Eye-Tracking to Enhance Usability: A Race Game

A. Ezgi İlhan
Faculty of Fine Arts, Design & Architecture, Department of Industrial Design
Atılım University
Ankara, Turkey
ezgi.ilhan@atilim.edu.tr

***Abstract*—An important field of research in human-computer interaction studies is the usability of computer games. This paper provides brief definitions of human-computer interactions and usability, and also describes the relevance of these interactions to computer games. Design decisions concerning game elements such as graphical user interface, feedback messages, position and the colour of functional buttons located on the game screen play an important role in identifying the usability and playability of computer games. This study uses eye-tracking technology in order to record eye movements to focus the action of "seeing", which reflects the inner world of humans. A managerial racing game was chosen as an example to analyse its usability. In this context, the design of the social race game was reviewed by recording eye movement data of the participants. The results of eye-tracking data were supported by user comments, which were finally used to improve the design and usability features of the game.**

Keywords—Human-computer interaction; usability; eye-tracking; social race game

I. INTRODUCTION

Human-computer interaction studies become more and more popular in the modern world due to the high number of computer users. Human-computer interaction is an interdisciplinary study field that covers the design, application and improvement of technologies. It mainly focuses on the relationship between humans and the computer. Thus, this field is related to human-centred disciplines such as psychology, sociology, cognitive sciences, ergonomics and industrial design and computer-focused disciplines, such as computer science and software engineering. Human-computer interaction studies can be conducted with four constituents, i.e. user, task, product and the context. Users are observed while performing some of the given tasks by using the products of related technology in the focal context. According to these observations, necessary data are obtained and used in order to improve the systems. Human-computer interaction is a strong study field for designers to ensure the success of a technological product. This product can be an application, web site or a computer game. The visual designs like colours, images, page layout and graphical user interface can be analysed within the scope of human-computer interaction studies [1], [2].

Usability, on the other hand, can be defined as an easy, efficient and effective usage of a product. The technological product can be considered as usable if the target user group can accomplish determined tasks after receiving the necessary training and technical support related to product use. Usability also identifies the user satisfaction showing the success percentage on the tasks that are required to be done [2].

One of the significant fields of human-computer interaction studies is the issue of usability. Use of the technology varies depending on the personality and needs of different people. This change in the interaction with technical systems requires more research on usability. Hence, designing more usable technologies can be achieved by human-computer interaction studies [3].

In recent years, usability of computer games gained a strong research potential under human-computer interaction field [4].Usability, playability, graphical user interface, and user friendliness are important terms of games that necessitate deeper analysis from players/users' point of view. Game controls should be enjoyable, clear and easy to be controlled by the players. Usability of the game is as important as the success of game mechanics and dynamics [5]. Furthermore, in order to increase the number of players by creating positive user experience, usability problems of the game should be eliminated. Thus, usability and playability tests should be conducted with the target player group before the game release.

Testing of the game is an important process to understand the player behaviours and expectations. For that reason, some studies related to game and usability adapts a set of heuristics of playability with usability research during the development cycle [6]. In order to detect usability problems of the game, eye-tracking technology can be used. Eye-tracking technology introduces location, duration and the path of eye movements of participants related to a product. It is used in human-computer interaction studies in various fields like human-related academic research, cognitive science, marketing and user-experience design. According to the sequence and path of eye movement and duration of gaze time, it creates heat, attention and interest maps [7].

Eyes reflect emotions of people and give clues about how they perceive the world. People get more than 90% of information from the outside world through their eyes [8]. However, eye movements are deleted quickly from the short-term memory. 47% of people forget or ignore where they looked [9]. For this reason, eye-tracking studies are beneficial for designers to record eye movement and gaze points, to understand visual interest, to reveal excitement and to analyse the usage scenarios of the product. Eye tracking studies answer usability questions like what participants see/cannot see, where they look at, what they think about and how they

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behave/feel related to the focal product. They evaluate the effect of the design and show the interesting points that are appealing to users.

This paper will analyse the usability of a social race game with the help of the data provided by eye-tracking technology. This section provides the background of the study giving a general overview of the topics concerning human-computer interaction, usability of games and eye-tracking technology. The information gathered from the literature reviews helped to design the methodology of the study. Therefore, Section II of the paper will explain the methodology of the study including the selection of game tasks, choice of the user group and place of the study, and collection of data. It will also mention the purpose and design of the study. Section III will present qualitative and quantitative analysis of collected data. It will discuss eye-tracking data in terms of the usability and playability of the game. Section IV will cover general outcomes and conclusions of the study. Final Section V will indicate limitations of the study and make suggestions for the future work.

II. METHODOLOGY

A. Selection of Game Tasks

Main purpose of the study is to analyse the usability of the game via recording eye movements of the participants. A car race management game belonging to simulation and strategy genres was selected for the study. In the game, the player, who acts as the manager, races in different paths. After developing the cars, pilots and the pit team in the city, the player registers to the new races. The priority of game tasks was determined firstly in order to be prepared for game analysis:

1) *Main goal of the game*: To race -several paths
2) *Assistive goals of the game*:

- To modify the car - the garage
- To heal the car - the garage
- To improve the pilot by tactics and skills - the academy
- To improve the pit team by skills - the academy
- To rest the pilot – the tavern
- To entertain the pilot – the tavern
- To make the pilot lose weight– the tavern.

These tasks were grouped according to the different places in the city. Since it is a managerial race game, the only task assigned to the players was to participate in the race at least once. Other than that, participants were not assigned any special tasks in the game. They were totally free to play the game as they desire in order to define the usability and playability problems of the game. Their actions in the garage, academy and the tavern were collected to analyse the success of the assistive purposes of the game.

B. Selection of Participants

The game is considered under mid-core category. It is going to be played on a social platform and the potential player group is approximately 20 year-old boys. Hence, the aim is to find young participants who can give beneficial feedback to improve the usability and playability of the game.

For the validity of usability tests, the minimum number of participants should be 5. Usability problems can be assessed with 75% success, when there are at least 5 participants. The gestures and mimics, comments and voices and eye movements of users can be collected to test the usability of the product [10]. At the beginning of the study, a pilot study was conducted in order to check if technical tools supported the study, the process was working as initially intended and the observation time was enough to collect necessary data. Upon ensuring these in the pilot study, final studies were started with the focus group of participants. The participants were selected according to their interest in computers and computer games. 10 players, who have experience in these subjects, participated in the study. 10 players were considered to give beneficial and sufficient feedback so as to ascertain the usability problems of the game. The study took nearly half an hour for one participant.

C. Venue and Equipment

Usability tests can be conducted in human-computer interaction research laboratories. The participant and the observer are placed in separate rooms in these laboratories. The observer has the control to watch, hear and record the reactions of the participant [2]. That study was held in the Human-Computer Interaction Research and Application Laboratory of Computer Centre in Middle East Technical University in Ankara, Turkey. Eye-tracking analyses were made by Tobii Studio software, since Tobii 1750 eye tracker was used to record eye movements.

D. Data Collection Tools

The study collects both eye-tracking data and questionnaire results of the participants. Eye-tracking analysis will be explained in detail within the scope of this paper.

1) Eye-Tracking: In design and development processes, designers have some priorities. They focus on some aspects of the game more than the others. Yet, the usability and playability features of the game are determined as a result of the usage path and the action choice of players. How players respond to the game with their playing habits, emotions and attitudes contributes tothe game development process.How players interact with the game during eye-tracking reveals different usability and playability aspects of the game.

For performing data collection through eye-tracking, the observer takes place in the laboratory to welcome participants. With already prepared questions, it is time for the observer to get more detailed information during the game - player interaction period.

While recording eye movements, the goal is to collect detailed information from players' perspectives to interpret game features. The questions that need answers related to the race, garage, academy and the tavern are listed below:

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Fig. 1. Race screen.

The Race

- **Registration:** What is the process of registration for the race?
- **Race screen:** Is it easy to realize tactic buttons in the race? How often are they used (see Fig. 1)?
  - Is it easy to realize the pit stop button? How many of them cannot see this button and were eliminated from the race? Is it easy to take actions and control the game in the pit stop? Can players use all of the actions?
  - Do players control health bar displays on Race GUI?
  - How do players use the interfaces and information display screens during the race? Can they understand the given information easily?
- **Race type:** How do players feel in different types of races (ranking or elimination)?
- **Race ending:** What kind of actions do players take after the race?



Fig. 2. The garage.



Fig. 3. The academy.

The Garage

- Can players understand how to heal the car (see Fig. 2)?
- Can players understand how to modify the parts of the car? Do players compare the properties of new parts during the modify process?
- Can players understand how to change the car from the action panel?

The Academy

- Can players understand how to improve the pilot and the pit team (see Fig. 3)?
- Can players easily register their pilots to new classes by scheduling?
- Can players understand how to change the pilot from the action panel?

The Tavern

- Can players understand how to improve the pilot (see Fig. 4)?
- Which rooms do players use mostly?
- Can players understand how to change the pilot from the action panel?

2) Questionnaire: In order to understand the players' feelings about the game, a questionnaire was used in addition to recording eye movements. Since the priority is the race, questions and answers related to the race are far more critical than the city buildings (the garage, the academy and the tavern). The scope of the study is comprised of analysing the eye-tracking data of participants. Hence, technically useful comments, collected with the questionnaire to support eye movements, are given in detail in this paper. However, the results of other questionnaire questions will not be explained in this paper.

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Fig. 4. The tavern.

III. Analysis and Discussion

According to eye-tracking data of 10 participants, the heat maps of different scenes were created. Both these maps and the answers of the questionnaires were analysed together sensitively to interpret game features. In order to improve the usability of the game, some assertions are done concerning the race, the garage, the academy and the tavern screens.

The Race

- **Registration:** During the registration, the players choose the time of the race they play. The system presents the races in each minute but does not let them register to the races that will start in less than two minutes. This makes players confused in that they cannot register to races for that period of time and they look for other actions to be occupied with. Since the race is the core part of the game, lack of feedback is a serious problem causing race preventions.
  - After the registration, the time remaining for the race is shown on the map screen. However, it is placed under the panel, which made it impossible to control when the registration panel is open. The time for the race on the city screen also has a problem of not being realized due to its shape and colour.
  - The race notification appears on the screen giving the information that there is less than five minutes before the race starts. However, the player misunderstands that the race would start after five minutes, which necessitates a change in this wording.
  - The type of the race is provided on the registration panel. Although it is only text, it was designed like a button, which confused the players.
- **Race screen:** Race GUI and the buttons caused some confusion for the players. While they were trying to watch their car on the track, tactic buttons and the GUI drew attention, which disrupted the players while following their cars.
  - Eye movements of participants focused on the tactic buttons located on the lower left part of the screen. Although the focus is the race, players give tactics from that part and the eye movements were generally on this part of the race screen. Thus, there is a need to change the place of controls (see Fig. 5).
  - Players do not understand if they actually drive the car or just give managerial instructions as giving tactics. It seems like they prefer driving.
  - Once players realize that they need to give tactics during the race, they start to feel the autonomy to choose the needed tactics. The problem is the hesitation to use tactics because they consume pilot energy. For the first several levels, energy loss should be in the minimum level to encourage users to race.
  - Tactic costs (how much they decrease the pilot energy) and benefits (what they provide for the race) cannot be easily understood due to the lack information while they are being used.
  - Even if players find the tactic panel they are not keen to use it because tactic names are not appealing.
  - Some of the tactic animations make players misunderstand that they do totally different actions rather than their own benefits.
  - Players do not understand the effect area of the handbrake tactics. This is one of the things that will be learnt by playing.
  - Some of the players have no idea about the word “pit”, so the “P” letter on the button is meaningless for them. It may be written as “enter the pit stop” on the button to give a clue about that action.
  - Due to the distance of pit stop button from other controls, it was impossible to see the red warning light to click and use the pit. The control displays and the pit button should be closely related to each other on the screen.



Fig. 5. Heat map of eye movements during the race.

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- When players clicked the pit button accidentally during the race, they could not cancel that action. As a result, they entered the pit and lost time in the race. Therefore, it was indicated as a boring experience to lose time due to the lack of the cancelation action.
- In the race, the initial position of each car is different than the others. There are three different locations to start. In order to start at the forefront, players wanted to have some actions to do until the race.

- **Race type:** Once the players start to control the black display that has the ranking, best lap time and best pit time, they want to get better values and race to be the top ranking player (see Fig. 5).
  - Players generally don't understand how they are eliminated in the race because they generally miss the moment of elimination. Therefore, there is a need for an instant feedback.
  - When player's car is captured by the destructor car, it is excluded from the race. However, players don't understand the function of the black destructor car, which follows other cars behind them. An animation may be added in order to show that the black destructor car beats other cars.
  - Players have difficulty when they play on the second path in the type of destructor elimination races. The playability problem should be addressed by redesigning to improve the balance within levels.
- **Race ending:** When players are out of race due the exhaustion, they want to know the main reason of their elimination from the race. When their curiosity is clearly answered by a race finish panel, they could have a solution to play better in the following race.
  - If pilot energy and car health drops down to zero, the player is out of the race. When he does not heal them in the city, these values are saved and the next race starts with these values. In that case, the player is eliminated in the first lap of the race, which is a meaningless loss of time and money for the registration. If the pilot or the car has no health, the race can start with a health of 20%. Lack of information about the car and the pilot after the race make players feel uncomfortable. The final values of the car and pilot should be shown to the players in the city. This would make players heal them in the city in order to prepare for the following races.

The Garage

- Players cannot see the attributes of the car easily, so they do not know which actions to choose in the garage at the first look, as illustrated by the heat map of eye movements in Fig. 6. They try to focus the car; however they are not informed what to do exactly for that purpose. In order to understand the need of either healing the car or modifying the parts, the car attributes should be shown clearly on the action panel.



Fig. 6. Heat map of eye movements in the garage.

- Tapping area of the car parts cannot be clicked easily. Car parts should be distributed better on the screen and the click area overlay should be fine-tuned for the parts.
- Players want more functional options for the cars to be able to have competitive advantage in the races over other players. There should be more customization options like different engines with different fuel consumption.
- Players want to distinguish themselves from others with different cars. Thus, they want to change the body of the car. There may be more alternatives in terms of different forms and colours even if they do not functionally change anything in the game.

The Academy

- The heat map of the eye movements in the academy is shown in Fig. 7. It is clear that eye movements focus on the action panel on the lower part of the screen. Through this action panel, players register their pilots to academy classes expecting that the classes would start right away. 77% of them do not understand that there is a schedule and pilots take classes automatically according to the schedule. Feedback message should be clear and users should receive a notification when a class starts.
- Tactics' costs and benefits are confusing for the players. Hence, there should be a tooltip for every tactic and skill class in the academy showing them each detail.
- Names of the rooms and classes are not clear. Wording must be lucid and tell the player what it is directly related to.
- Players want to control previously learnt tactics in the academy. This can be seen in the inventory, but a skill tree should be adapted into the academy action panel, as well.

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Fig. 7. Heat map of eye movements in the academy.



Fig. 8. Heat map of eye movements in the tavern.

The Tavern

- Players want to see the attributes of pilots in detail, therefore the heat map of eye movements in the tavern focused on the action panel, as seen in the Fig. 8. However, they cannot see this information easily so they do not know which actions to be taken in the tavern. In order to minimize this confusion, pilot attributes should be shown on the action panel located on the lower side of the screen.
- Players cannot recognize the selected room in the tavern due to lack of visuals. The rooms should be noticeable when clicked. It should be achieved by applying an overlay to the selected room.
- Players want to see a meaningful animation of the actions taking place in the rooms. It may not be feasible to create animations for all actions but at least there may be some motion, movement and some kind of visual feedback telling that there is something happening there.
- Since the name 'tavern' does not cover all the actions available in the building, this name of the building should be changed.
- Weight loss of the pilots does not result in a noticeable change in the game play as it is so small compared to the car weight. It can be applied with a multiplier and can have a higher effect on the race, which can improve the playability feature of the game.

For the open-ended question of the questionnaire, which asks for the first thing that players remember from the game, most of the players commented that they mostly remembered the city buildings and their functions. The buildings can be considered helpful for the playability of the game in order to support the race part. The usability of city buildings was evaluated as being easy, clear and enjoyable.

IV. CONCLUSION

This study was focused on the triangular relationship of human-computer interaction, usability and computer games. It provided tangible data collected from eye movement recordings of the participants. It focused on a managerial race game to question and to analyse usability problems.

For the game example, playability and usability factors play as significant roles as the fun factor, game mechanics and dynamics. As mentioned in the literature, playability and usability properties support each other mutually in the game. If one is lacking, the success of the game is debatable. Thus, in this study participants played the game in front of the observer and generated useful data in order to enhance the usability of the game. At this point, one answer given by players to one of the questionnaire questions should be remembered. They need to have instant and detailed feedback in every step and they do not want to wait unnecessarily during gameplay.

As a result of conducting eye-tracking studies, usability related problems such as unclear waiting, insufficient feedback messages, confusing graphical user interface, crowded game screen elements, inefficient controls, and unobtrusive images were detected.

The elements of graphical user interface and visual components like icons, buttons and display controls were redesigned to support gameplay. Their arrangements on the screen were organized again to let players take actions easily. In order to eliminate usage-related problems, the game was enriched by clear feedback messages.

This study helped to understand that eye-tracking technology could beneficially be used to improve a game in the design and developing process. Besides games, in order to improve the features of all digital products and interfaces, human-computer interactions and eye-tracking technology can be used effectively to determine the shortcomings during

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development steps. Taking the advantage of human-computer interaction research, necessary changes can be made before the final product release.

V. LIMITATIONS AND RELATED WORK

Since a game is a voluntary choice of players to have fun, satisfaction of players defines the success of the game. Having further ideas concerning a game design by the help of feedbacks from its users means further usability and experience development. This research shows that the more test groups are analysed with a higher number of participants, the more the game can be improved to achieve usability and playability success and the fun factor.

For the time being, the study was conducted with the user group involving young players. Nonetheless, since it is a mid-core social racing game, it can be preferred by different participants having distinct sex, interest and age properties. Several changes in these properties of the test group may lead to more exciting and marginal results for the development of the game. For the future work, the target group can be altered and the number of participants may be increased to compare and ensure the results with current study. Related work may be applied to hard-core games played on different platforms or mobile games to test their success in terms of usability and playability, as well. The laboratory circumstances can be adapted to collect eye-tracking data from different types of platforms. Moreover, interaction between the user and the computer to improve user experience related to separate products can be interpreted usefully via using eye-tracking technology.

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