Enhancing the Sense of Immersion and Quality of Experience in Mobile Games Using Augmented Reality

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A B S T R A C T
Augmented Reality (AR) has introduced new forms of interaction and presentation in mobile applications. Mobile games have also taken the advantages of this technology to implement novel techniques for interaction between players and game objects. This paper aims to study the effect of AR technology on the sense of immersion and quality of experience in mobile games. In particular, we compare Virtual Reality (VR) camera with AR camera in terms of enhancing the sense of immersion and quality of experience in mobile games. A comprehensive user study is performed to find if there is a significant difference in the sense of immersion between the players using these different cameras. We also analyze how the quality of experience is affected by this parameter.

1 Introduction

Thanks to the advancement of smartphones, the mobile games industry is growing much faster than PC games. This has resulted in a big growth of revenue for mobile games in comparison to movie Box Office sales. This growth is also compatible with people’s tendency to search for mobile games on the web [1]. According to [2], more than 80% of the time on mobile is spent inside games and other applications.

Recently, pervasive games [3] in which a game environment is present within the ordinary world have attracted many players (e.g., Pokemon Go). These games require players to physically attend in some specific locations designed by the game in order to encounter game challenges. In these games, the physical environment becomes a part of the gaming environment. Such games can be implemented using different techniques such as AR. This technology by introducing a new form of interaction between players, non-player characters (NPCs) and game objects provides new opportunities for mobile games development. Using AR, it is possible to seamlessly mix real-world interactions and computer-controlled contents such that virtual objects are overlaid on the real-world.

Unlike traditional mobile games in which the game world is limited to the small screen of a smartphone, in AR games, the gaming environment is extended to the ordinary world [4]. In this setting, the gaming environment includes a mix of physical and virtual objects and characters. AR technology has also introduced a new form of interacting with game objects and characters, where a user can manipulate a game object by changing her hand’s gesture in front of AR camera or changing the position of AR camera regarding an AR target. In AR games [5], virtual objects and characters are shown in accordance with the real environment, captured by the camera of a mobile device. This entails dealing with real and virtual objects at the same time during the game. These unique features...
Research has shown that players are more entertained in a gaming environment where they are immersed in that environment [8]. Unlike PC games, in which bigger screens can be used to immerse a player in the gaming environment, different techniques must be used in mobile games for this purpose [9]. As one of these techniques, this paper studies the effect of using AR in mobile games to increase the sense of immersion for players. In particular, we compare AR and VR cameras in terms of increasing the sense of immersion in mobile games. We hypothesize that seamlessly mixing of virtual and physical objects can result in a better sense of immersion in AR camera in comparison to VR camera. We aim to show mobile games based on augmented reality can define a new approach to immersing players based on novel interactions between virtual game objects and the real environment. To validate this hypothesis, a user study is conducted to evaluate the role of AR and VR cameras on the sense of immersion in mobile games. Various statistical methods are used to analyze the results. Finally, we study how the quality of experience is affected using VR camera, single AR camera, and stereoscopic AR camera.

This paper is organized as follows. In the next section, we review the techniques to increase the sense of immersion in mobile games. The Ziggurat game is elaborated in Section 3. In Section 4, the details of the user study conducted to evaluate the prototypes are provided. Finally, in Section 5, we conclude the findings of this paper.

2 Sense of Immersion in Mobile Games

Although being immersed in a game is not the goal of a player in playing, research has shown that being immersed in a game can result in more fun and entertainment [10]. Various definitions for the sense of immersion have been proposed in the game literature. Taylor et al. argue that immersion can be defined as being immersed in the activities of a game during the game. This is different from the illusion of being in the game environment, which is known as the sense of presence [11]. According to 3, immersion is a feature of technology transferred to players while playing a game. Unlike VR, in which making a virtual environment as real as possible is the goal of increasing the sense of immersion, the environment is already real in AR. Consequently, the goal of increasing the sense of immersion in an AR environment is creating real interactions between physical and virtual objects and characters in the game.

Immersion has also been defined in terms of context immersion, which is known as awareness experience based on interactions and communications [12]. The sense of immersion in the real space is the consequence of this experience, which is not the same as the sense of immersion in virtual reality. Fischer et al. argue that augmented reality bridges the gap between virtual and real objects that consequently results in a higher sense of immersion [13]. This is realized by changing the presentation of virtual objects according to the game context and the state of a player.

One of the main goals of a game designer is to draw a player in the game scenario and environment. In this state, it seems that players lose themselves in this environment. As a consequence of this situation, a player may not notice what happens around her in the real world (the feeling of being in the game). This unique experience defines the sense of immersion in a computer game. Immersion has also been stated in terms of flow, cognitive absorption and presence [8]. Flow shows to what extent a player is drawn in a game. As an immediate consequence of flow, nothing but the game matters to a player. This also results in time distortion such that a player does not realize how time passes. A high involvement with a game, which is also known as cognitive absorption [14] is affected by parameters including time distortion, dissociation, attention focus, heightened enjoyment, control, and curiosity. This concept is also known as an attitude towards a software [8]. Finally, the term of presence refers to a sense of being in a virtual environment [15]. Wittner et al. define presence in terms of control, sensory, distraction and realism that directly affect the sense of presence in computer games [16]. Note that even though simple 2D games such as PAC-MAN may result in time loss, a player in this game does not feel that she is in the world of enemies.

2.1 Realizing the Sense of Immersion in Mobile Games

Techniques such as the design of the game camera as a first-person shooter, creating stereo sounds, using a bigger game screen, increasing the quality of graphics in the games, and creating intuitive interactions between players and game objects and characters can be used to increase the sense of immersion in computer games [17, 15]. The advent of VR games has dramatically changed the techniques to realize the sense of immersion for players. VR Games make it possible to create the illusion of being in a world rather different from the real world [19]. On the other hand, AR technology has changed the concept of immersion in computer games by bridging the gap between what is real and what is not real. This has resulted in the increase of the feeling to be present in the game that consequently leads to providing more fun and enter-
tainment for players in AR games [20].

It is estimated that AR will be one of the top ten technologies in future years that will affect the form of presentations and interaction between human and machine [21]. AR is known as overlaying 3D models or 2D images on the real image captured by the camera of a smartphone. Some major IT companies such as Apple and Google have significant investments in this technology to incorporate their products with AR.

AR applications can be implemented using marker-based or location-based tracking techniques [22, 24]. Unlike location-based AR, in which data received from a compass, accelerometer, gyroscope, and GPS indicate what and how to show computer-generated data on the image captured by the camera of a device, in marker-based AR, this is the position of a marker relative to the camera determines the details of overlaid computer-generated data. Tourism AR applications are one of the well-known location-based AR applications in which layers of synthesized data (e.g., the information about points of interest in the surrounding) are added to the reality [25]. In marker-based augmented reality, markers indicate the details of augmenting the real images with computer-generated data [26, 27]. The prototypes proposed in this paper are marker-based augmented reality games. Consequently, game objects and characters are shown on the screen of a smartphone once a player holds the camera of this device in front of the marker. In the next section, the details of these prototypes are elaborated.

3 Zigorat Mobile Game

The main focus of this paper is to study the effect of using AR in increasing the sense of immersion in mobile games. To achieve this goal, we have proposed a mobile game called Zigorat, which is implemented using VR and AR cameras. The source code of this game is available on the website of Cognitive Augmented Reality lab (www.carlab.ir) in the faculty of Multimedia at Tabriz Islamic Art University.

The main character of this game is a ladybug designed as a third-person character. NPCs (non-player characters) of this game are a set of spiders acting as enemies of the ladybug. The 3D models and animations of spiders and the ladybug are extracted from Unity Asset Store. However, the models are modified to comply with the requirements of this game. In particular, selecting the colors for the game objects and the environment has been based on the opponent process theory of colors [28], which is widely used in computer graphics and information visualization [29]. This theory entails that red-green, blue-yellow, and black-white are three opponent color pairs, where each color can be easily distinguished from the other color in that pair.

The name of this game is taken from the shape of the gaming environment, which is a 3D model of a ziggurat. Generally, a ziggurat is a rectangular stepped tower surmounted by a temple. The ziggurat modeled for this game has five floors connected through stairs. A predefined path is designed in this environment, where a player needs to pass the whole path in order to reach the temple at the top of this ziggurat. The game is the effort of the main character of this game (a ladybug) that tries to reach the top of the ziggurat without contacting the spiders (enemies). The game starts at the first floor, where the ladybug must find her way to the top of the ziggurat. The ladybug has to collect 5 stars on her way in order to open the temple’s door. The path is made of blocks, where each step is a single movement from one block to another. There are some barriers on the path that blocks moving. In order to increase the sense of immersion in this game, various sound effects are applied on games objects, characters, and movements. The internal architecture of this game is shown in Figure 1.

Figure 1. The Internal Architecture of Zigorat Game Including Artificial Intelligence Modules, Sensors, Movements and Interactions.

3.1 AI in Zigorat

Generally, the AI in games is designed based on the sense-think-act model [30]. This model entails that an AI agent first needs to sense the environment in order to make a proper decision. The agent makes a decision based on this data as well as the states of a player, other agents, and the game. Finally, the agent performs some actions in order to affect the game state. None-player characters of this game are a set of spiders that are equipped with different artificial intelligence components. In terms of sensing the environment, visual sensors (using the RAIN component of Unity), as well as direct passing game data to AI agents, are used. For thinking, finite state machines (code-based) as well as behavior trees [31] (using the RAIN component of Unity) are employed. Finally, to implement the act of AI agents, RAIN Waypoint Network, RAIN Waypoint Route, and Unity Navigation...
Figure 2. Finite State Machine (FSM) Model Developed for Spider 3 Developed in C# in Unity.

Figure 3. Behavior Tree for Spider 1 Developed Using RAIN Component in Unity.

Mesh are used. An overview of behavior tree and FSM for spiders are shown in Figures 2 and 3, respectively.

A player can take various strategies such as hiding, fighting and shooting when encountering spiders. On the other hand, spiders can patrol in a predefined path or move towards the player when sensing a player. They follow the player until this player is within the predefined range. The augmented reality part of this game is implemented using Vuforia package of Unity game engine.

4 Experience

Since this paper aims to study the effect of using AR camera on increasing the sense of immersion and quality of experience in mobile games, the Ziggurat game described in the previous section is implemented using VR and AR cameras. In terms of AR camera, both single AR camera and stereoscopic AR camera are taken into account. In particular, we first compare single AR camera and VR camera in terms of creating the sense of immersion. Then, we compare stereoscopic AR camera and single AR camera to study the effect of using head mounted displays on the sense of immersion. An overview of the same ladybug game implemented based on VR camera, single AR Camera, and stereoscopic AR camera, are shown in Figure 4, Figure 5 and Figure 6 respectively. As shown in Figure 4, two predefined cameras are used in the VR mode, where a user can switch between them by clicking on the camera number. In the VR mode, the main character of the game can be moved from one block...
to another block by tapping on the neighbor blocks.

**Prototypes.** The single AR camera prototype is implemented using marker-based AR. In this prototype, the ziggurat and the characters of the game are shown on the screen once the predetermined marker is scanned by the camera of the mobile device. In this single AR mode, the player can turn the mobile (or the marker) in order to see the game environment from different viewing angles. Similar to single AR camera, stereoscopic AR camera is also implemented using marker-based AR. The difference is in the presentation of the game environment, where two of the same window is shown near each other as shown in Figure 7. Using stereoscopic AR requires employing head-mounted displays such as Google cardboard. In our experiments, we used the VR-Box head-mounted display. In order to use these glasses, the stereoscopic AR application is implemented as a mobile application and installed on a mobile device. Then, the user puts this mobile device on the glasses. Alternatively, digital head mounted displays such as HTC Vive\(^1\) can be used, where the application is directly installed on the glasses.

Although the same Ziggurat game is used with single AR camera and stereoscopic AR camera, the interaction between the player and the game is developed using different techniques. In the single AR camera mode, the player moves from one block to another by tapping on the neighbor blocks on the screen of the mobile device. However, this option is not available in the stereoscopic AR camera as the player puts the smartphone inside the head-mounted display. To implement the interaction between the player and the gaming environment in stereoscopic AR camera mode, ray casting technique is used. In this technique, a pointer is shown on the screen, where focusing on the target for one second makes it possible to move to that block.

**Participants.** In order to conduct a user study to evaluate the effect of AR camera on creating the sense of immersion in mobile games, a total of 24 volunteers from the students of Tabriz Islamic Art University were recruited. The details of the participants including familiarity with the concept of AR and the experience of playing an AR game are shown in Figure 7. As shown in this figure, although 46% of participants did not have an experience of playing with AR games, more than 84% of participants were familiar with the concept of augmented reality. According to the time they have spent on playing games, participants can be categorized as semi-professional game players. In addition, since most of the players were recruited from the faculty of multimedia, they are involved in the game industry and producing digital games.

**4.1 Experimental Design**

Since the focus of this paper is to study and compare VR and AR camera in terms of creating the sense of immersion and enhancing the quality of experience in mobile games, we designed a user study in which the type of camera was an independent variable (VR, single AR, and stereoscopic AR). According to t-test experiments on the background information of participants, there was no statistically significant difference between the participants. This allowed us to remove these parameters as independent variables in the experiments.

The sense of immersion, as well as the quality of experience, was measured as dependent variables. In order to measure the sense of immersion, the questionnaire proposed in [8] was used. This questionnaire includes questions to determine to what extent a user feels that she is immersed in the gaming environment. This questionnaire has sixteen questions covering different aspects of immersion using a 5-point Likert scale. Participants answered to what extent they agree with the statements of this questionnaire. These questions are 1) I felt myself to be directly traveling through the game according to my own volition, 2) It was as if I could interact with the world of the game as if I was in the real world, 3) I was unaware of what was happening around me, 4) I felt detached from the outside world, 5) At the time the game was my only concern, 6) I did not feel the urge at any point to stop playing and see what was going on around me, 7) I did not feel like I was in the real world but the game world, 8) To me it felt like only a very short amount of time had passed, 9) I felt that I really empathized/felt for with the game, 10) I was interested in seeing how the game’s events would progress, 11) I was in suspense about whether I would win or lose the game, 12) I found myself so involved with the game that I wanted to speak to the game directly, 13) I enjoyed the graphics and imagery of the game, 14) I enjoyed playing the game, 15) The controls were not easy to pick up, and 16) I

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\(^1\) https://www.vive.com/
became unaware that I was even using any controls.

To measure the quality of experience, we used the questionnaire proposed in [32]. This questionnaire is specifically designed to evaluate the quality of experience of mobile AR games. The questions in this questionnaire are categorized into context awareness, quality of experience, self-expressiveness, and cognitive efforts groups. Context awareness includes 1) This system attaches new meanings to places, services, products etc., 2) Increased the understandability of my environment and its objects. The quality of experience includes 3) This system offered me new experiences, 4) Brought significant benefits to my everyday life, 5) The system was captivating, 6) I got a lot from augmented reality services, and 7) The system Delighted me. Self-expressiveness includes 8) This system helped to inspire my creativity, 9) The system helped me to develop myself, and 10) The system offered me a suitable way to express myself. Cognitive efforts include 11) The system was easy to use, 12) Did not require too much of my attention, and 12) Interfered my understanding of what is real and what is virtual. In order to address the problem of individual differences on the dependent measure, we used within-subjects design. This way, we removed individual differences in terms of feeling immersion. As a within-subjects design, all participants used three versions of Ziggurat. The primary analysis is to verify if the type of camera has an impact on the participants’ sense of immersion.

For each participant, the experiment was started after signing the consent form. Then participants filled out the pre-questionnaire regarding their background. According to the background information of participant, although most of the participants were familiar with the concept of augmented reality, few of them had experience of playing AR games. For this reason, the concept of augmented reality was shortly described for the participants. In addition, they had the opportunity to play with sample AR games (different from ladybug) for 5 minutes before involvement in the experiment. After playing with each game prototype, they were asked to fill out the immersion questionnaire. Participants were free to leave the experiment in any steps of this study.

4.2 Results

4.2.1 Sense of Immersion

According to the pairwise Wilcoxon-Mann-Whitney test conducted on the subjective data regarding the sense of immersion, there were statistically significant differences between the sense of immersion in VR camera and AR cameras. In the pairwise Wilcoxon-Mann-Whitney test, Z-score is a measure of standard deviation that is used to indicate if the null hypothesis is rejected. This is decided based on the p-value (the probability that the null hypothesis is falsely rejected). As shown in Table 1, the results based on the confidence level of 0.05 supports the hypothesis that single AR camera and stereoscopic AR camera result in a higher sense of immersion in mobile games in comparison to VR camera. On the other hand, the results showed no statistically significant differences between single AR camera and stereoscopic AR camera. Consequently, the hypothesis that stereoscopic AR results in more sense of immersion compared to single AR camera is rejected. We argue that this is due to the low quality of the head-mounted display employed in the experiments. In order to support this argument, digital head mounted displays such as Oculus Rift or HTC vive can be used. We put forward this experiment for future work.

4.2.2 Different Aspects of Immersion

During the experiments, we noticed some participants who did have a positive attitude to the game were reporting a low degree of immersion for stereoscopic AR. This made us study the relations between the sense of immersion in mobile games and enjoying the game. Since the questionnaire used in the experiments covers different aspects of immersion including temporal dissociation, focused immersion, heightened enjoyment, control, autonomy, emotional involvement, and attention, we further analyzed data to find to what extent each aspect of immersion may be affected using augmented reality.

In particular, questions in [8] were classified to three categories including Focused Immersion (questions 3, 4, 6, 8, 10), Emotional Involvement and Enjoyment (questions 5, 7, 9, 12, 13, 14), and Control and Autonomy (questions 1, 2, 11, 15, 16). According to the pair-wise analysis of data using ANOVA, among regular VR camera, single AR camera and stereoscopic AR camera, there were statistically significant differences between VR camera and single AR regarding focused immersion and control and autonomy (see Table 2). Accordingly, there were statistically significant differences between regular VR camera and stereoscopic AR camera. However, no statistically significant differences found between single AR and stereoscopic

| Table 1. Pair-Wise Comparison of Sense of Immersion Using Wilcoxon-Mann-Whitney Tests |
|-----------------------------------------------|-----------------------------------------------|
| Sense of Immersion                           | Wilcoxon-Mann-Whitney                         |
| RegularVR, SingleAR                          | Z = -2.63, p = 0.00343                        |
| RegularVR, StereoscopicAR                    | Z = -3.56, p = 0.00013                        |
| SingleAR, StereoscopicAR                     | Z = -0.41, p = 0.89421                        |
Table 2. Pair-Wise Comparison of Sense of Immersion for Focused Immersion, Control and Autonomy and Emotional Involvement and Enjoyment Using ANOVA.

<table>
<thead>
<tr>
<th></th>
<th>ANOVA Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Focused Immersion</td>
<td></td>
</tr>
<tr>
<td>VR, SingleAR</td>
<td>$F(1, 47) = 24.1511, p &lt; 0.05$</td>
</tr>
<tr>
<td>VR, StereoscopicAR</td>
<td>$F(1, 47) = 34.2556, p &lt; 0.05$</td>
</tr>
<tr>
<td>AR, StereoscopicAR</td>
<td>$F(1, 47) = 0.7822, p = 0.805$</td>
</tr>
<tr>
<td>Emotion Involvement</td>
<td></td>
</tr>
<tr>
<td>VR, SingleAR</td>
<td>$F(1, 47) = 16.2467, p &lt; 0.05$</td>
</tr>
<tr>
<td>VR, StereoscopicAR</td>
<td>$F(1, 47) = 29.1423, p &lt; 0.05$</td>
</tr>
<tr>
<td>SingleAR, StereoscopicAR</td>
<td>$F(1, 47) = 15.2333, p &lt; 0.05$</td>
</tr>
<tr>
<td>Control and Autonomy</td>
<td></td>
</tr>
<tr>
<td>VR, SingleAR</td>
<td>$F(1, 47) = 19.7438, p &lt; 0.05$</td>
</tr>
<tr>
<td>VR, StereoscopicAR</td>
<td>$F(1, 47) = 18.3111, p &lt; 0.05$</td>
</tr>
<tr>
<td>SingleAR, StereoscopicAR</td>
<td>$F(1, 47) = 0.4568, p = 0.754$</td>
</tr>
</tbody>
</table>

Table 3. Pair-Wise comparison of Quality of Experience using Wilcoxon-Mann-Whitney test.

<table>
<thead>
<tr>
<th>Quality of Experience</th>
<th>Wilcoxon-Mann-Whitney</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regular VR, SingleAR</td>
<td>$Z = -3.24, p = 0.00143$</td>
</tr>
<tr>
<td>Regular VR, StereoscopicAR</td>
<td>$Z = -4.13, p = 0.0009$</td>
</tr>
<tr>
<td>SingleAR, StereoscopicAR</td>
<td>$Z = -0.39, p = 0.7502$</td>
</tr>
</tbody>
</table>

AR. The results of experiments showed that for the parameter of emotional involvement and enjoyment, there are statistically significant differences between VR camera and single AR, between VR and stereoscopic AR, and between single AR and stereoscopic AR. This shows that although stereoscopic AR does not lead to a higher sense of immersion, in comparison to the single AR, better emotional involvement and enjoyment happens in stereoscopic AR in comparison to single AR.

4.2.3 Quality of Experience

To evaluate the quality of experience using different prototypes, participants were asked to express to what extent they agree with the statements proposed in [32]. The responses were stated using a 5-point Likert scale. According to the results of a pair-wise analysis of data using ANOVA, there were statistically significant differences between VR camera and single AR regarding context awareness, quality of experience, and self-expressiveness. Accordingly, there are statistically significant differences between regular VR camera and stereoscopic AR camera. On the other hand, no statistically significant differences found between single AR and stereoscopic AR. The results of experiments showed that for the parameter of cognitive effort, there are statistically significant differences between VR camera and single AR, between VR and stereoscopic AR, and between single AR and stereoscopic AR. This leads to the conclusion that stereoscopic AR can result in less cognitive effort in comparison to single AR. One possible explanation for this observation is that single AR mode requires holding the mobile device in one hand while playing the game, while in stereoscopic AR, both hands of a player are available during the game.

4.2.4 Limitations

This research suffers from some notable limitations as follows. First, a comprehensive user study involving more participants are required to support the idea proposed in this paper. Second, a long-term analysis is required to find the effect of AR in increasing the

Table 4. Pair-Wise Comparison of Sense of Immersion for Different Aspects of the Quality of Experience Using ANOVA.

<table>
<thead>
<tr>
<th></th>
<th>ANOVA Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Context Awareness</td>
<td></td>
</tr>
<tr>
<td>VR, SingleAR</td>
<td>$F(1, 47) = 32.2333, p &lt; 0.05$</td>
</tr>
<tr>
<td>VR, StereoscopicAR</td>
<td>$F(1, 47) = 61.1125, p &lt; 0.05$</td>
</tr>
<tr>
<td>AR, StereoscopicAR</td>
<td>$F(1, 47) = 0.2512, p = 0.9822$</td>
</tr>
<tr>
<td>Quality of Experience</td>
<td></td>
</tr>
<tr>
<td>VR, SingleAR</td>
<td>$F(1, 47) = 35.2485, p &lt; 0.05$</td>
</tr>
<tr>
<td>VR, StereoscopicAR</td>
<td>$F(1, 47) = 45.6584, p &lt; 0.05$</td>
</tr>
<tr>
<td>SingleAR, StereoscopicAR</td>
<td>$F(1, 47) = 0.6444, p = 0.655$</td>
</tr>
<tr>
<td>Self-Expressiveness</td>
<td></td>
</tr>
<tr>
<td>VR, SingleAR</td>
<td>$F(1, 47) = 65.1411, p &lt; 0.05$</td>
</tr>
<tr>
<td>VR, StereoscopicAR</td>
<td>$F(1, 47) = 31.7844, p &lt; 0.05$</td>
</tr>
<tr>
<td>SingleAR, StereoscopicAR</td>
<td>$F(1, 47) = 0.9814, p = 0.850$</td>
</tr>
<tr>
<td>Cognitive Efforts</td>
<td></td>
</tr>
<tr>
<td>VR, SingleAR</td>
<td>$F(1, 47) = 21.2355, p &lt; 0.05$</td>
</tr>
<tr>
<td>VR, StereoscopicAR</td>
<td>$F(1, 47) = 25.4588, p &lt; 0.05$</td>
</tr>
<tr>
<td>SingleAR, StereoscopicAR</td>
<td>$F(1, 47) = 49.2453, p &lt; 0.05$</td>
</tr>
</tbody>
</table>
sense of immersion. In other words, playing a game for few minutes may not represent the feelings of players about the sense of immersion. Finally, self-reported questionnaires such as the one used in our user study may not fully reflect the feelings of the players regarding the sense of immersion and quality of experience. We argue that biofeedback such as EMG or heart rate may better reflect this sense while playing games.

5 Conclusion and Future Work

In this paper, we were interested to find out if using augmented reality in mobile computer games can result in enhancing the sense of immersion and quality of experience in players. We developed a mobile game using VR camera, single AR camera, and stereoscopic AR camera. We asked participants to rate their sense of immersion while playing the game using standard questions. The results of this user study supported our hypothesis that Ziggurat game with single AR camera and stereoscopic AR camera leads to a higher sense of immersion in comparison to VR camera. On the other hand, the results showed that there are no statistically significant differences between single AR and stereoscopic AR in creating the sense of immersion in mobile games. Our experiments also showed that emotional involvement and enjoyment are higher in stereoscopic AR in comparison to single AR. For future work, we aim to conduct more comprehensive experiments to support the idea of enhancing the sense of immersion using AR.

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