small box on the tabletop contains the signs that wizards will use during the game.

Figure 15. Pictures of experiment organization.

4.1 Method

This section aims to introduce how data is collected, give thorough information about the participants and sampling, as well as the procedure of the experiment.

4.1.1 Method of Data Collection

Observation and questionnaire are the methods of data collection for this study. The questions are designed to collect both qualitative and quantitative data. Most of the quantitative questions request answers in a scale from ‘A lot’ to ‘Not at all’. The means to report the quantitative data is descriptive statistics since the number of the participants is limited. The data from observation is reported qualitatively regarding three aims of the experiment: exploring collaboration, learning and design.

4.1.1.1 Questionnaire

There are two kinds of questionnaire; one is pretest-posttest questionnaire to see if the game facilitates learning or not, and the other has diverse questions to collect data about the game design, collaboration, and learning. The following sub-sections explain about both kinds of questionnaires and a pilot test before the experiment.

- Pretest-Posttest Questionnaire

The pretest-posttest questionnaire aims to measure the participants' learning about traffic rules. The questions on both tests are the same; pretest is given to the players of the game before the experiment, and the same is given after the experiment as a posttest to compare their answers and examine learning (see appendix 4). The questions for the pretest and posttest are adopted from the normal traffic rule exams available on the Web (Driving test sample, n.d.). There are eight questions which four of them are control questions and not relevant to the traffic rules presented in the serious game. While the other four are relevant to the traffic rules the players deal with during the game. Comparing the results of the pretest with posttest will show whether the game has a learning role or not.

- General Questionnaire

Another questionnaire is given to the players after the game in two forms. One form is for the users who drive the car and the other is for the user who put the signs. There is no need to provide any questionnaire for the Wizards because the research does not measure the Wizards' collaboration and learning since they play the role of computers. The questionnaire aim is to measure the collaborative learning of the users and validation of design (see appendices 5 and 6). There is a section on questionnaires to ask about personal data that includes the name, age, and driving experience; to relate all three questionnaires done by one person at the end for the data analysis (pretest, posttest, and questionnaire). This is followed by three sorts of questions in both questionnaires; the questions referring to the serious game design (n. 1-7), then the questions considering learning (n. 8-10), and the rest refer to the collaboration (n. 11-16). In the data analysis, the results of questionnaires along with the observation are discussed exclusively and conclusions are drawn based on both data collection techniques.

- Pilot Questionnaire

After the questionnaires are designed, a pilot test is done to be sure that the questions are understandable, and the participants can answer them clearly. Before the experiment starts, a person who did not participate in the game read the questions and tried to answer them. The result from the pilot test shows that questions are clear, although there are some words need to be defined for a non-English speaking person such as Carriageway and cross street. Additionally, it should be noted to respondents that the multi-choice questions of pretest-posttest questionnaire might have more than one correct answer. There were some more suggestions to make the questionnaire easier to answer, like assigning numbers to the signs of the question number ‘2’ on the general questionnaire in order to ask the participant to just indicate a number rather than draw the sign.

4.1.1.2 Observation

During the experiment, the participants’ activity is recorded by two video cameras and photos are taken by a photo camera. Notes are taken in six stages, each ten minutes is resumed in a separate log to be able to analyze the participants’ performances through time.

Since there are two tabletops and nine participants involved, it was difficult to take notes of all actions. The observer had to go back and forth between the tables as the tabletops were located separately; thus, it was not possible to take note from all of the activities and conversations. Part of data is collected in the time of experiment and part of the analysis is done by watching the videos afterwards. During the observation, the notes are taken based on the signs of collaboration, learning, challenges, and design issues. These indicators are used later for data analysis to address the research questions.

4.1.2 Sampling Strategy

There are nine participants in the experiment. Six of the participants play the game and two play the role of the Wizard on each tabletop. One of the participants controls the Wizards to adopt all the rules of the game. As it is observed in the design tests of the game and explained in section 3.3 Paper Prototyping and Design Tests, there are many rules in the game that remembering them even with the written rules in hand is very difficult and confusing for the Wizards. It would be better that the Wizards practiced the game several times before the experiment to learn all the rules but due to the time limitation it was not possible. Instead, a person who participated in former tests of the design and was aware of the situation was chosen to control and guide the wizards during the experiment. The experiment shows that this decision was very appropriate because in this way the researcher had time to do the observation, take notes, and make right decisions based on the game situation.

4.1.2.1 Limitation of Sampling

The samples are students and researchers of INSA de Lyon who were in contact with the author of the thesis. The ideal sampling for the test would be to determine students of a driving school for testing the prototype because they are in the learning process of the traffic rules and would play the game as part of their education; in this way, their collaboration would be in a real context. But due to the constraints of this research, it was not possible to find the ideal samples. Although it is tried to involve the samples who do not know driving or they are in the process of learning in the 'Driver' role which move the car and react to the signs.

Lack of time is another limitation for identifying the population and sampling process. For further research, it is suggested to identify the samples from a driving school. The language barrier is another constraint that affects the sampling process. Since the country the research is taken place is France but the research is being done in English, the samples should have a good level of English; that is why the samples are taken from the students and researchers of the university. Even with the good level of their English language, during the experiment sometimes participants switched to the French language and the researcher had to remind them to talk in English. Specially, when there was a challenging situation in the game and participants were excited to discuss and play, switching to French was unintentional and out of control as it was more comfortable and efficient for them.

4.1.2.2 Background Information of Participants

As mentioned in the sampling section, there are six players in two teams. Four of them act as drivers and two as indicators of signs. For the selection on who drives and who puts the signs the fact that they have driving license or not was considered. It would be preferable that for the experiment there are at least four participants without driving license who play the role of the drivers, but unfortunately due to the limitations of sampling, it was not possible. The personal data asked on the question form cover name, gender, age, driving license, and driving experience. Part of the personal data is taken as to relate several questionnaires of one person for the data analysis. Here, for participants' identification, they are named by their group and their role so as to follow their activities in various levels of collaboration, learning, and design interaction. Since the amount of participants is very limited, age and gender does not play a role in the experiment's results. The following table shows the participants' information that is necessary for the data analysis:

Background information	Driving license	Driving experience
Team A, Driver 1	Yes	7 Years
Team A, Driver 2	Yes	8 years
Team A, Sign indicator	Yes	14 Years
Team B, Driver 1	No	
Team B, Driver 2	Yes	17 Years
Team B, Sign indicator	Yes	10 Years

Table 1. Background information of participants

4.1.2.3 Ethical Considerations

To invite the participants to the experiment and receive their agreement, an email was sent to ask for their participation. Additionally, to inform them about the ethical issues, a letter of consent for participation in research was signed by both participants and the researcher. The letter of consent informs the participants about the confidentiality of the information collected and protecting their identity (See the letter of consent template in appendix 10).

4.1.3 Procedures

The experiment uses the Wizard of Oz methodology to justify the design. As the serious game design is based on collaborative learning on table tops, the experiment needs two Wizards to act the role of tabletops (See section 3.4 Simplifying the Design for Experiment). Examining how drivers (four participants) and sign indicators (two participants) collaborate while playing the game and learn from each other is the main aim of this experiment.

The time for the experiment was considered as two hours. 1:45 minutes for the whole experiment, and 15 minutes in case there is a lack of time. The itinerary of the experiment from the beginning to the end is as follows:

- 10 minute: Pretest
- 20 minute: Explanation of the game and rules to the participants
- 1 hour: Playing the game
- 15 minute: Posttest and general questionnaire

Each player and wizard has a copy of relevant rules to refer to if needed during the game (see appendices 1 and 2). And the summary of the rules was printed in A3 size and hanged on the wall to remind the major rules to the participants while playing the game (see appendix 3). These rules are described in full context in section 3.3: Paper Prototyping and Design Tests. In addition, a video camera is installed on top of each tabletop to record the experiment.

During the experiment, several rules were changed based on the participants' performances which the reasons are described in the section: 4.2 Results. The main change in the experiment's organization is limiting the time of each turn since the time of the experiment was limited and participants took a lot of time for discussion and making decisions.

4.2 Results

This section presents the results analyzed from questionnaires and video records of observation as well as the observation notes. The results are coded and represented to address the research questions of this study. The tables of codes are available in appendices 7, 8, and 9. The data collected from experiment is analyzed in order to examine three objectives of the study. Firstly, to see if the serious game supports collaboration; secondly if the game facilitate learning; and thirdly if the design of this serious game on tabletop is well justified for the experiment.

4.2.2 Supporting Collaboration

Regarding collaboration, at first interviews are coded and the results are presented, then the indications from observation are discussed (to see the codes from questionnaires regarding collaboration refer to appendix 7). The results from questionnaire show that all of the participants found the game collaborative. Five player stated 'A lot', and one checked 'A little' for the level of collaboration. Majority mentioned that they had a lot of discussion with their team members, and collaboration was very efficient in their team. Among them, one stated this level as 'Average'. Five of the collaborators believe that it is more efficient to play in a team rather than alone, just one player stated the contrary. There were a few or no misunderstanding among the team members concluded from their answers.

The observation showed that the game collaboration is very efficient. The players were collaborating the whole time during the game. This collaboration mostly included the discussion about building a strategy in different levels of the game, advising each other to choose an appropriate sign, asking about meaning of traffic signs, and understanding the game rules. In the first half of the game, discussions among collaborators were very long in order to decide what to do with no mistakes. In this way, both teams had a few progress in moving the car in the first thirty minutes. Observing the slow progress of the cars led us to set a time limit for each turn.

Here, it is valuable to explain various sorts of collaboration by samples from the observation. Most of the collaboration was to decide about location of the signs on the road, construction of a strategy for next moves in the game, learning the traffic rules and road signs, and understanding the game rules. Although, majority of the conversation was surrounding the strategy of sign allocation on the roads to limit the opponent team rather than moving the car and pushing the buttons.

Regarding the collaboration over constructing a strategy, the participants started to discuss about the possible actions even before the game starts. For instance team ‘B’ members discussed about a strategy to get the most money possible and agreed on a path covering majority of banks in the game:

> Driver ‘2’ in the team ‘B’ shows the path the opponents have to take by their sign choice: “They can go there (pointing to the map with three banks) but what we want is to make them go here (pointing to the part with two banks). So we should put a turn right sign on this intersection and turn left on the other intersection.”

There was almost no silent moment in the game. The players were saying their decisions out load; even when they were performing the actions, they presented with gestures and voice:

> While pushing the button turn left, one of the ‘B’ members made the sound of turning by mouth then said “speed 50” out loud while pushing the button.

Many times the players asked each other if their decisions are helpful or not, and if their team members agree with their suggestions:

> “…and we have to think about annoying them (the opponent)...should we put the sign right now or wait to see what they do first?” (Driver 2, Team B)

And sometimes, they disagreed with their team members:

> “we will put this sign here and there, oh but next turn they will put a sign that does not allow us to go there so we go here” (Driver 2, Team B)

> ”No! we have to wait one turn to remove one sign here!” (Sign indicator, Team B)

During the whole game, both teams were busy discussing. Even when it was not their turn, they talked what they could do the next turn. Additionally, they were estimating the other team’s actions and tried to think about future turns:

> “they will be here the next turn (pointing at the map)! when they remove this sign, we should move a sign near the bank” (Driver 1, Team A)

One part of collaboration was to help each other understand the rules of the game and remind what actions should be done. Samples like the following conversation was repeated many times:

- Driver 2, Team B: “We cannot remove this sign”
- Sign indicator, Team B: “Yes, we can move it!”
- Driver 2, Team B: “No, it’s too close to the car!”
- Sign indicator, Team B: “Oh yeah!”

Although each player had a specific role, during the game they considered all the roles as a shared responsibility. For example, everyone in a team was giving opinions about where signs should be located or what button should be pushed:

> “…so maybe we can put a sign here to slow them down?” (Driver 2, Team B)

Also, they were reflecting on each other’s roles, like one driver pointed at the button on the side of the other driver to show he should use that one. One of the interesting points in the observation was that the players were totally aware of the game flow of their team and also the opponent team. Whenever they hesitated and did not understand what just happened, they tried to figure out by asking from team members, wizards, or even looking on the opponent’s map. “we have no more of this sign left, so we cannot do that” which this sentence shows awareness about the signs in front of their team member. And this quote shows awareness toward their competitor: “You are cheating! This is more than 50 distance!”. Even sometimes the players made the wizard aware of a situation: “now you should move the virtual car” (Driver 2, Team A to Wizard A)

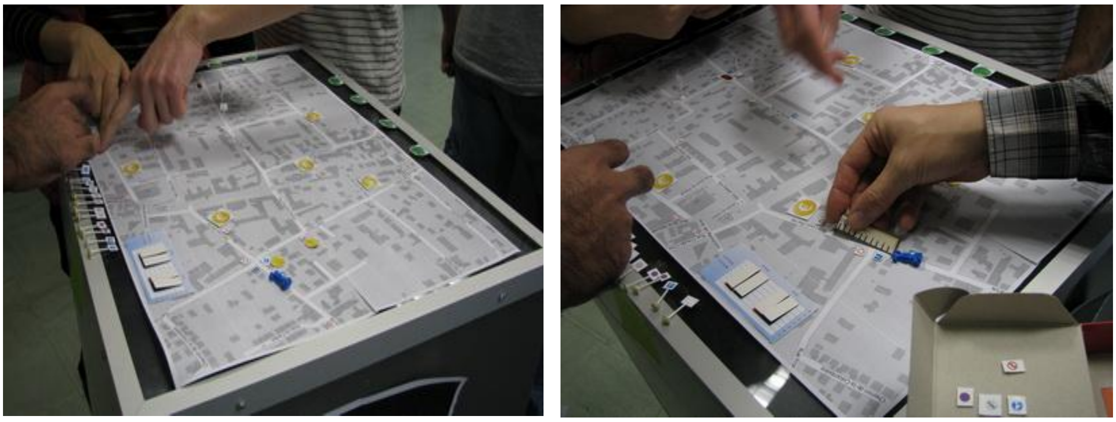
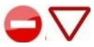
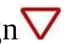


Figure 16. Pictures of experiment collaboration.

4.3.3 Facilitation of Learning

In this section, the results from the learning questions are described completely as they are relevant to the traffic rules presented in the game, so both differences from the pretest and posttest as well as their mistakes are taken into account in the data analysis. If players made an error in pretest and make the same error in the posttest, it means that they did not learn the rule from the game. In the pretest-posttest questionnaire the answers toward the control questions are not considered in the analysis, just the difference is considered to see if the user answered to the questions carefully or randomly. The learning questions aim to see if the users know the speed limit inside the city and also the definition of these signs:  .

The results of the pretest-posttest questionnaire show that the game facilitates learning. The comparison between the answers of pretest and posttest declares that four players out of six learned more about the traffic rules and the traffic signs indications. Two players learned that the speed limit inside the city is 50 km/h while they answered wrongly in the pretest. And two players learned about the meaning of the priority sign . The pretest-posttest questionnaire has a limited amount of questions and cannot examine all the teaching and learning features of the game, although these samples show that this game has the learning ability.

There are two cases that the players answers incorrectly to the posttest questions, which it can mean that the game was not efficient to teach them about these particular traffic rules: one of the users answered correctly regarding the sign  definition in the pretest, but in the posttest committed a mistake. Another user did not learn the definition of sign since indicated the action (slow down) rather than the definition (give way) in the posttest.

There are some differences for two of the users' answers toward the control questions, one difference among four questions for one of the users and two differences for the other. Additionally, there was no possibility to assess the learning results of one user since this player could not participate in the first twenty minutes of the experiment and did not fill out the pretest. With all the explanation given above, it can be considered that these drawbacks are negligible to report about the learning possibilities of the game. As mentioned above, there are enough clues to conclude that the game can facilitate learning.

To have a thorough conclusion about learning ability of the design, the learning outcomes of the pretest-posttest is merged with the results of the general questionnaire and observation. The general questionnaire asks the users' opinion about the learning ability of the game. These questions cover their opinion about scale of learning, what they have learned during the game, and how helpful they find the game in driving. Three players indicated that they learned 'A bit' and two players learned 'Average'. Just one of the users indicated 'Not at all' followed by:

"I don't say learn but remember!" (Sign indicator, Team A)

This sentence is a good remark to refer to the background information of the users. Since five players already have a driving license and years of experience, this sentence shows that for most of them, playing the game was to remember the rules that they learned before. In the same way, the team 'A' driver stresses:

"I just didn't remember this sign:" (Driver 1, Team A)

And another team member answers:

"Nothing (I did not learn anything). I remember some signs that I don't see in everyday life." (Sign indicator, Team A)

Regarding the helpfulness of the game in driving, three players said the game is a bit helpful and three mentioned average. It is expected that if the participants were from a driving school students who are passing the driving courses, their learning level would have increased much more than our participants. For instance, the driver ‘1’ of team ‘B’ with no driving license indicates that she learned “The signs of driving” during the game. Additionally, driver ‘2’ of team ‘A’ mentions that “Signs placements and few road signs” were learnt.

The indications perceived in the observation confirms the participants statements in the questionnaire. Players discussed about the meaning of the signs and traffic rules during the experiment. For the participants who do not know the traffic rules, the discussion might be more about the meaning of the rules rather than developing strategies to win the game. For instance, the participant with no license asked many questions during the game regarding the signs’ indications:

> Driver 1, Team B: “What is the meaning of this sign?
>
> Sign indicator, Team B: ”If you put this sign here you cannot go to this road!”
>
> Driver 1, Team B: “What is this sign?”
>
> Driver 2, Team B: “Speed breaker, if you go too fast you will (have gesture like jumping a car) so you must be careful!”

This sort of conversation was repeated by other players as well. Questions about the priority sign, no enter and no stop sign, application of speed limit 30, and in general the appropriate location of signs on the road were observed. There was also questions regarding the car actions and using the buttons:

> Sign indicator, Team B: “When we will use the speed 30 (button)?”
>
> Driver 2, Team B: “Oh, maybe when we are here (pointing to a pedestrian sign), when we are close to children. Or when you have something like that (pointing at a sign) you have to slow down!” (Driver 2, Team B while pushing the button)

Each team committed an error during the whole game. The red team had an error from putting the sign incorrectly and the blue team put a stop sign in the middle of the road. Although there was a book of traffic rules available for the users, no one looked through, and they preferred to ask each other about the traffic rules rather than finding out individually. Sometimes the wizards explained about the meaning of the signs to the players and if they can put it on a specific location or not. This shows that a manual of traffic rules available on tabletop can be used by players during the game.

Figure 17. Collaboration and learning during the experiment.

4.3.4 Validation of Design

The participants' answers to the questionnaire show that Speed 30 and 50 were the most buttons used, and U-turn was the one that was not used by most of the users. The signs that were used frequently were the direction signs, prohibition to turn right and left signs, 30 speed limits, and no enter signs.

Most of the mistakes committed by users are related to forgetting the game rules rather than mistakes in driving. Only one person mentioned that he put a wrong sign on the road. The rest mentioned mistakes like putting the signs too close to the car or putting two signs in one place. All of the users stated that they understood the game rules, and most of them felt comfortable with the rules of the game on 'Average' level. One of the users mentioned that the rules were a bit fuzzy at the beginning and another suggested to have a "Better explanation of the game." (Driver2, Team A); the rest suggested changing some of the rules, for instance: "Rules to put and remove the signs" (Driver2, Team A) and "The possibility to put a sign near another sign." (Sign indicator, Team A). Driver '1' of team 'B' stated that the distance for the car movement is too short in each turn. All the suggestions and change of the rules which were carried out during the observation should be implemented for the next design cycle. This research reports the changes that can be made in the future works but will not test the modifications.

Most of the users perceived the game ‘A bit’ to ‘Average’ level close to the real life situation. One of the users suggested a change relevant to the design which is a positive remark and would help the design become more tangible:

> “All the buttons shouldn’t look like the same, because they don’t make similar actions.” (Driver1, Team A)

And another stated:

> “I thought that the driving control buttons weren’t very useful.” (Sign indicator, Team B)

One more point regarding a more tangible design was “There is a lack of rendering of the dynamism of driving (i.e. slowing down before a turn etc.)” (Driver 2, Team B). It is true that the paper prototype version of the game lacks dynamism. In the future design and implementation of design in tabletops, many movements are done by computer and the game will be more dynamic.

All the players declared that they enjoyed a lot playing the game. This is totally obvious from the observation as well since the players were all the time discussing and showed a lot of interest during the game. No sign of boredom was observed.

During the experiment, several game rules were changed to simplify the game. It seems that the game rules were too complicated because the entire time during the game, the rules of the game was asked by the users and wizards. This kind of questioning was hectic in the beginning and then reduced till the end. For the future design cycles of the game, it is suggested to simplify the game rules that is easy for the users to remember and apply. Some samples of participants’ questions are as follows:

> Sign indicator, Team A: “Can I put one and remove one sign at the same time?”
>
> Wizard, Team A: “No, you must wait one turn!”
>
> Or
>
> Driver 2, Team B: “First we have to move the car and then remove the sign.”

> Wizard, Team B: "I think you can first put the sign and then move the car"
>
> Driver 2, Team B: "No (reading the rules' paper) first move then remove the signs."

The experiment shows that actions in future turns are not predictable, and teams were surprising each other by their actions. On each turn, while players thought about a possible strategy and estimated the opponents' action, they faced a different challenge and had to think, discuss, and solve a new problem.

The observation confirms that the players did not use the buttons very often; and whenever they used, they were not enthusiastic about it. This will be solved in the tabletop version if they use the buttons to move the car otherwise they cannot do anything, in this way having buttons for movement would be more realistic. Thus, there should be a change in design to have either a physical car without buttons or a virtual car that moves by manipulating the buttons. The experiment showed that having a physical car and buttons at the same time is not logical.

Setting up a turn-based feature for the design of this game was advantageous since both teams had time for discussions, reviewing the rules, and talking about strategies between their turns. Many times they reached an agreement to perform specific actions during the time between the turns. After each turn finished by a team, their wizard said out load: "Your turn!" This indication should be implemented in design, for example a sign on tabletop to state the start of actions.

Some rules were set during the game to simplify the performances:

- In the beginning, users were confused to distinguish the decorative signs which existed from the beginning on the map from the virtually located signs. it was decided to put a point by pen on decorative signs to make a distinction.
- Another rule was specified is if cars are already in 30 speed, they would not need to slow down for a danger sign.
- If a sign is located too close to the car by players, it will not be an error. It will be considered as a warning by wizard so that the player correct the distance.
- Players were confused about application of the park sign. They asked several times during the game if they had to put a parking sign besides a bank to be able to take the money or not. The rule was declared that it is not necessary, they can just stop

and drag the money. Although setting a park sign is advantageous for them; since by putting this sign next to the bank, the opponent cannot put a sign there to forbid them from stopping.

- If a car did not stop in the previous turn it means that it is still moving and there is no need to push the speed button every turn. The wizard suggested to add an indicator to the design to show that the car is moving or not and what the car's speed is.
- After thirty minutes of the game, since it took too long for each team to decide and act in a turn, it was decided to limit the time to three minutes for each turn. This decision made the game flow much faster, and enhance better.
- The number of banks should be more on the map to rise the competition. In this game, just ten minutes before the end of the game both cars were close to a money and could take it during the last turns of the game.

There were some challenges regarding the design in the game that will be solved in the tabletop version. Some of these difficulties can be describes as follows:

- Measuring the distance was difficult for the users. The wizards corrected the distances whenever there was a mistake. It happened one time that team 'A' had disagreement about the form of turning by team 'B', and the distance they went forward.
- There was an error in the map design, the location of one bank was not identical for both teams and led to a confusion in the game.

From the observation, it is concluded that the rules of the game should be simplified, because part of the game's time was spent on understanding and following the rules of the game rather than traffic rules. In the tabletop implementation, it should be tested if synchronization of actions simplifies the game or not.

Chapter 5. CONCLUSION

This research aims to introduce a collaborative learning serious game that facilitates learning of traffic rules. This study presents the process of serious game design and results from an experiment to test its qualifications. This chapter sums up the findings of the experiment and relates them with the research questions and objectives. Significance of the research and suggestions for the future works are described. Here, an overview on the results of the experiment in relation to some of the previous research explained in Chapter 2 Literature Review is provided.

- Summary of the Results

The aim of this section is to sum up the results and compare with the hypothesis of this study. The design process and tools that are presented in this study intend to create a serious game with collaborative learning on tabletops. The experiment was planned in a way to assess the qualifications of design regarding collaboration, learning, and validity of design. Validation of design refers to the quality of design from both interaction and game design point of view.

Data collected from both questionnaire and observation show that the game supports a high level of collaboration. All the players were engaged in the discussions during the game and were following the activities enthusiastically. They were asking many questions from each other and for performing actions they discussed about possible strategies. In general, participants collaborated intensely during the game and found the way of team collaboration efficient in their performance. They discussed a lot during the game to reach agreements for actions, learn about the traffic rules, warn each other about the game's rules, and set strategies to defeat the opponent. As discussed in Chapter 2, Communication is a required part of collaboration that facilitates the exchange of information (Shah, 2008). As it was observed during the experiment, communication had a key role during the game in problem solving and decision making. Due to the successful collaboration model presented in section 2.1 Collaboration and Serious Games, and from a comparison with the results of design experiment, it is concluded that the serious game supplies a successful collaboration among players. The game has a clear face-to-face communication where each player has a role and specific authority to contribute to the collaborative environment, and all the actions of team members are tightly relevant and must be coordinated to reach a satisfactory result. Users are required to respect the rules of the game and reach a mutual agreement for each turn to reach a productive collaboration.

The results from observation show that a part of collaboration is done among the team members to decide about a strategy to reach the best results. Locating the correct signs on the road while following the game rules was the main portion of collaboration. Participants asked many questions from each other and asked help regarding the game rules, traffic rules and meaning of signs. Almost the whole time of the game, players were busy discussing with each other even between their turns. They tried to estimate their opponents' actions and reach agreement for their future activities. The results from questionnaire and observation show that the participants enjoyed playing the game and found the game scenario attractive.

All the players had an active role in the game. They also showed a lot of enthusiasm. Sometimes they were laughing and making jokes about their actions which showed that they enjoyed playing the game. For instance, in the last turn, even though the red team knew they cannot get more points, they still liked to play. In general, the users felt comfortable asking about the meaning of the signs from each other. In the first half of the game discussions were more than the second half, because they needed to learn about the rules of the game and ask each other questions about the road signs they did not know. In future design stage of the game, it is suggested to apply more traffic signs so as to raise the discussion toward road signs' applications and meaning. Additionally, it is advised to have different set of road signs on each table, thus in all the levels of game users face various signs that they do not have on their table, and in each turn they have to discuss about the new signs.

By definition of Lehtinen (1999), collaborative learning takes place when students work together on learning tasks. The next hypothesis of this serious game design is that the collaboration to perform activities and win the game leads to learn the traffic rules. Accordingly, it is required to examine whether the serious game design incorporates learning tasks for the players or not. Based on the outcomes of observation and comparison of pretest and posttest, participants have learned about the traffic rules and signs via playing the collaborative learning game. Although majority of the participants knew already about traffic rules and had many years of driving experience, they faced some signs of which they did not remember their meaning and had to ask from their team members. The experiment shows that the learning tasks are more challenging for those with no driving license.

To sum up, the users have found the game relatively helpful in learning the traffic rules and driving. The results of the pretest-posttest support the conclusion and user judgments about their learning as it is visible that users learn a traffic rule and they answer correctly to the posttest questions. The results from the observation verify the questionnaire’s data. It is observed that the participants ask questions about the traffic rules and road signs from each other, also it is perceived that the form of the game and strategy engaged the users a lot in the game to think, discuss and solve the problem. This result shows that the game was challenging enough for users to lead to a strong collaboration.

The interface design and game scenario was tested in the experiment. After experimenting the collaboration on tabletops is done, the suggestions for design modifications can be implemented based on the way of collaboration. As Tang et al. (2006) consider, designing collaborative interfaces for tabletops involves understanding of how groups manage their acts over a tabletop.

Based on Schneider et al. (2012) design principles to support collaborative learning processes, it is observed that the game scenario was quite engaging, participants showed enthusiasm for playing and winning the game. Adopting mixed reality for the serious game design was quite fitting the learning objectives. Players were attracted and engaged fully in the game by manipulation of physical signs and cars. The territoriality of tabletops was suitable for the users as each user was responsible for a side of tabletops buttons or signs.

By setting strategies and reflecting on opponent's actions, players have a sense of autonomy as well. During the experiment, it is observed that the rules should be simplified for users in order to feel more comfortable with the game rules. Some of the game rules and interface design changed during the experiment to improve the game flow. For the detailed modifications, see section 4.3.4 Validation of Design.

- Perspectives

The suggestion for future research is to implement in the tabletop design and examine the effect of computer to synchronization of actions. The observation shows that the time taken by wizards to perform the actions and reflect on the players' moves is quite long, thus implementation of the game would make the game even more attractive and dynamic. Further research can compare the turn-based with a real time version of the game and evaluate collaborative learning of both. As it is explained in section 3.4 Simplifying the Design for Experiment, the limitation of sampling and paper prototyping modified the experiment from four tabletops to two. In case of sufficient financial and technical resources it is advantageous to measure the level of collaborative learning in the original territoriality of the serious game.

For such a research in Master level, one cycle was considered but before implementing the game into tabletops, more experiments should be done to complete the necessary design cycles. In the various cycles, the appropriate amount of players, simpler game rules, more learning subjects , and time management for turns should be applied.

This research is done to introduce a new collaborative learning system in serious game design. Adopting tabletops as an opportunity for learning traffic rules collaboratively can be considered by driving schools. Also primary schools can use a very simple version to teach children the safety traffic regulations. The same idea can be utilized for urban planning of traffic regulation in the cities.

The significance of this study is to present a collaborative learning design for learning traffic rules. Additionally, it offers a new application of mixed reality in serious games over tabletops. The serious game design is proven to have a high level of collaborative learning; and the scenario offers an attractive turn-based game which requires strategic problem solving.

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Appendix 1: Rules of the Game for Users

- The game finishes when the whole money finishes on the map.
- In each turn, first the car can move (the maximum movement is the size of the ruler from the car to any direction), then two signs can be assigned or removed on the map.
- To drag the money to your side of the table, the car must be on the same side of the road as the money is located.
- No sign can be put too close to the cars (the size of the ruler from the car to all directions).
-  You cannot add or remove any signs in this location.
-  You must remove the sign when the red circle appears.
- You cannot remove the signs that are assigned in the previous turn, if a sign is added you cannot remove and if any removed you cannot add in that precise location until next turn.
- After moving the car and assigning the signs, your team's turn is over and you cannot change anything till next turn. Actions cannot be cancelled.
- U-turn takes one full turn.
- Two signs in one location is not allowed.
- Each table has its own physical and virtual signs, do not mix them.
- By Stop or Park, the turn ends for the car.

Appendix 2: Rules of the game for the Wizards

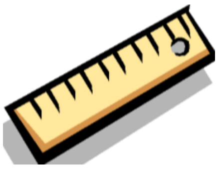
- The game finishes when the whole money finishes on the map.
- The game is turn-based and in each turn, the sequence of actions start with moving the car then assigning the signs; in each turn the car can move once and two signs can be assigned or removed on the map.
- If a sign is assigned too close to any of the cars that is less than the length of the ruler, show this message: The sign is too close to the car! Please choose another location!
- When a sign is added or removed, put a yellow circle close to the sign and keep it for one turn // It means that the users must wait one turn to be able to change a sign placed by their opponent.
- If a team removes a virtual sign while there is the physical replica on the other table, an orange circle must be shown next to the physical sign to inform the user to remove the physical sign.
- STOP sign can be assigned just in the intersections, if happens anywhere else, consider it as a mistake for the user! The same applies to the priority sign. Regarding the Park sign and forbidden to park, the effect is from the sign onwards to the next intersection.
- Actions cannot be cancelled.
- It is not allowed to put two signs in one location!
- To react to the signs, users must reach the sign and push the right button:
  - For stop sign: stop button. It ends the movement of the car for this turn.
  - Going to a different direction or U-turn, and react to the direction signs: Turn right, Turn left, and U-turn buttons; U-turn takes one full turn.
  - To park and get money: Stop then Park button.
  - To move in 30 or 50 KM/H speed: Speed 30 or Speed 50 button.
  - To be careful, react to the priority signs: Slow down button. The car moves 30 KM/H until the end of this turn.
  - To start the car: Speed 30 or Speed 50 button.

Appendix 3: Summary of the Rules

 An error happened!

 Do not add or remove any signs in this location!

 Remove the sign!

No sign can be put too close to the cars! 

Actions cannot be cancelled.

U-turn takes one full turn.

Two signs in one location is not allowed!

Stop or Park ends the turn for the car.

Appendix 4: Pretest-Posttest Questionnaire

Your name:

1-What is the maximum permitted speed limit inside the city?

A.40 B.50 C.60 D.70

2-When can you use the horn in a built-up area?

A. When danger appears.
B. To draw attention while overtaking
C. To draw the attention of a pedestrian

3-Where is stopping prohibited?

A. On the railway crossing

B. On the carriageway where visibility is restricted

C. After the pedestrian crossing on this side of the road you are proceeding

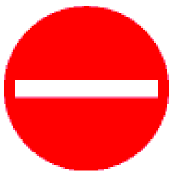
4-When changing lanes you should:

A. Signal and then proceed.
B. Check your mirrors and your blind spot and then proceed.
C. Check your mirrors, signal, check your blind spot and then proceed.
D. Check your mirrors, signal and then proceed.

5- This sign means:

A. No left turn.
B. No right turn.
C. Keep to the left.
D. No turning.

6-This sign means:

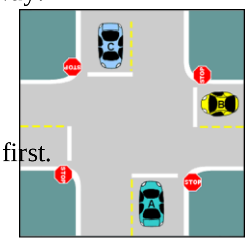


A. No through road.
B. Yield to oncoming traffic.
C. Do not enter.
D. One way only.

7-This sign means:

A. Do not enter.
B. Merge.
C. Allow approaching traffic at the cross street to go first.
D. Slow down.

8-If each of these vehicles arrives at the four-way stop at the same time, who has the right of way?



A. Car A.
B. Car B.
C. Car C.
D. All of them. Drivers should use eye contact and hand signals to indicate who will go first.

Appendix 5: Questionnaire for the Player (Driver)

Personal data: Name: Age: Gender: F ◯ M ◯

Do you have a driving license? Yes ◯ No ◯

If yes, how many years do you have driving experience?

1- Among these buttons, which ones did you use the most? Please indicate by their number.

(1) (2) (3) (4) (5) (6) (7) (8)

2- Is there any button on your side that you did not use at all? If yes, which? And why?

3- Have you committed any mistake during the game?

A lot ◯ Average ◯ A bit ◯ Not at all ◯

If yes, what were the mistakes?

4- Have you understood the rules of the game?

A lot ◯ Average ◯ A bit ◯ Not at all ◯

5- Did you feel comfortable with the rules of the game?

A lot ◯ Average ◯ A bit ◯ Not at all ◯

If not, what do you think should change?

6- How close is the game to the real life situation?

A lot ◯ Average ◯ A bit ◯ Not at all ◯

7- Have you enjoyed playing the game?

A lot ◯ Average ◯ A bit ◯ Not at all ◯

8- How much have you learned about traffic rules during the game?

A lot ◯ Average ◯ A bit ◯ Not at all ◯

9- What have you learned by this game that you did not know before?

10- Do you find this game helpful in driving?

A lot ◯ Average ◯ A bit ◯ Not at all ◯

11- Do you think you could get a better score if you played alone rather than in a team?

Strongly agree ◯ Agree ◯ Disagree ◯ Strongly disagree ◯

12- Have you experienced any misunderstanding with your team members?

A lot ◯ Average ◯ A bit ◯ Not at all ◯

13- Have you found the collaboration efficient in your team?

A lot ◯ Average ◯ A bit ◯ Not at all ◯

14- How much did you discuss with your team members for performing the actions?

A lot ◯ Average ◯ A bit ◯ Not at all ◯

15- Have you found this game collaborative?

A lot ◯ Average ◯ A bit ◯ Not at all ◯

16- Do you have any suggestion for the interface design and collaborative design of the game?

Appendix 6: Questionnaire for the Player (Locator of the Signs)

Personal data: Name: Age: Gender: F ◯ M◯

Do you have a driving license? Yes ◯ No◯

If yes, how many years do you have driving experience?

1- Among these signs, which ones did you use the most? Please indicate by numbers.

(1) (2) (3) (4) (5) (6) (7) (8) (9) (10) (11) (12) (13) (14) (15)

2- Is there any button on your side that you did not use at all? If yes, which? And why?

3- Have you committed any mistake during the game?

A lot◯ Average ◯ A bit ◯Not at all ◯

If yes, what were the mistakes?

4- Have you understood the rules of the game?

A lot ◯ Average◯ A bit◯ Not at all◯

5- Did you feel comfortable with the rules of the game?

A lot ◯Average ◯ A bit ◯Not at all ◯

If not, what do you think should change?

6- How close is the game to the real life situation?

A lot◯ Average◯ A bit◯ Not at all◯

7- Have you enjoyed playing the game?

A lot◯ Average◯ A bit◯ Not at all◯

8- How much have you learned about traffic rules during the game?

A lot ◯ Average◯ A bit◯ Not at all◯

9- What have you learned by this game that you did not know before?

10- Do you find this game helpful in driving?

A lot ◯ Average ◯ A bit ◯ Not at all ◯

11- Do you think you could get a better score if you played alone rather than in a team?

Strongly agree ◯ Agree ◯ Disagree ◯ Strongly disagree ◯

12- Have you experienced any misunderstanding with your team members?

A lot ◯ Average ◯ A bit ◯ Not at all ◯

13- Have you found the collaboration efficient in your team?

A lot ◯ Average ◯ A bit ◯ Not at all ◯

14- How much did you discuss with your team members for performing the actions?

A lot ◯ Average ◯ A bit ◯ Not at all ◯

15- Have you found this game collaborative?

A lot ◯ Average ◯ A bit ◯ Not at all ◯

16- Do you have any suggestion for the interface design and collaborative design of the game?

Appendix 7: Codes from Questionnaire Regarding Collaboration

General questionnaire regarding collaboration	More efficient if played alone rather than in a team	Misunderstanding with team members	Collaboration efficiency in the team	Discussion with team members	Found the game collaborative?	Suggestions
Team A Driver 1	disagree	A bit	Average	A lot	A bit	
Team A Driver 2	Strongly disagree	A bit	A lot	A lot	A lot	"Better explanation of the game." "Implement it?"
Team A Sign indicator		A bit	A lot	Average	A lot	"Put it in informatics please?"
Team B Driver 1 (No license)	Agree	A bit	A lot	A lot	A lot	
Team B Driver 2	Strongly disagree	Not at all	A lot	A lot	A lot	"Define the roles more strongly at the beginning." "There is a lack of rendering of the dynamism of driving (i.e. Slowing down before a turn etc.)"
Team B Sign indicator	Disagree	Not at all	A lot	A lot	A lot	"I thought that the driving control buttons weren't very useful."

Appendix 8: Codes from Questionnaires Regarding Learning

Difference of Pretest-Posttest	Control questions (4)	Learning questions (4)	Comment
Team A Driver 1	No difference	Two differences: The user learned the definition of the sign . In the pretest, the user answered correctly regarding the sign  definition, but in the posttest answered wrongly.	
Team A Driver 2	No possibility to see the difference. One mistake in posttest (because of the description in the comment, the user might not know about the possibility to have two correct answer for this question)	The user answered to all of the posttest learning questions correctly.	The user could not participate in the first 20 minutes and did not fill out the pretest.
Team A Sign indicator	Two differences: In both questions wrong answer in pretest was corrected in the posttest	No difference	
Team B Driver 1(No license)	One difference	One difference: The driver learned that the speed limit inside the city is 50 One mistake stayed the same: The driver did not learn the definition of sign. And indicated the action (slow down) rather than the definition (give way)	This is the only user who did not have a driving license
Team B Driver 2	No difference	One difference: The user learned the definition of the sign 	The user indicated that one of the control questions does not offer the best answer.
Team B Sign indicator	No difference	One difference: The driver learned that the speed limit inside the city is 50	

General questionnaire regarding learning	How much did you learn?	What did you learn?	Helpfulness in driving	Closeness to real life situation
Team A Driver 1	A bit	"I just didn't remember this sign: "	A bit	A bit
Team A Driver 2	A bit	"Signs placements and few road signs"	A lot	Average
Team A Sign indicator	Not at all "I don't say learn but remember!"	"Nothing. I remember some signs that I don't see in everyday life."	A bit	A bit
Team B Driver 1 (No license)	Average	" The signs of driving"	Average	Average
Team B Driver 2	A bit		Average	A bit "It misses a bit of realism"
Team B Sign indicator	Average		Average	Average

Appendix 9: Codes from Questionnaire Regarding Design

General questionnaire regarding design	Most used buttons or signs	Useless button or signs	Committed mistakes	Understanding of game rules	Feeling comfortable with game rules	Suggestions for change	Closeness to real life situation	Enjoying the game
Team A Driver 1	Speed 50	U-turn	Not at all	A lot	A lot	"All the buttons shouldn't look like the same, because they don't make similar actions."	A bit	A lot
Team A Driver 2	Speed 30	Slow down	A bit "At first I didn't know that we can't put 2 signs in the same corner"	A lot	Average	"Rules to put and remove the signs"	Average	A lot
Team A Sign indicator		(wrong questioning)	Not at all- a warning "It was a sign too close from the car at the beginning of the practice."	Average	Average	"The possibility to put a sign near another sign."	A bit	A lot
Team B Driver 1 (No license)	Speed 50	U-turn	A bit "put the sign too close to the car"	A lot	A lot	" The distance is too short"	Average	A lot
Team B Driver 2	Turn right/ Turn left/Speed 30/ Slow down		Not at all	Average- at the beginning	Average	A bit fuzzy at the beginning	A bit "It misses a bit of realism"	A lot
Team B Sign indicator		(wrong questioning)	Average "I put a wrong sign on the road"	Average	Average		Average	A lot

Appendix 10: Letter of Consent for Participation in Research

Subject: Letter of consent for participation in the master research experiment of Mehrnoosh Vahdat, research intern at SILEX LIRIS laboratory at INSA de Lyon.

I certify that I have given my consent to participate in an experiment of Master research: Designing a Collaborative Serious Game on Tabletops for Learning Traffic Rules by Mehrnoosh Vahdat on testing a design prototype. I voluntarily agree to participate in this study and I understand that my participation is not mandatory.

During this experiment, I agree that my activity can be recorded and published in the research results. I understand that the information collected is strictly confidential and is reserved for the exclusive use of the investigator.

I am informed that my identity will not appear in any report or publication and the video recorded information and photos will be treated confidentially. I agree that the data recorded during this study can be stored in databases of Tallinn University Informatics Faculty and also INSA de Lyon LIRIS laboratory.

Date:

Name of participant:

Signature:

Name of experimenter:

Signature: