City Knights: Spatial Realism and Memorability of Virtual Game Scenes in Pervasive Gameplay

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***Abstract*—Realistic 3D city models are gaining popularity and becoming increasingly available. Correspondingly, pervasive games such as Pokemon GO are becoming widely popular. The use of realistic virtual environments in serious applications has been studied from the point of view of spatial memorability, yet the use of realistic virtual environments in the context of pervasive location based games is still unexplored. We assess the impact of spatial realism on the memorability of virtual environments in pervasive gameplay with a pervasive role-playing game City Knights. We conducted a field trial with 13 participants involving virtual environments in three conditions, where the spatial similarity to the access points of the virtual environments varied. Our findings indicate that spatial similarity is one of the qualities affecting the memorability of virtual environments. We suggest that this knowledge can be exploited in designing smoother transitions between virtual and physical environments in pervasive games.**

Keywords*—*pervasive games; pervasive displays; mobile gaming; virtual environments

I. Introduction

Pervasive games aim at blurring the boundaries of traditional gaming. They take advantage of urban infrastructure and latest technological advancements in creative ways to compose gameplay that expands what is considered traditional gaming [1] [2].

Realistic virtual scenes and models of cities are becoming widely available. In addition to being used in simulation training and visualizing change for citizen participation [3] [4], these models and virtual cities have the potential to be used as game scenes for both traditional digital games as well as pervasive games. The potential of using so-called *mirror world* like virtual environments (VEs) [5] in gameplay has been mostly unexplored. The benefits of utilizing game-like elements in bringing life into virtual city models can help counter the issues many virtual cities are having in terms of obsolesce and related low commercial interest [6].

Memorability of realistic VEs has been explored mainly from the perspective of navigation and in VEs, with the goal of benefiting more serious applications where VEs are being used for *e.g.* simulation training or navigation guides [7]. The blurring of boundaries between what is "real" and what is "play", and the resulting blending of the gameplay into the daily life, is an intrinsic trait of pervasive games [1] [3]. Hence, controlled lab experiments are not optimal in studying pervasive games and gameplay which is why we conducted a field study in a real urban setting, *in the wild* [8].

As a construct, we used a pervasive role-playing game called *City Knights* [9]. The game features three-phased gameplay: quests, conquering locations and a "boss fight". The players can play multiple rounds over one tournament, with each game round culminating in a "boss fight". The boss fights are accessed through a screen of situated pervasive displays (Fig. 1) that has a *window on the world* [10] view into the virtual game scene. This design enables us to explore the impact of spatial realism on the memorability of virtual game scenes and pervasive gameplay. With spatial realism, we refer to the mapping between a VE and the real-world location of the situated display providing an access point to the VE. Our field trial involved three distinctive VEs: one with spatial similarity with the corresponding physical location, another as a well-known location with landmarks, while third merely depicted a generic street corner in the virtual city.

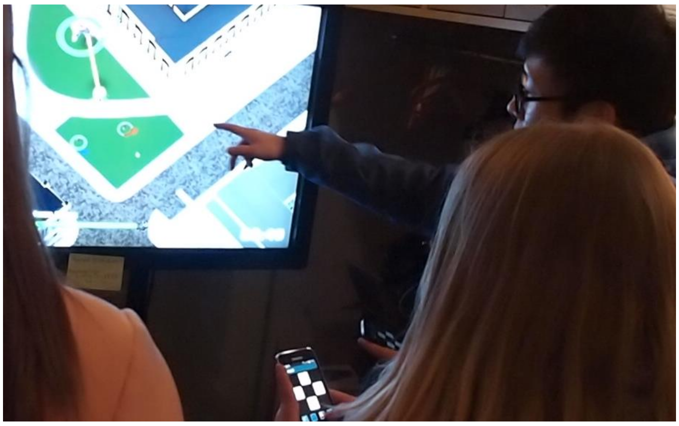

Fig. 1. City Knights boss fight at a situated display.

The main contribution of this study is the assessment of the impact of spatial realism on the memorability of virtual game scenes in pervasive gameplay. The paper is structured as follows: In Section II we discuss relevant literature as background for our research. Section III presents the schema theory underlying our analysis. The design and implementation of City Knights is described in Section IV. Section V reports the setup of the field trial and Section VI discusses the findings. Section VII concludes the paper.

II. Background

VEs based on physical world e.g. "real world" environments have been used in many existing games. However, quite often the game environment is simplified to a cartoonish version of the original [11] [12]. Simulation games such as flight simulators or racing games based on real life events often feature more realistic VEs. While the choice of utilizing realistic, semi-realistic or non-realistic VEs is motivated by the desired outcome, there are obvious benefits in using virtual game environments that are not tightly coupled with a real-world counterpart. For example, game scenes do not have to obey the laws of physics, or it may be more comfortable for the player to wander inside hallways that are more spacious than typically found in real-world architecture [13]. Realistically proportioned game scenes however provide a possibility for more direct visualization of player movements [14] and other sensor data collected from physical locations. Although VR goggles have become more and more popular, the most used display for VEs is still a 2D screen providing a *window on the world*. The screens have become smaller and mobile on the streets, but alternatively pervasive displays could be used as window on the world as these displays can be found in many urban environments [10].

A. Attention Displacement between Physical and Virtual Environments

Pervasive games entwine gameplay and daily life in several ways, and the distinction between the two is not always clear. Hence, embedding VEs into this context is not straightforward. If players are provided with access to both physical and virtual elements inside a single gaming experience, one or the other typically prevails [15] [16]. There are only few games where physical and virtual game scenes have been blended successfully. Typically, these feature a simple game scene shown on a mobile phone screen, e.g. a map enhanced with a few 3D objects and/or an avatar [1].

Unsmooth attention displacement between physical and virtual environments poses a challenge for creating games where both physical and virtual elements are utilized, especially if the *window on the world* [17] is not truly mobile as are the screens of smart phones and other portable devices. Augmented reality (AR) is one option for blending partial contents from virtual as a direct projection onto physical. However, AR has high battery consumption on mobile devices [18] and is therefore often offered as an option that can be toggled on or off in a game application. As a result, AR is not often used, as demonstrated by the design and use of *Pokemon Go* [19] [20].

B. Memorability, Presence and Immersion

When mere 2D images are used for depicting locations, memorability is more related to the semantic qualities of an image than their unusualness or visual esthetics [21]. Similar findings have been reported regarding memorability of 3D VEs [22] [23]. Among others, known landmarks are a type of semantic quality affecting memorability of VEs [22] which relate to the mental maps [23] [24] created by the VE users. Memorability and memory tests have been used to measure the level of presence in VEs [25]. Memorability can be seen an important aspect of immersion, and through this connection an important contributor to the game flow itself.

According to Slater [26], presence has three aspects: the sense of being there, individual's recognition of what is there as real or present, and a memory of "there" as a real place. Prior research suggests that presence should be considered an everyday phenomenon and a "basic property of normal conscious experience". Therefore, isolating measurements of presence in experiences combining VEs and physical environment can be difficult [26] [27] [28] [29]. For this reason, we are interested in the transition between the physical world and the VE, with a specific focus on situations where a transition in attention displacement and therefore a seam or a rift in presence occurs. This point of transition is dictated by game mechanics, so we cannot deduct much from the frequency of events [30]. Furthermore, in pervasive games the experience of presence can be considered to persist throughout the game, as it is with life in general.

Pervasive games are entwined with everyday life and the boundaries of virtual and physical are blurred [1]. We presume that game developers in general aspire high presence that relates to high immersive qualities. Pervasive games are said to aim at blurring boundaries between real and play, but we cannot assume that successful blurring of those boundaries is a measure of successful pervasive game. However, if this is the aim of a developer of pervasive games, then smooth attention displacement should be pursued in moving between virtual and physical realms.

Finally, in relation to immersion and memorability of VEs, spatial realism has not been explored in the context of pervasive games where the transitions from virtual to real are blurry and presence is persistent. Spatial expansion is an intrinsic quality in pervasive games [1], which may take place both in physical and virtual arenas and span through the globe [28]. The characteristics of space, location or "hybrid space" [31] become even more meaningful when pervasive games are location based. We suggest there is a gap in knowledge on the role of spatial realism of virtual scenes in the context of pervasive games and particularly at the point of transition between the two realms, physical and virtual.

III. Theory

Semantic qualities of maps and environment are found to be more important than aesthetic qualities [21]. When people navigate a new environment, their prior experience affects how they perceive, comprehend, or retain the new information. This process is described in *schema theory*, which suggests that perception, language comprehension and memory are processes which involve the interaction of new information with the old, schema-based information. Schemas are knowledge structures and can be represented in a VEs as landmarks, objects that fit in that context [24] [32], or in our case, what is shown on the located displays and how it relates to the location where the VE is accessed.

Schema theory states that memory retrieval is schema related. Schema-based information may be used in the process of retrieving information from memory. When people are exposed to large amounts of information, they ingest more information than they can communicate when recalling is required. Schema theorists suggest that schemata (memory maps in non-theoretical language) are further used to guide the search for information from memory. Information not related to the schemata will be harder to recall than schemata related information [32]. Therefore, there should be a difference between how people perceive their recollection of details of a VE and how well they can actually remember the details upon inquiry. At one level people may remember recognizing a location, but at another level they may not be able to remember the location or how it was detailed, especially if they have not acquired a good mental map or schemata of the location. We will next discuss the concept and implementation of the City Knights game, which we used as a construct for our study.

IV. City Knights

City Knights is a location based mobile game that takes place in downtown urban area. The underlying game dynamics follow those of typical pervasive live action RPGs. Each game round involves three distinct phases: *quests*, *conquering a location* and a "*boss fight*". There are no technical restrictions on team size or the number of teams. So far, tournaments have been conducted with 3-4 teams of 3-5 players. In this section, we will go over the gameplay of City Knights, with a focus on the boss fights stage (Fig. 2). This stage is where the players access realistic VEs through situated displays, thus where the attention displacement from the physical location to the virtual environment takes place. The models for the VEs are from the same source as the ones in the 3D virtual city model of downtown Oulu [15][33]. Our previous constructs for exploring the coupling of hybrid space [2] with its virtual counterpart for pervasive gaming include Campus Knights [34] a game preceding City Knights.

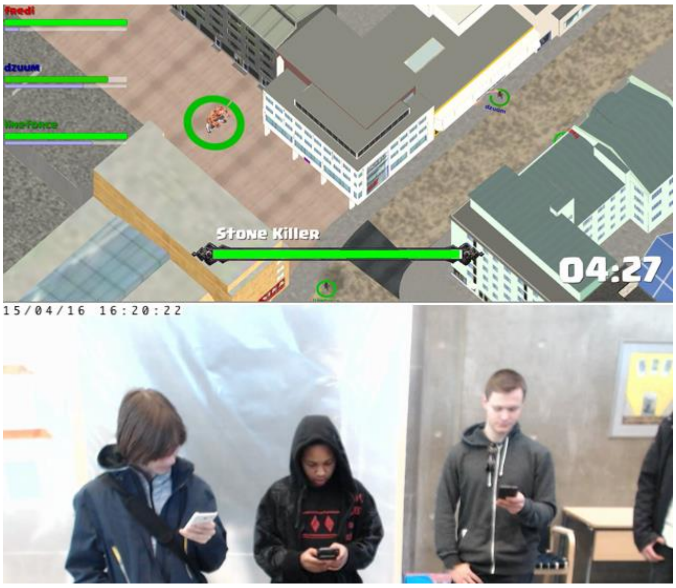

Fig. 2. Action shots from a "boss fight" from the screen (up) and players around it (bottom), figure taken fron City Knights pilot. The game location is a generic street corner from the virtual city scene.

A. GamePlay

The game mechanics and design of City Knights is inspired by the role-playing game (RPG) genre. The game has three distinct phases: 1) quest phase, 2) conquering a location and 3) a boss fight. During the quest phase of the game, the players roam around the city searching for QR codes. They are aided by hints given by the mobile game application. Completed quests give players in-game currency they can use buy consumable and equippable items from the game store (Fig. 3:B).

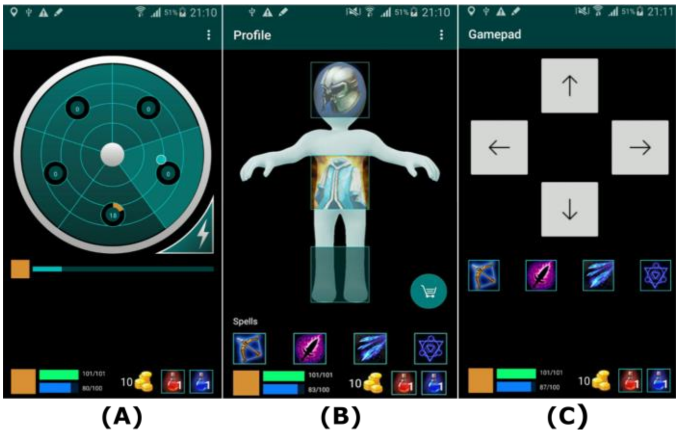

Fig. 3. Example Screenshots from the City Knights mobile game application. (A) The radar screen shows the zone around a display. (B) The player inventory shows current equipment and provides access to the game shop. (C) In boss fight player's avatar in the VE is controlled with arrows. Player's current health, weapons, spells and potions are shown at the bottom.

Once players feel they are "buffed" enough and have accumulated a sufficient amount of equipment for a boss fight, they can attempt to conquer a location around a specific situated display. These locations are ring shaped zones within 10-60-meter radius around the displays. The zones are further divided into five sections (Fig. 3:A) that can be separately occupied by different team members to conquer the location faster. This design is meant to inspire team collaboration and coordination, and to provide different social setting in comparison to the other two game phases; in quests players are dispersed around the city and in boss fights players are co-located by a display. Once the players have conquered a location, they gather by a situated display at the center of that specific zone to gain access to the VE that hosts the boss they need to defeat (Fig. 2, Fig. 4).

Fig. 4. Situated displays (here waiting to be situated) provide access to boss fights conducted in VEs.

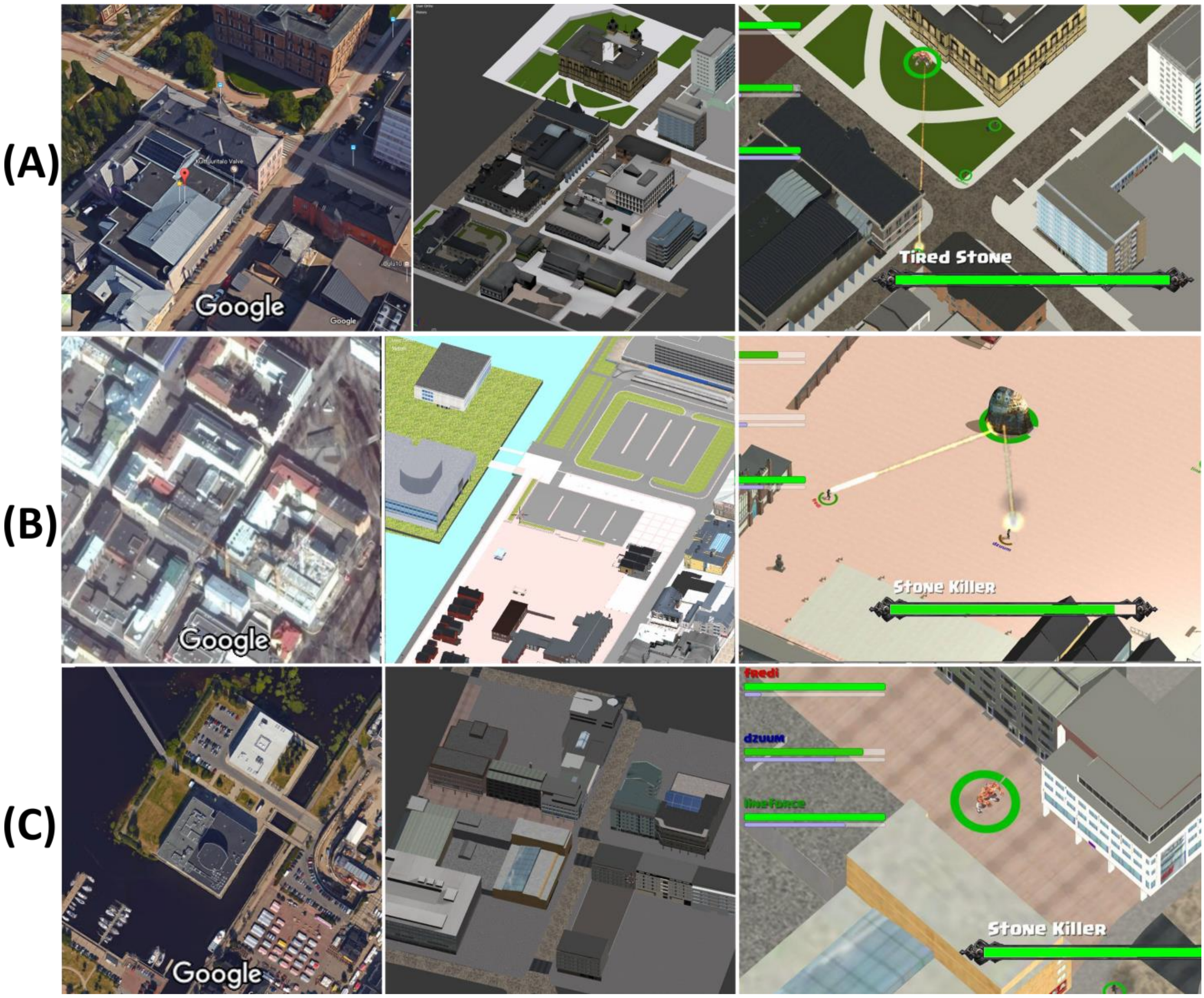

Fig. 5. The three virtual game scenes in City Knights. The leftmost images show the location of the situated display, the middle images show the virtual game scene and the rightmost images show action shots of the boss fights in the VE. Row (A) is the well-known location with spatial realism, (B) is the well-known location with landmarks, and (C) is the location depicting a generic street corner.

The display shows a hovering text "Waiting for Knights" (Fig. 4) on top of the spawn point of the player avatars till the moment at least one of the players in a team has initiated the fight and is close by the screen. The players can wait for their fellow players to come to the site before searching and challenging the boss.

In the following subsection, we describe the VE boss fight arenas more in detail.

B. Virtual Game Scenes: the Boss Fight Arenas

The players have an isometric view of the virtual game scenes i.e. "the boss fight arenas" (Fig. 5) shown on situated displays. Players are presented in the scene by avatars, as previous work has shown that a sense of agency, possibility for task performance and avatar presence all have a positive relation to presence [22]. Players control the movement and behavior of their avatars with their mobile game application (Fig. 3:C). A display has a conjoined view of the VE, so that if an avatar moves further away, the view expands so that all avatars are always visible on the screen. If an avatar goes behind a building, a circular avatar highlight is visible atop the building. The top left corner of the display shows the current status of players' health (hit points).

The distance between the spawn point of avatars and the boss varied in the VEs. The spawn points were selected so that all of them are behind a corner from the boss so that the boss would not be instantly visible when players initiate a boss fight. We wanted to give the players an opportunity to wander inside the scene and get used to the controls before engaging in the boss fight.

The scale of the virtual game scenes is 1:1, so that a meter in the real world corresponds to a meter in the virtual world. The level of detail (LOD) of the scenes is high, LOD8 in the LOD1-9 scale defined by Biljecki *et al.* [35]. Table I shows relevant details of the three virtual game scenes. Scene A (Fig. 5:A) was a well-known location that had spatial similarity with the real-world location where the display was situated. Scene B (Fig. 5:B) is a well-known location with known landmarks. Scene C (Fig. 5:C) is a generic street corner that corresponds to the physical game area. Scene C was used as a control condition in our study, although the virtual street corner does have a corresponding physical street corner in the city within the game area and the area hosted three of our quest QR codes during the trial.

TABLE I. DETAILS OF VIRTUAL GAME SCENES

Scene	Average polygon count	Distance between avatar spawn point and display (m)	Distance between avatar spawn point and boss (m)
A: Well-known location with spatial similarity	203 k	31	61
B: Well-known location with landmarks	220 k	420	80
C: Generic street corner	30 k	545	121

C. *Technical Implementation*

Fig. 6 shows the high-level architecture of City Knights that involves a game server, a database, situated display(s) and smartphones. The displays host Unity [36] game scenes that communicate with the mobile game application running on Android smartphones via the server using REST and UDP/REST protocols. The database provides persistent storage for game and player data and the game server stores and upkeeps the game state.

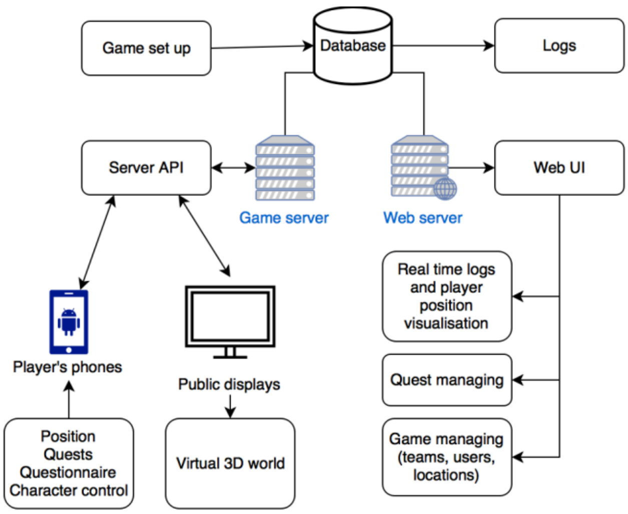

Fig. 6. Hight level architecture of City Knights.

V. METHOD

We conducted a field trial to study the effect of spatial realism of virtual game scenes on their memorability in the context of pervasive gameplay. Participants were recruited through mailing lists, social media and a website dedicated for player recruitment. Eventually, 13 participants in teams of: 5, 4 and 4. Their average age was 22 years (*SD*= 2.13). Four of the 13 participants were female. Participants were asked to fill in the immersive tendencies questionnaire (ITQ) [37] during the sign-up to assess any individual differences in their reaction to game scenes. Two questions of the ITQ questionnaire were presented on site: "How mentally alert do you feel at the present time?" and "How physically fit do you feel today?" Eleven players stated that they were familiar with location-based games. Game analytics data was gathered by logging player actions and locations at the game server. Further, we conducted semi-structured interviews right after the game. The interviews were conducted separately for each team. Both audio and video recordings of the interviews were made to assure data integrity.

A. *Field Trial Setup*

The field trial took place at downtown area of the city of Oulu, Finland. The players were given 15-minute introduction to the game and the mobile game application. Teams then engaged in three 45-minute game rounds with 15-minute breaks in between the rounds to rest and regroup at the game base. Fig. 7 shows the locations of the three situated displays and the quests. The combined distances between the situated displays was 1.25 km. The game area was undefined, but the QR codes of the quests were placed inside a 500 m x 500 m ~ 0.25 km2 area (Fig. 7). The players were allowed to roam freely around the city during the game. However, player location data showed that each player stayed inside the downtown area where the game was played throughout the whole three-hour field trial. When enquired what was most challenging in gameplay, one participant in fact responded, "The walking!"

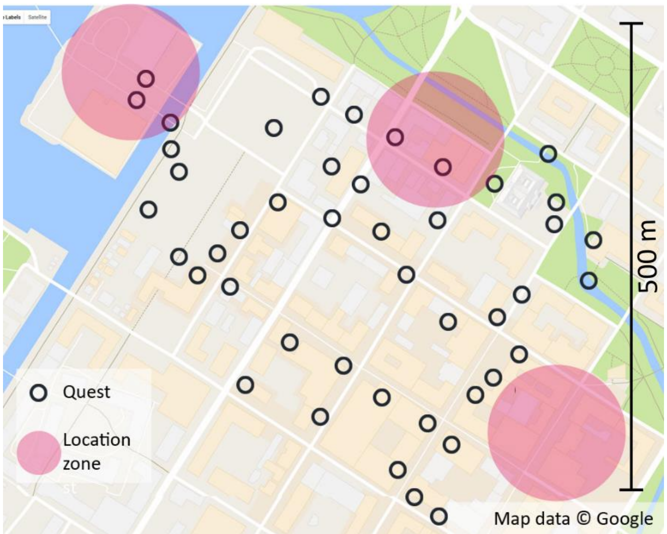

Fig. 7. Game area and the experimental setup. In the center of each Location zone there was a situated display.

The boss fights were of equal difficulty. The distance of the boss and the avatar spawn point varied between scenes. This, in turn, influenced how easy it was for the players to navigate the scenes and therefore to the exposure time to the scene. All teams stated in the interviews that they had a chance to encounter each boss at least once. However, since players could play the game at their own pace and visit different boss fight locations in their own preferred order, there were differences on how many times they visited each location.

VI. RESULTS

A. Qualitative Results on Memorability

The interview data was transcribed and one interview translated in the process. The coding schema was adapted from the schema theory on memory on locations. We added one category based on our observations, "Faulty recollection", on the players remembering locations wrong on occasion or admitting that they did not remember or were unable to recollect a scene. The categories and their explanations in our coding schema are shown in **Virhe. Viitteen lähdettä ei löytynyt.**The final coding results and example quotes can be found in Table III.

TABLE II. CODING SCHEMA

Category	Description
Recollection	Subject states they remember recognizing a location
Recognition	Subject recognizes and names the location
Details Remembered	Subject remembers and mentions details, landmarks, location etc.
Faulty recollection	Subject remembers a location or a detail from that location wrong. Or admits not remembering the location at all.

Albeit we adapted the states of recollection to our coding schema from a well-known theory on spatial memory, we conducted parallel coding by another observer and point-by point agreement testing using Cohen's Kappa [38] [39] to point the interpretability of the material and or results. The strength of agreement on recognizing, which scene was in question was considered "very good". This assessment was done since tying the player comments to the right field locations was one aspect in interpreting the interview transcripts, albeit during the interview the players were enquired separately of each VE and game site. The value of observed agreement was 49/56 (88% of the observations), the weighed Kappa value was 0.776, and the number of agreements expected by chance therefore 32%.

On the coding schema (TABLE II.) categories, the strength of agreement was considered "good". Number of observed agreements was 43/56 (77%) and the weighed Kappa value was 0.647.It is notable that while all participating teams had a recollection of recognizing all three VEs (Table III), they were not able to name or describe the generic street corner scene (Fig. 5:C). In fact, it had the highest frequency of faulty recognitions. The well-known location with spatial realism (Fig. 5:A) was at par with the well-known location with landmarks (Fig 5:B).As expected, landmarks supported recognition and recollection of virtual game scenes, as illustrated by an example quote: "Yes, but the water was a bit away from the place. We were fighting at the market square closer to the market hall and the <well known statue by the site>" (player J24). Collectively, such comments from fellow players could kindle memories, as all players were familiar with the city. Spatial similarity may have not aided in a similar way, since the sense of space is more of a subjective experience. This would explain why from the interview data we were able to recollect and code more details remembered on site B, the well-known location with landmarks. The following quote highlights how difficult it is to remember a specific location based on someone else's recollection of spatial qualities of the location: "I was like yeah, I have been walking there, I know the place" (Player S24). Further, the naming of locations subjectively is not very distinctive; here, there, somewhere. This also made interpretation of the interview material more challenging.

B. Other Observations

We enquired the participants about how significant it was for the gameplay to have the virtual scenes on familiar locations. They replied with varying level of enthusiasm that familiar sites were fun, interesting and significant for gameplay; "*My first location based game, and when those virtual world locations*

TABLE III RESULTS FROM THE CODING AND EXAMPLE QUOTES FROM THE MATERIAL

Category	Frequencies			Quote
	A: Well-known location with spatial similarity	***B: Well-known location with landmarks***	***C: Generic street corner***	
Recollection	10	7	7	"Yeah, they were places from Oulu" (Player J24)
Recognition	6	4	0	"When we were at Valkea, I think we were in the market square in the game" (Player J24)
Details remembered	3	6	0	"This Valve was good, when I saw it I was like: Oh, its Valve. Like I started there in front of this place." (Player E20)
Faulty recollection	4	1	8	"Oh yeah, it was behind the city hall!" (It was not) (Player M20) "And I don't remember the library one, but we only did it once." (Player E20)

were according to the real locations it was more interesting." (Player V20).

During our field trial, one participant described how she had imagined that she is walking in the VE scene while leaving the display after a boss fight. For her this made particular sense as she had entered the scene from that same location.

VII. Discussion

Based on our results the familiarity and landmarks of a scene worked as expected, and the players did not just remember the location, but were further able to remember details and describe the location better than the generic street corner scene, which the players were not able to remember after initial recognition. The scene with spatial realism was similarly recognized and recollected as the location with landmarks, although we cannot deduct whether spatial realism results in more memorable VEs for pervasive games than landmarks. In point-by-point agreement testing, the expected agreements by chance on our coding is 32%, which suggests that there is room for interpretation in our coding schema and results. From the results, one can still conclude that spatial realism is an influencing factor in embedding VEs into pervasive games in a memorable way. It is notable that with the game scene from the generic street corner the players only remember recognizing the scene but are unable to recollect any details. Furthermore, quite a few of them later in the interview stated they do not remember the VE at all. Our findings therefore suggest that spatial realism is one of the semantic features of virtual environment affecting the memorability of VEs. This is especially noteworthy in the context of pervasive games.

A. Smooth attention displacement between the physical and the virtual environment

We suggest spatial similarity of the projected VEs to the physical access point as one solution for smooth transition between the two realities. Albeit, mobile screens are more portable and a map projection of locations does offer a smoother transition between realities, pervasive displays can in addition provide a site for co-located gameplay for the players and heighten their sense of co-presence and social presence. In the future, it would be interesting to survey what are the most viable platforms for projecting VEs in pervasive games. As smart phones are effectively small computers with 3D rendering capabilities, there should be other more imaginative options for utilizing the city infrastructure in pervasive games. This could potentially help combat the effect mobile games have on attention on the physical environment [15] [40] by shifting attention away from the phone screen and more to the actual context of the gameplay, the city, and the people.

B. Limitations

Our analysis of how the players recalled the VE game arenas is based on interview data only. We believe that differences in the level of memorability correlates with the spatial similarity of the VEs to the physical locations where the boss fights were conducted. However, there may be other aspects in game play that affected the memorability of those scenes, such as the contents of the discussions the players had while searching the bossed in VE. We missed the opportunity to record those discussions. However, we believe that the effect of the discussions on the memorability would have had a similar correlation as the complexity and the spatial realism of the game scenes had on memorability.

VIII. Conclusions

There is a connection between memorability, presence and immersion. All of which are important for a game to have an impact on the players. The cognitive jump from spatially similar location to another across physical and virtual is smooth and further creates a more memorable game experience for the players. The memorability of the spatially realistic scene compares to that of already established connection between the VE scenes with landmarks, however recollecting details of the scene seems to be easier from a familiar scene with well-known landmarks.

VEs can be either very fantastic or quite abstract such as visualizations of datasets. Navigation in such environments has its own challenges. We aimed at closing the seam between the virtual and the physical by allowing the players to step into the virtual environment from a spatially similar location i.e. the blending of the virtual and real is done gradually to ease the transformation into the fantastic environment. Perhaps in other applications than pervasive games, this method could be utilized to transform into the more abstract environments of data visualization.

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