Measuring the Effect of Gaming Experience on Virtual Environment Navigation Tasks

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Abstract

Virtual environments are synthetic 3D worlds typically viewed from a first-person point of view with many potential applications within areas such as visualisation, entertainment and training simulators. To effectively develop and utilise virtual environments, user-centric evaluations are commonly performed. Anecdotal evidence suggests that factors such as prior experience with computer games may affect the results of such evaluations.

This paper examines the effects of previous computer gaming experience, user perceived gaming ability and actual gaming performance on navigation tasks in a virtual environment. Two computer games and a virtual environment were developed to elicit performance metrics for use within a user study. Results indicated that perceived gaming skill and progress in a First-Person-Shooter (FPS) game were the most consistent metrics showing significant correlations with performance in time-based navigation tasks. There was also strong evidence that these relations were significantly intensified by the inclusion of participants who play FPS games. In addition, it was found that increased gaming experience decreased spatial perception performance.

Keywords: Virtual environments, computer games, user experience, evaluation, navigation tasks.

Index Terms: I.3.7 [Computing Methodologies]: Computer Graphics—Three-Dimensional Graphics and Realism; H.5.2 [Information Systems]: Information Interfaces and Presentation—User Interfaces

1 Introduction

Virtual environments are synthetic, spatial, usually 3D, worlds commonly seen from a first-person, or third-person perspective under the real-time control of a user [1, 5]. In essence virtual environments are a form of 3D user interface where tasks are directly performed in a 3D spatial context [5]. Virtual environments are increasing being used in a wide variety of application areas including engineering, micro- and nano-technology, aero and space engineering, ergonomics, defence, medicine and surgery, heritage, education and information visualisation [26].

One of the most commonly encountered virtual environments or 3D interface is the modern 3D computer game. The current generation of computer games present realistic virtual worlds featuring user friendly interaction and the simulation of real world phenomena [27]. For many people, computer games will be their first, and most frequent, experience of a 3D virtual world. This has implications for evaluating performance in virtual environment and 3D interface based applications. Prior experience of interacting with virtual environments can have a notable increase in user's performance in virtual environment evaluations [9, 11]. As virtual environment applications become more common there will be a need to accurately measure and accommodate participant's prior experience in order to balance empirical studies of virtual environment interaction. If experimental studies do not distinguish between experienced and inexperienced users, there is a danger that any conclusions may be over generalized [6].

There is anecdotal evidence that participants in virtual environment evaluations with prior computer gaming experience interact more efficiently with the environments and exhibit higher performance than those without. This can be problematic if prior gaming experience of participants can significantly skew evaluation results. This paper describes a study to evaluate the validity of this hypothesis. The impact of prior gaming experience in the performance of navigation tasks in a virtual environment has been investigated.

Section 2 describes related work in the areas of 3D user interface evaluation, the impact of gaming experience, and navigation tasks. Section 3 will consider measuring gaming experience, our research hypotheses and three testing environments, including a 2D game, a 3D game and a virtual environment supporting navigation tasks. A user study has been performed and is described in Section 4. Results of the study are discussed in Section 5. Our conclusions will be presented in Section 6.

2 Related Work

There are three areas of related work relevant to the research presented in this paper; evaluation of 3D user interfaces, particularly virtual environments, the impact of gaming experience and navigation tasks in virtual environments.

2.1 Evaluation of 3D User Interfaces

As with traditional 2D human-computer interaction evaluation, the main purpose of 3D user interface and virtual environment usability evaluation is the identification of usability problems or issues, leading to changes in design in an iterative fashion to increase usefulness and usability [5]. Evaluation also aims to increase overall understanding for developing design guidelines, and to develop performance models, which can be used to predict the performance of a user on a particular task [5, 8, 16, 29].

As identified by [3], there are a number of distinctive characteristics of virtual environment evaluation. Issues involved can be roughly partitioned under physical environment issues, evaluator issues, user issues and evaluation type issues. For a study into how gaming experience effects virtual environment evaluations, user issues are particularly relevant.

[3] and [5] have comprehensively classified evaluation methods for virtual environments. These include cognitive walkthrough, heuristic evaluation, formative evaluation, summative evaluation, questionnaires and interviews.

Defining a set of usability metrics is vital for meaningful virtual environment evaluation. Bowman et al. [5] categorises metrics as:

- Task performance metrics, e.g. speed, accuracy and number of errors.

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- System performance metrics, e.g. frame rate and latency factors that affect the user's experience.

- User preference metrics.

The latter type of metrics refers to subjective perception of the interface by the user, for example ease of use and ease of learning. Subjective factors are commonly evaluated with questionnaires indicating user experiences of issues such as presence [30], user comfort/disorientation [24] and cybersickness [17].

2.2 Impact of Gaming Experience

Frey et al. [11] examined the effects of game experience on psychological experimenting within virtual environments. They focused on whether training could diminish the performance differences between users who play games, and users who do not. The study used a questionnaire to evaluate participant prior experience and used a commercial game engine, Quake III Arena[1], to measure performance. Control of movement was restricted to forwards, backwards and turning motions via a keyboard. They found that users without prior experience profited greatly from training whilst those with prior experience did not. However, those with prior experience still performed significantly better than those with the limited training.

Enochsson et al. [9] investigated the influence of computer game experience on the performance of virtual endoscopy. Seventeen medical students performed a virtual gastroscopy. Computer game experience was defined as either occasionally, daily or never. They found that the students that played computer games were 11% more efficient than those who did not play computer games. Moreover the computer game players were faster in performing the virtual task. This is similar to the results of Grantcharov et al. [12] who found that PC gamers made fewer errors and took less time to complete tasks in the MIST-VR medical simulator than did those without gaming experience. This indicates that computer games may contribute to the development of skills that could be relevant for the performance of laparoscopic surgery [12], i.e. indicating a performance bias by gamers.

In a fire evacuation simulator based on computer game technology [25], previous gaming experience was found to be a factor in participant evacuation times. Expert gamers completed evacuation scenarios in less time than experienced gamers, who in turn evacuated in less time than non-gamers. Gaming ability in this case was defined by participant answers on a pre-session questionnaire.

Castel et al. [7] considered the effects of action video game experience on the efficiency of visual searches. Following the work of Green and Bavelier [13] - who suggested that experience with playing video games may alter and improve the attentional system (also see [14]) - Castel et al. [7] found that video game players (i) had significantly faster reaction times and (ii) were more efficient in searching through displays than non-video game players. Their findings confirm that there are clear differences in performance between gamers and non-gamers in visual attention tasks.

Interestingly, Feng et al. [10] found that only the use of action video games, such as First-Person-Shooter (FPS) games, promoted improved performances in spatial tasks. They note that non-action games may be less likely to have beneficial effects as they require reduced spatial attentional capacities in players. They also found gender differences in improvements based on action video game trials. Females showed larger improvements than males. However, gender differences are beyond the scope of the current work, which focuses on the non-gamer/gamer distinction, and will thus not be considered here further.

[1] http://www.idsoftware.com/games/quake/quake3-arena/ [last access 16/10/2008].

2.3 Navigation Tasks in Virtual Environments

There are five major classes of interaction in virtual environments namely navigation, selection, manipulation, system commands and symbolic input [5]. Exploring how gaming experience may affect all classes of virtual environment interaction is outside the scope of the research reported here. We have focused on navigation and in particular on navigation tasks.

Navigation is the most common task within virtual environments [21]. Darken and Peterson [8] present an overview of navigation in virtual environments. Navigation is a general label that constitutes two sub activities; travel - moving from one location to another - and wayfinding, "the cognitive process of defining a path through an environment, using and acquiring spatial knowledge, aided by both natural and artificial cues" [5, pg227]. There has been significant research into the interaction techniques of travel (see [2, 4, 18]), resulting in quantitative comparisons of travel techniques. There has also been extensive work into wayfinding aspects such as how users respond to environment cues such as landmarks, maps and trails [8, 20, 23] and external navigation aids [22].

Poor navigation support is a strong contributor to reduced usability. Contributing issues include user disorientation [8, 24], wayfinding problems [20] and interaction difficulties [16]. One way to support navigation is the use of explicit navigation aids [23].

Burigat and Chittaro [6] found that there were significant difference in how much inexperienced users benefit from different navigation aids compared to experienced users. They note that these differences are strongly influenced by the virtual environment where navigation takes place, for example abstract vs. geographic environments. In their study experienced users were participants who had multiple navigation sessions in virtual environments and had designed a virtual environment while inexperienced users had basic experience of using computers but no experience in navigating virtual environments, including 3D games or 3D editing programs.

Waller [28] investigated the relations between a number of individual differences in spatial learning including computer attitudes and experience, proficiency with a virtual environment navigational interface and the ability to acquire and transfer spatial knowledge from a virtual environment. He found that spatial ability and interface proficiency have the strongest effect on virtual environment spatial knowledge acquisition and that measures of spatial knowledge in a virtual environment maze were highly predictive of later performance in a similar real-world maze.

3 Measuring Gaming Experience

The primary goal of the work described here is to explore relations between a user's previous gaming experience, their actual gaming performance and their virtual environment navigation performance. We have explored three hypotheses:

- H1 *Participants will exhibit performance in virtual environment navigation tasks comparative with their performance in computer game environments.* It is reasonable to assume that if a participant is skilled at computer games then transferable skills such as hand-eye coordination should aid them in a virtual environment.

- H2 *Participants with prior computer gaming experience will perform better in new computer game and navigation task environments. These participants should exhibit improved speed, accuracy and spatial-awareness in their interactions.* Computer games often require speed, accuracy and an awareness of spatial surroundings. It is reasonable to assume that this develops skills that are traversable to new computer game and virtual environments.

- H3 *Participants who play FPS computer games regularly will perform best in all criteria set out by H2 in a virtual environment.*

3.1 The Testing Environments

In order to support a user study (Section 4), three testing environments were constructed (by the second author). Two computer games and one virtual environment were designed and implemented. Game1 (Section 3.1.1) was a 2D arcade style game, Game2 (Section 3.1.2) was a FPS action game and a test virtual environment (Section 3.1.3) was populated with a number of navigation based tasks.

A comprehensive study of the currently available 3D tools, virtual reality toolkits and computer game development environments, suitable for both virtual environments and computer games, was completed (also see [27]). In order to rapidly develop the virtual environment and the 3D game environment (Game2), the Valve[2] Source runtime engine and SDK was determined to be an appropriate choice. The Source engine has an excellent set of tools for rapid environment development, excellent support and documentation, and a powerful set of features tailored towards first-person viewpoint environments [27]. By developing the virtual environment and Game2 in the same development system, factors such as frame-rate, latency, rendering technique and lighting model were controlled between the test virtual environment and the 3D game environment. Also mechanisms for collecting performance metrics, such as timing information, were added to the built environments.

3.1.1 Game1 - *Breakout*

Game1 was a recreation of the game *Breakout* (see Figure 1). Breakout is a simple 2D bat and ball game involving a paddle, a ball and rows of coloured blocks. The objective is to destroy as many blocks as possible by bouncing the ball off the paddle into the blocks. The player typically has three lives and loses a life each time they fail to bat the ball. It is suitable as the 2D game example because it provides a good measure of hand-eye coordination and reflexes. The Microsoft XNA Framework[3] (C#.NET 2.0) was used to develop Game1. The XNA framework has a number of advantages such as managed code with object orientation and Just-In-Time compiling, and a state-of-the-art game framework designed to accelerate game development using C# and to maximise performance. Additionally the XNA framework has extensive documentation and support and is freely available. The performance metric from Game1 will be the final game score.

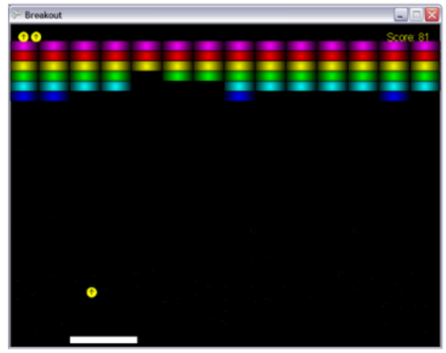

Figure 1: Game1 - Breakout.

3.1.2 Game2 - *Escape from Quarantine*

FPS computer games have a similar viewpoint and interface to first-person desktop virtual environments. This genre has therefore been chosen for Game2 to restrain the interaction technique variables for the user study.

Game2 is a generic FPS game designed so that it increases linearly in difficulty as the player progresses through the game. This is a defining characteristic of many single player FPS games. The performance metric for Game2 was the extent of progress (measured by sub-stage reached) through the game before the player is killed, or reaches the end of the level.

The scenario for Game2 is a coastline filled with enemies. The storyline is that the coastline has been quarantined due to an alien infestation and therefore the player must travel to safety at the end of the coastline, eliminating any enemies in their path. The game initially provides the player with only a crowbar and a pistol with limited ammunition as weapons. Additional resources are available as the player progresses through the environment.

Game2 was built as a Half-Life 2[4] (HL2) modification using the Source engine. The HL2 resources provided a solid foundation for a generic FPS as well as a wide range of enemies which can be used to achieve a linear gradient of difficulty. Figure 2 shows external and internal locations in Game2.

3.1.3 Navigation Task Virtual Environment

The navigation task virtual environment is a desktop-based virtual environment and contains a series of navigation-based tasks for participants to complete. The virtual environment was built using Valve Software's SDK[5] for the Source engine and extended Half-Life 2's base code using Microsoft Visual C++ 2005 Express Edition.

The purpose of the virtual environment was to collect navigation task performance metrics. It was designed as a linear series of rooms, each containing a task measuring a specific metric. The rooms were separated by mid-way rooms with instructions on the walls for the next task. This layout ensures that the task metrics are measured independently and allows clear instructions to be given for each task in isolated environments.

The virtual environment had a fixed horizon and any paths are sufficiently wide to minimise cybersickness. At the very minimum, intersecting walls have a different texture to aid navigation. The subsequent sections (3.1.4-3.1.7) describe the specific tasks used to elicit the navigation task metrics.

3.1.4 Task 1

The first task (see Figure 3) is designed to measure the participant's spatial perception and is based upon experiments described in [24]. Instructions are given in a start room for the participant to navigate to a finish room. Immediately after completing the navigation task, participants were asked to identify a 2D plan, or birds-eye view, of the environment from four different paths to determine if they had constructed an accurate mental model of the environment. The

[2]http://www.valvesoftware.com [last access 16/10/2008].

[3]The Microsoft XNA Framework is similar to a C++ library or a Java repository. It provides commonly used utility classes, streamlined for games. It also provides a common baseline architecture and structure for developing 2D and 3D games. For further information see http://msdn2.microsoft.com/en-us/xna/default.aspx [last access 16/10/2008].

[4]Half-Life 2 is a FPS game which uses the Valve Source 3D engine. For further information please refer to http://half-life2.com/ [last access 16/10/2008].

[5]The Valve SDK is a collection of source code, resources - i.e. textures and sounds - and tools supplied by Valve Software for developing games that run on their proprietary 3D Game Engine, *Source*. For further information please refer to http://developer.valvesoftware.com/wiki/SDK_Docs [last access 16/10/2008].

alternatives consisted of the actual path (alternative *B* in Figure 3) and of paths both more and less complex than the actual path. This provides a rudimentary metric and an indication of a participant's spatial perception, i.e whether an environment is perceived as more or less complex than it actually is [24].

Figure 2: Game2 - Escape from Quarantine.

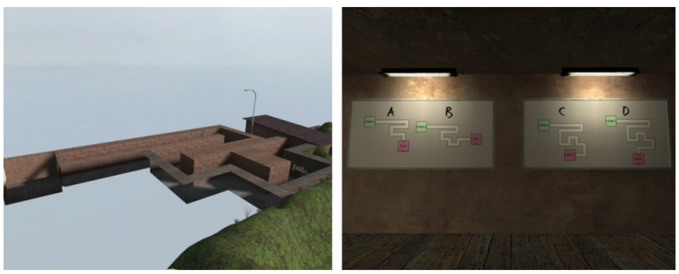

Figure 3: Task 1: The simplest task required participants to walk along a path and then to identify their path from four alternative layout illustrations to measure spatial perception.

3.1.5 Tasks 2 and 3

Tasks 2 and 3 are designed to measure the participant's searching abilities for naïve and primed searches, respectively. The resultant metrics are search times. The tasks are based on similar work by [4].

Both rooms contained an identical maze with an entrance and exit (see Figure 4). Participants are instructed in the first instruction room to find the exit of the subsequent maze in the quickest possible time. Once a participant has completed the first maze, they are then informed in a second instruction room that the next maze is identical and that they should again find the exit with speed. The virtual environment records how long it takes for a participant to complete each task.

3.1.6 Task 4

The fourth task required the participant to jump across an alarmed floor using wooden boards as stepping stones (see Figure 5). The floor glowed red when it was stepped on. Times were recorded for the durations spent on the floor, classified as a mistake. This measured participant's advanced movement abilities.

3.1.7 Task 5

The final task is designed to measure the participant's speed when travelling with high accuracy. Participants are instructed in an instruction room that they must traverse a narrow path suspended between two platforms in the fastest possible time (see Figure 6). If a participant falls off the path they are teleported back to the beginning of the path. The resultant metric is the time taken to successfully cross from one platform to the other.

As illustrated by Figure 6 the path contains at least one 180° turn and at least six 90° turns. As described by [15], this provides a fairly complicated path for traversal by unskilled participants. Moreover, the path is only in two dimensions to maximise the range of potential scores. Finally, the participant is not allowed to jump in this task.

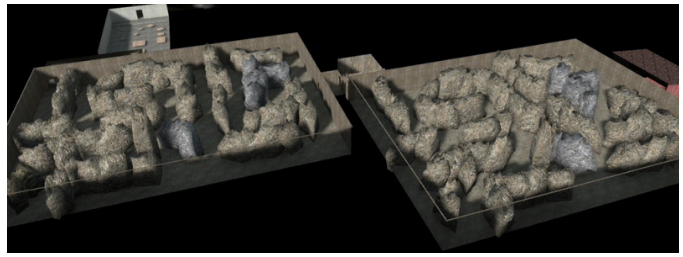

Figure 4: Task 2 and 3: The next tasks were identical mazes. Participants were asked to find the exit. These tasks measured participants search times for naïve and primed searches, and hence travel and wayfinding abilities.

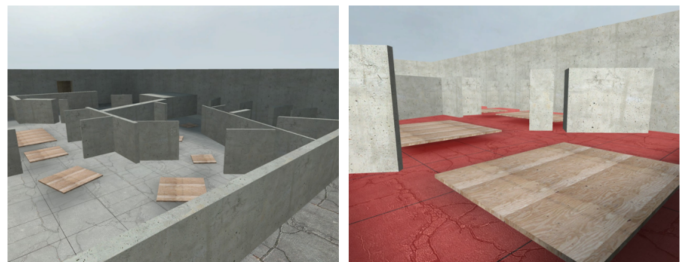

Figure 5: Task 4: Jumping across an *alarmed floor* using wooden boards as stepping stones. The floor glowed red when it was stepped on.

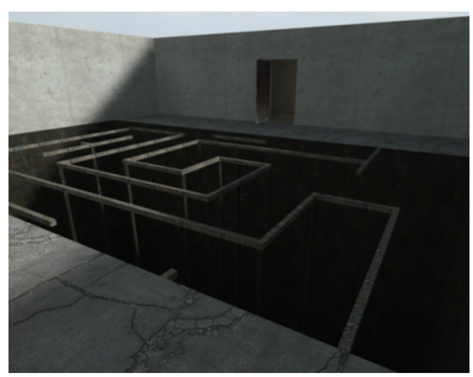

Figure 6: Task 5: The final task required participants to walk along a complicated path above a ravine as fast as possible. This measured participant speed when travelling with high accuracy requirements.

4 User Study

A user study with eighteen users was conducted to measure the gaming experience measures. The participants consisted of seven females and eleven males with ages ranging between 19 and 22.

User study sessions were spread across 21 days and depending on the skill of the participant, completion times ranged from 35 to 90 minutes.

The user study sessions were carried out by the second author and participants were observed from behind in a quiet room without interruptions (see Figure 7). The computer specifications were an AMD 64 3500+ Processor, 1GB PC 3200 Crucial Ballastix RAM, Nvidia GeForce 6800 GT graphics card with Samsung SyncMaster 710N monitor, Logitech MX518 mouse, Nvidia nForce Onboard Audio with Sennheiser HDR 130 headphones and a standard keyboard.

Figure 7: A participant in the user study.

4.1 Procedure

A pre-session questionnaire was completed by all participants collecting demographic data, their perceived skill level at computer games, their game playing habits and general computer usage data. A consent form was also signed by all participants. Participants were unpaid.

Each participant had one attempt at each of the three environments, starting with Game1, followed by the navigation task virtual environment and finally Game2, the FPS game. Participants were provided with written instructions, including interface control details, for each environment.

In Game1, participants had one game, consisting of three lives, i.e. three misses of the ball. The ball was fired using the spacebar whilst the paddle was controlled using a mouse.

In the test virtual environment, the instructions for the navigation tasks were provided in the environment as notice boards on the walls. After the final task, participants completed a questionnaire on their satisfaction with the virtual environment interface, realism of the environment and engagement with the tasks. The viewpoint angle was controlled with the mouse whilst other movement was achieved using the keyboard based on the WASD[6] layout and the spacebar was used for jumping in Task 4.

In Game2, participants had one attempt to progress through increasingly more difficult game stages. As they progressed, enemies became more numerous and of a more deadly nature. Participants were limited by health and ammunition. After dying in the game, participants completed a questionnaire on their satisfaction with the game interface, realism of the environment and engagement with the scenario. The viewpoint angle and movement controls were the same as for the test virtual environment with the addition of *left mouse button* to fire the gun, *shift key* to run, *numbers 1-9* to select weapons and *F* for a flashlight.

At the end of a session, all participants completed a post-session questionnaire where they could suggest improvements to the games and the test virtual environment.

Table 1: Mean data of the four gaming metrics.

Game metric	N	Min.	Max.	Mean ± Std. Dev.
Perceived skill level (1-7)	18	1	6	3.22±1.86
Number of years gaming	18	0	18	10.1±4.57
Game1 score	18	193	1153	510±318
Game2 stage reached (0-11)	18	0	11	6.00±3.27

Table 2: Computer game genres.

First-Person-Shooter	Real Time Strategy
Arcade	Turn Based Strategy
Flight Simulation	Role Playing (3D 1st person)
Role Playing (3D 3rd person)	Role Playing (Other)
Sport (2D)	Sport (3D)
Beatem up / Fighting	Racing
God games (SIM style)	Other

5 Results

5.1 Gaming Metrics

The main objectives of the user study were to collect gaming metrics and to compare them to user performance in the navigation task environment. There were four gaming metrics collected; from pre-session questionnaires, (i) participants perceived skill level at computer games, (ii) the number of years of gaming experience, and from performance metrics from the two example computer games, (iii) the score from Game1 (Breakout) and (iv) the stage reached from Game2 (Escape from Quarantine). A summary of the mean data from these four metrics is shown in Table 1.

A Spearman Rank correlation[7] was performed on these four metrics and the only significant correlation was between *perceived skill level* and *Game2 stage reached* ($rs = 0.905, p < 0.001$). None of the participants perceived themselves as *expert gamers*, although ten participants perceived themselves as being above the mean level of the study, i.e. above 3.22.

A history of gaming habits and in particular, preference for game genre was collected from participants. Participants were asked which game genres (see Table 2) they played regularly, i.e. 2 or more times a week, within the past 3 years. Feng et al. [10] classified inexperienced players as reporting no video game playing in the last 3 years or more. We are using this 3 year period as one measure to indicate gamer/non-gamer distinction.

As FPS gamers typically play regularly[8], a Mann-Whitney U test[9] was performed to determine whether playing FPS games had a significant effect on *perceived skill level* (U = $1.00, p < 0.01$), *Game1 score* (U = $24.00, p < 0.05$) and *Game2 stage reached* (U = $2.50, p < 0.01$).

As shown by Figure 8, participants who played FPS games in the past 3 years performed significantly better in both games and

[6] For further information on the WASD layout see http://en.wikipedia.org/wiki/Wasd [last access 16/10/2008].

[7] Noted in remainder of this paper as *rs*.

[8] Feng et al. [10] classified experienced players as playing for 4 or more hours per week.

[9] Mann-Whitney U test is a non-parametric test for assessing whether two samples come from the same distribution.

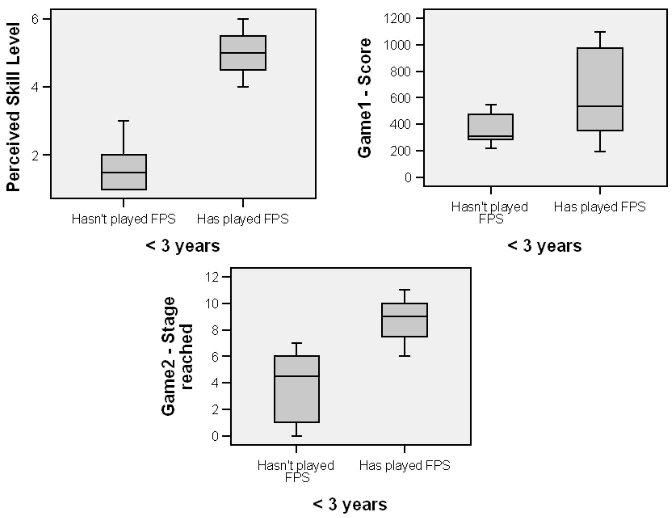

Figure 8: The effect of FPS experience on the gaming metrics.

perceived themselves as having higher skills.

5.2 Navigation Task Performance

5.2.1 Spatial Perception (Task 1)

For Task 1 (see Section 3.1.4), participants walked through an alleyway and were then asked to identify the path they had taken. Each path was assigned a score indicating the degree of path complexity perceived by each participant. A *-1* indicated they perceived a less complex path, a *0* indicated the correct path, and *1* or *2* indicated more complex path perception.

The only significant correlation with any of the gaming metrics was with the *number of years a participant had been playing games* ($rs = 0.787, p < 0.01$). Interestingly, as shown by Figure 9, this would suggest that participants who have played games for more than 10 years tend to overcomplicate their spatial perception of an environment.

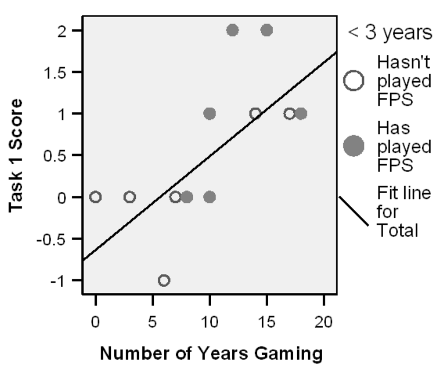

Figure 9: Significant correlation between Task 1 score and number of years of gaming experience.

5.2.2 Naïve Search (Task 2)

For Task 2, participants were asked to find the exit in a maze as fast as possible[10].

[10]NB. One participant's data was removed due to an excessively large completion time.

The only statistically significant correlations of the gaming metrics with the time of completion metric were negative correlations with *Game2 stage reached* ($rs = -0.550, p < 0.05$) and *perceived skill level* ($rs = -0.557, p < 0.05$).

This suggests that only certain types of gamers are significantly faster at naïve searches, such as gamers with FPS experience in the past 3 years. This is supported by Figure 10 in conjunction with a Mann-Whitney U test that shows FPS experience has a significant effect on the time of completion, ($U = 34.5, p = 0.027$). This agrees with the findings of [11].

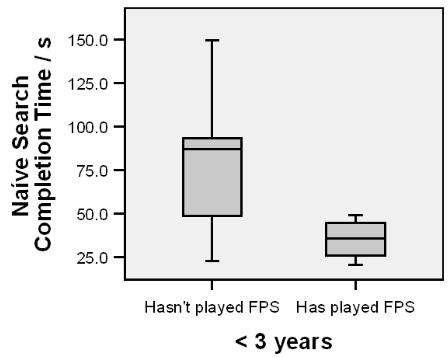

Figure 10: The effect of FPS experience on naïve search time (in seconds).

5.2.3 Primed Search (Task 3)

For Task 3, participants were asked to find the exit in the same maze as Task 2 as quickly as possible[11].

Significant correlations of the gaming metrics with the time of completion metric were negative correlations with *Game2 stage reached* ($rs = -0.647, p < 0.01$) and the *perceived skill level* ($rs = -0.726, p < 0.01$).

This also suggests that only certain types of gamers are significantly faster at primed searches, such as gamers with FPS experience in the past 3 years. Whilst indicated by Figure 11, this was not shown statistically ($U = 17.0, p = 0.74$). It should also be noted that the gap has narrowed between participants with FPS experience and those without between the naïve and primed searches. Whilst most participants retraced their steps, several participants took a direct path to the exit indicating a good sense of spatial orientation. All these participants had FPS experience and perceived themselves as highly skilled.

Whilst both naïve and primed searches show negative correlations to perceived gaming ability, the correlation is more significant for the primed search, -0.557 and -0.726 respectively. This suggests that users who perform well in games or perceive themselves to be good at games will complete both searches in shorter times than others, particularly primed searches.

5.2.4 Jumping Ability (Task 4)

Task 4 (see Section 3.1.6) required participants to jump along a series of wooden boards. Metrics were recorded for the amount of time spent on the floor - classified as a mistake.

The amount of mistakes recorded had significant negative correlations with the *perceived skill level* ($rs = -0.795, p < 0.01$) and *Game2 stage reached* ($rs = -0.749, p < 0.01$).

A low number of mistakes required skilful use of the controls to produce precise movements and accurate spatial awareness. These

[11]The same participant, as in Task 2, was removed due to an excessively large time of completion.

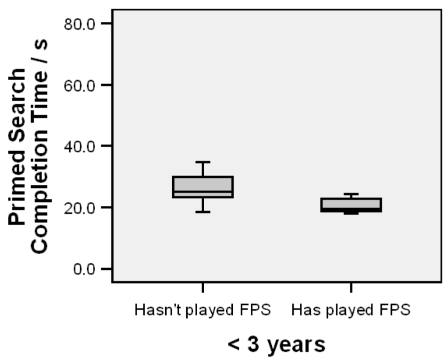

Figure 11: The effect of FPS experience on primed search time (in seconds).

are qualities are exhibited mostly by the FPS gamers as confirmed by a Mann-Whitney U test ($U = 12.0, p = 0.012$).

5.2.5 Travel with Speed and Accuracy (Task 5)

Task 5 required participants to navigate across a very narrow path suspended above a ravine as quickly as possible. This required high speed and high accuracy travelling ability by the participants.

The completion time had significant negative correlations with *Game1 score* ($rs = -0.542, p < 0.05$), *Game2 stage reached* ($rs = -0.907, p < 0.01$) and the *perceived skill level* ($rs = -0.836, p < 0.01$).

As indicated by Figure 12, FPS gamers clearly completed this type of task with ease compared to the other participants. This is confirmed by a Mann-Whitney U test ($U = 5.0, p = 0.002$). It is likely that this is because FPS games require highly accurate rapid movements while playing, are generally played frequently, and use a very similar interface.

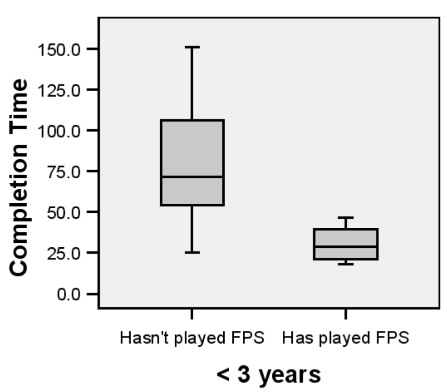

Figure 12: The effect of FPS experience on task 5 completion time (in seconds).

Observations, by the second author, also identified that the performance depended greatly on the travel technique used. For example, FPS gamers moved at a constant speed and hardly looked downwards at their path, even on corners. Conversely, non-FPS gamers generally tapped along, looked down often, and attempted corners in small steps. This could suggest that FPS gamers have much better spatial awareness and may have developed their technique from practice. Also practice in such environments may have allowed FPS gamers to develop familiarity with the keyboard/mouse style interface used, leaving them to focus on the immediate task.

5.3 Hypotheses Validity

- *H1 - Participants will exhibit performance in virtual environment tasks comparative with their performance in computer game environments.*

  This hypothesis was true for Game2 and the virtual environment navigation tasks, but not for Game1 or the spatial perception task. This is likely due to the fact that the interfaces for the virtual environment navigation tasks and Game2 are very similar in contrast to Game1 which is significantly different.

- *H2 - Participants with prior computer gaming experience will perform better in new computer game and navigation task environments. These participants should exhibit improved speed, accuracy and spatial-awareness in their interactions.*

  Statistical analysis has suggested that this hypothesis is correct. This must be taken in context of the limitations of the environments built for this research. Only two games were tested and only five ground-based navigation tasks were considered. This has implications for generalising the results to other virtual environments, which typically have diverse navigation and interaction features. It is also likely that the use of the same game engine for the FPS game and the navigation task environments will have influenced issues such as interface interaction, e.g. for keyboard and mouse travel. However, this allowed a number for environment conditions to be standardised between the environments (see Section 3.1) and the tasks in both environments were intentionally developed to be dissimilar.

- *H3 - Participants who play FPS computer games regularly will perform best in all criteria set out by H2 in a virtual environment.*

  There is strong evidence that this hypothesis is correct wherever H2 is valid.

5.4 Other Issues

The poor correlations shown by the Game1 metric may suggest that general hand-eye coordination is not a direct significant factor for gaming ability or virtual environment task performance. However, this may have been caused by specific features of the Game1 implementation. In Game1 each block had a different score, meaning strategy was an important factor. Those participants that were familiar with the game would have had an advantage over those who had not played the game before.

Metrics of speed were clearly dominated by FPS gamers. This is likely the result of a number of factors. Firstly, FPS gamers practice often, and through repeated virtual world exposure have improved their virtual world navigation skills, particularly for travel, wayfinding and spatial awareness. Secondly, observations during the user studies indicated that FPS gamers were also fastest at doing all of the tasks, which suggests that haste goes hand-in-hand with FPS gaming. This is similar to [14] who note that playing action video games enhances players abilities, particularly the number of objects that can be tracked over time through changes in visual short-term memory skills. Also Feng et al. [10] observe that playing action video games can enhance performance on spatial tasks.

Most importantly, FPS gamers may be more familiar with a variety of navigation controls, to the extent that the interaction is *transparent*, similar to *invisible* technology [19, pg75-77]. The technology, or in this case the interaction mechanisms, should not intrude upon the work of the user. This reduced cognitive load would allow FPS gamers to concentrate more on their immediate task. This may have also been a factor in FPS gamers applying more strategy in the games, resulting in better scores and performance.

6 Conclusion

This paper has described the effects of gaming experience on virtual environment evaluations involving navigation tasks. Perceived gaming skill and progress in a linear FPS game were found to be the most consistent metrics. Moreover, these metrics gave the best indication of performance in example virtual environment navigation tasks.

Both perceived gaming skill and progress in a linear FPS game showed strong significant relations to performance in naïve searches, primed searches, the number of mistakes when performing an advanced travel technique (jumping) and in travelling time requiring high speed and accuracy.

It has been proposed and demonstrated that these relations are largely due to the inclusion of gamers with FPS game experience. It has been suggested that this is because FPS gamers generally play frequently in 3D environments requiring rapid accurate movements, where they have developed better coordination, movement, spatial awareness and navigation abilities. Moreover, interaction with such interfaces becomes familiar and *transparent*, leaving gamers to focus on the immediate task.

As prior experience with computer games has been shown to have a marked effect on participants abilities in virtual environment evaluations it is important to factor such issues into the design and procedure of evaluation studies. However, many of the results presented here are defined by a coarse grained distinction between gamers, non-gamers and FPS gamers. As gaming technology becomes more widespread, it will be important to consider how an individual's prior experiences may be best balanced against other participants in order to control bias in evaluation studies. A step toward this will be a more fine grained approach to participant skill/ability classification. This may require the development of a gamer profile including both similar metrics to those used in this paper, metrics over other 3D interface tasks such as selection and manipulation and metrics for subjective conditions such as user disorientation, cybersickness and presence. There is much existing research literature on these topics and future work will involve consolidating this knowledge, in the context of computer gaming experience, for a gamer profile classification framework.

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