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Measuring and defining the experience of immersion in games

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Abstract

Despite the word's common usage by gamers and reviewers alike, it is still not clear what immersion means. This paper explores immersion further by investigating whether immersion can be defined quantitatively, describing three experiments in total. The first experiment investigated participants' abilities to switch from an immersive to a non-immersive task. The second experiment investigated whether there were changes in participants' eye movements during an immersive task. The third experiment investigated the effect of an externally imposed pace of interaction on immersion and affective measures (state anxiety, positive affect, negative affect). Overall the findings suggest that immersion can be measured subjectively (through questionnaires) as well as objectively (task completion time, eye movements). Furthermore, immersion is not only viewed as a positive experience: negative emotions and uneasiness (i.e. anxiety) also run high.

Keywords: Immersion; Games; Eye tracking; Pace; Affect

1. Introduction

1.1. Conceptual background of immersion

Computer games are actively enjoyed by millions of people around the world. Progressing greatly from the early graphics of Pong and Space Invaders in the 1970s, modern games often have huge virtual environments for people to explore. Controls are more sophisticated, allowing people to carry out a wider variety of manoeuvres in a game. Through the use of the internet people can even play against opponents who are thousands of miles away.

However despite these differences in game design and appearance, successful computer games all have one important element in common: they have an ability to draw people in. Providing an appealing distraction from everyday worries and concerns, computer games allow people to "lose" themselves in the world of the game. Sometimes people find the game so engaging that they do not notice things around them, such as the amount of time that has passed, or another person calling their name. At such moments, almost all of their attention is focused on the game, even to the extent that some people describe themselves as being "in the game."

This experience is referred to as "immersion", a term used by gamers and reviewers alike. Immersion is often viewed as critical to game enjoyment, immersion being the outcome of a good gaming experience. However, although there seems to be a broad understanding of immersion in the gaming community, it is still not clear what exactly is meant by immersion and what is causing it.

In an attempt to understand immersion further, Brown and Cairns (2004) conducted a qualitative study in which they interviewed seven gamers and asked them to talk about their experiences playing computer games. As

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intuitive as the word suggests, the resulting grounded theory found that immersion is indeed used to describe the degree of involvement with a computer game. The theory also identified a number of barriers that could limit the degree of involvement. These barriers arose from a combination of human, computer and contextual factors (e.g. gamer preference, game construction, environmental distracters), and the type of barrier suggested different levels of immersion.

In total, three distinct levels of immersion were identified. The first level of immersion was dubbed "engagement". To enter this level the gamer needed to overcome the barrier of gamer preference. The gamer needed to invest time, effort and attention in learning how to play the game and getting to grips with the controls.

From engagement the gamer may be able to become further involved with the game and enter the second level of immersion, dubbed "engrossment", by overcoming the barrier of game construction. Game features needed to combine in such a way that the gamer's emotions were directly affected by the game and the controls became "invisible". The gamer is now less aware of their surroundings and less self-aware than previously:

> A Zen-like state where your hands just seem to know what to do, and your mind just seems to carry on with the story (Brown and Cairns, 2004).

From engrossment the gamer may be able to become further involved with the game, by overcoming the barriers of empathy and atmosphere, and enter the highest level of immersion, dubbed "total immersion". In total immersion gamers described a sense of presence, being cut off from reality to such an extent that the game was all that mattered.

> When you stop thinking about the fact that you're playing a computer game and you're just in a computer (Brown and Cairns, 2004).

Total immersion required the highest level of attention and was a rare and rather fleeting experience when gaming, whereas engagement and engrossment were more likely to occur.

In another qualitative study, Haywood and Cairns (2005) considered children's engagement in an interactive museum exhibit. The key features of engagement identified were participation, narrative and co-presence of others. These first two suggest that, in non-game applications such as museum exhibits, people will be able to become immersed if there were some basic progressive structure that allowed the user to apply their own ideas in understanding the interactive system. Being grounded theories, the attributes of immersion identified by the studies are descriptive rather than predictive but nonetheless provide a sound basis for our research. These broad findings indicate that immersion has the following features:

- Lack of awareness of time.
- Loss of awareness of the real world.
- Involvement and a sense of being in the task environment.

2. Immersion and engaging experiences

The notion of absorbing and engaging experiences is not a new concept and there are several other concepts that have a relation to immersion that have already been considered. The three main ideas used widely to describe engaging experiences are flow, cognitive absorption and presence. However, we argue here that immersion is clearly distinct from these established concepts and a better understanding of immersion would be crucial in understanding the relationship between people and videogames.

2.1. Flow

Csikszentmihalyi has made an extensive study of positive experiences that people have (Csikszentmihalyi, 1975, 1990). Flow is described as the process of optimal experience, "the state in which individuals are so involved in an activity that nothing else seems to matter" (Csikszentmihalyi, 1990). Like immersion, when in the flow state people become so absorbed in their activities that irrelevant thoughts and perceptions are screened out. A typical excerpt from interviews conducted by Csikszentmihalyi (1975) illustrates this:

> When the game is exciting [chess], I don't seem to hear anything. The world seems to be cut off from me and all there is to think about is my game.

As well as sports and the artistic professions, there has also been recent work investigating flow experiences in web navigation, internet use and virtual reality environments (Chen et al., 1998; Rettie, 2001; Gaggioli et al., 2003).

Csikszentmihalyi (1990) presents eight components of flow in total: clear goals; high degree of concentration; a loss of the feeling of self-consciousness (sense of serenity); distorted sense of time; direct and immediate feedback; balance between ability level and challenge; sense of personal control; intrinsically rewarding.

Flow then clearly overlaps with immersion in the sense of distorting time and providing challenge that involves a person in a task. Indeed, immersion is evidently a precursor for flow because that sense of being so involved that nothing else matters is practically a colloquial definition of immersion. However, flow is a particular sort of experience, specifically an optimal and therefore extreme experience. Immersion is not always so extreme. Brown and Cairns' (2004) findings strongly indicate that immersion is a graded experience that progresses through degrees of engagement. A person can be highly engaged in playing a videogame but still be aware of things like needing to leave the game soon in order to catch a bus or go to a lecture. The player is still immersed in the game to some extent but they are not immersed to the exclusion of all else and therefore not in flow.

It may seem then that flow is simply the extreme end of immersion but there are games that could be considered to provide highly immersive experiences but which do not meet the basic criteria of flow. For instance, *Myst IV* does not have clear goals and it is only through playing the game that the player in time works out what is going on and what needs to be done. Moreover, there are many puzzles in *Myst IV* where there is no direct feedback and it is only much later that the consequences of actions can become clear. Also, when playing a particular game, the player can be challenged beyond their abilities, such as a boss monster at the end of a level, and lose. This would not qualify as a flow experience and yet it could still be a satisfying and immersive experience.

GameFlow was devised with a view to better positioning flow as part of the gaming experience (Sweetser and Wyeth, 2005). The notion of immersion, as we are using it, overlaps with GameFlow namely in that immersion requires concentration, a sense of challenge, control over the game and finally, emotional involvement and real world dissociation. These last two are defined as immersion within GameFlow. However, GameFlow also includes other factors such as player skills, clear goals, feedback and social interaction. These set GameFlow more in line with flow whereas immersion, we hold, is set apart from flow because of the superfluity of these same factors in having what could be described as an immersive experience.

2.2. Cognitive absorption

Agarwal and Karahana (2000) define cognitive absorption (CA) as a state of deep involvement with software. Similar to flow, CA is exhibited through the following five dimensions: temporal dissociation, attention focus, heightened enjoyment, control and curiosity. The main goal of CA research is to enrich understanding of user reactions to information technology. Surveying 288 students, Agarwal and Karahana (2000) suggest that people's responses towards information technology were influenced by two important beliefs: perceived usefulness and perceived ease of use.

A clear distinction between CA and immersion is that CA is an attitude towards information technology in general whereas immersion is the actual experience of a particular occasion of playing a videogame. That is, where immersion asks about similar factors to CA, it does so in regard to a specific instance of playing and unlike CA is not concerned with motivations for playing such as curiosity. Thus, whilst it may be possible for a person to be, in general, very able to be absorbed in using information technology, specifically, absorbed in playing games, there could be occasions where immersion is low. The personality trait does not predict specific states achieved and as they are experienced.

2.3. Presence

Presence has been a popular research area since the 1990s with the development of virtual reality technologies. However the term presence is still under considerable debate, and depending on one's definition there are different ways of measuring presence (Zahorik and Jenison, 1998). In accordance with the rationalistic tradition, Slater et al. (1994) define presence as a psychological sense of being in a virtual environment. Using factors they believed to underlie presence (control, sensory, distraction, realism), Witmer and Singer (1998) created a questionnaire to measure the degree of presence subjectively experienced. They found that the naturalness of the interactions with the virtual environments and how much they mimic real-world experiences affected how much presence is reported. Typically a helmet-mounted display was instrumental in providing isolation in virtual environments.

On the other hand, from a Gibsonian perspective, one can measure presence without the notion of subjective experience at all: presence is defined as tantamount to successfully supported action in the environment. Zahorik and Jenison (1998) claim that when the environment responds to the user's actions in a way which is perceived as lawful, presence is more likely to occur. Therefore they argue that presence should be measured by investigating the coupling between perception and action and assessing the degree of lawfulness between the virtual environment and the real world.

Whichever perspective one takes, we argue that presence is only a small part of the gaming experience: whereas presence is often viewed as a state of mind, we argue that immersion is an experience in time. Indeed, a double dissociation can be observed. Nunez and Blake (2006) make a distinction between presence games (e.g. role playing games, first person shooters) and non-presence games (abstract puzzles). However, we argue that even though games with simple graphics such as Tetris do not involve presence (i.e. it is unlikely you will feel like you are in a world of falling blocks) they can still be immersive, leading to time loss, not noticing things around you, etc. Presence is also possible without immersion: one could imagine a person feeling present in a virtual environment but not experience a lost sense of time (e.g. carrying out a boring task in a virtual simulation).

2.4. Immersion: the psychology of sub-optimal experience

In summary, immersion clearly has links to the notion of flow and CA and all three use things like temporal dissociation and awareness of surroundings as indicators of high engagement. However, immersion is concerned with the specific, psychological experience of engaging with a computer game. This need not be the most optimal experience, often falling far below being a fulfilling experience, nor even representative of a person's general experience of playing games. Immersion rather is the prosaic experience of engaging with a videogame. The outcome of immersion may be divorced from the actual outcome of the game: people do not always play games because they want to get immersed, it is just something that happens. It does seem though from previous work that immersion is key to a good gaming experience. The goal therefore of this paper is to be able to measure immersion so that we can better understand how people engage with videogames. Once we are confident we can reliably measure immersion, the long-term aim will be to understand what influences immersion and therefore how to develop better games.

3. Research questions

Given that gamers are able to identify immersion for themselves, yet the concept is rather under-defined, one aim of this paper is to consider player's subjective experiences of immersion, and develop an immersion questionnaire combining aspects of flow, CA and presence. By including a single question measure of immersion rating (i.e. rate how immersed you felt from 1 to 10) as well as a multiple question measure of immersion (a mixture of questions combining aspects of flow, CA and presence) we hope to overcome the problem Slater (1999) noted in the presence questionnaire; the concept being completely deterministic of its influencing factors.

Questionnaire measures can also be problematic because they rely on participants' subjective opinions (Slater, 1999). IJsselsteijn et al. (2000) explains that the search for objective measures to corroborate subjective measures is a common way to over come this problem. Whereas subjective measures require users to have a fair understanding of what it means to be "present" (or in this case, "immersed"); objective measures relate to user responses that are, in general, produced automatically and without much conscious deliberation. Therefore another aim of this paper is to relate these experiences to more quantitative, objective measures (task performance times, eye tracking). There were three experiments carried out in total.

Experiment 1 was founded on the premise that if a person becomes present in some alternative game world then there may be some measurable effect on their "return" to the real world. That is, in transferring from a game task to a real world task, the real world task performance would be impaired in proportion to the degree of immersion. The study did seem to indicate that this is the case but, as will be discussed, it is not clear what aspect of immersion is causing the effect and therefore whether it is immersion per se that is being measured by the real world task performance.

Considering non-intrusive measures that could be taken during an immersive activity, Experiment 2 is founded on the premise that as a person becomes more immersed in a game they might show a measurable change in their eye movements. Due to feedback from participants in these experiments, the immersion questionnaire was revised with simpler wording and the results from 244 participants were analysed in order to determine the factor structure of the questionnaire.

In Experiment 2, participants reported being immersed in what was supposed to be a non-immersive task, the user simply clicking boxes. As a result, Experiment 3 aimed to explore this further by investigating the variable of speed, the premise being that altering one component of a task will alter the immersive experience. As well as asking participants about their cognitive experiences, affective experiences were also measured through the State Anxiety Questionnaire and the Positive and Negative Affect Scale (PANAS).

4. Questionnaire development

The questionnaire is developed from findings of previous studies into the related areas of flow, CA and presence. Included are Agarwal and Karahana's (2000) five dimensions of CA: temporal dissociation; focused immersion; heightened enjoyment; control; curiosity. However, unlike the standard CA questions, the immersion questions relate to the particular experience of the given task rather than general experience of using software. These dimensions take a different approach to studies that focus on gaming as they measure the cognitive aspects of users' experience when using computer software. Clearly there is a great degree of overlap between games and general software usage and some of the factors found by Agarwal and Karahanna will be more relevant to gamers than others.

Other questions were derived from Brown and Cairns' (2004) study, namely: emotional involvement (empathising with a game's purpose or characters, wanting to speak out loud to the game, suspense about the game's events), transportation to a different place (how far disbelief about the game was suspended and to what extent participants felt that they were no longer attached to the real world), attention (distractibility by other thoughts, awareness of external events), control and autonomy (ease of controls, using the controls as travelling somewhere and interacting with a world).

Sixteen pairs of related questions were created (32 questions in total) using negative and positive wording in order to control for wording effects. Participants were asked how far they agreed with each of the statements as describing their experience of playing a game. Answers for each question were marked on a five-point scale, where 1 was strongly disagree and 5 was strongly agree. A final question was also included that asked how immersed the participant felt overall on a scale of 1 to 10, where 1 was not at all and 10 was very much so. Therefore there were thirty-three questions overall.

5. Experiment 1

5.1. Background of the experiment

Designing an intervention to reduce excessive game play, Eggen et al. (2003) created a physical agent that draws the player's attention away from the screen and invites the player to a non-keyboard physical interaction. They formulated the success of their intervention in terms of action space. When the player is immersed, his or her attention is focused upon the action space that is related to the game (i.e. the screen and the keyboard actions logically connected to it). Therefore if the player is forced to move their attention to the agent, the immersion must be broken. In other words, there are two interaction spaces and the player has difficulty switching between them.

Using this research as a basis, the goal of Experiment 1 is to relate the experience of immersion to the more objective measure of the time taken to complete a task in another action space. If a person is highly immersed in a game, one might predict that it would be more difficult for them to switch from the game space to the task space. As a result, their performance in the task will be impaired.

In order to manipulate immersion there are two conditions: in the control condition participants perform a simple button clicking activity and in the experimental condition the participants play the opening section of a first person shooter, *Half-Life*. The task is intended to require both cognitive effort and be physically based so that the participants really do have to switch from the game world into the physical real world in order to complete the task. The task chosen was a tangram task. These can be quite challenging and many people have not seen tangrams before. Thus, participants completed the task both before and after the game/control task so as to reduce the effect that novelty might have in impairing their ability to do the tangram.

5.2. Hypotheses

The main measures in the experiment were the subjective level of immersion as measured by a questionnaire of 32 questions, the time taken to complete the task before the experimental activity and the time taken to complete the task after the experimental activity. Naturally we expect the time to complete the task the second time to be quicker than the first time. However, immersion should interfere with the process. Accordingly, the hypotheses are:

1. The level of immersion in playing the game will be higher than the level of immersion in the control activity.
2. The improvement in task performance (as measured by task completion time) will be less in the experimental condition than in the control condition.

6. Method

6.1. Participants

Forty participants, all students from a London University, took part in this study. They had an average age of 21 (SD = 3.51), ranging from 18 to 36 years. Ten were male and thirty female.

6.2. Computer game and control task

In the experimental condition participants played Half Life, a 3-dimensional first person shooter game on a Dell Inspiron Laptop. Fig. 1 shows a typical view that a player would see whilst playing. Participants first played the ‘‘hazard training course’’ which required players to train their character through a series of tasks enabling them to become familiar with all the controls. The ‘‘hazard training course’’ gives participants maximum possible sense of control and autonomy, by gradually introducing controls to the participant within the game environment, whilst still maintaining a sense of purpose: to complete the course. The hazard training course takes between 10 and 15 min to complete depending on the skill of the player. Participants could begin the actual game once they had completed the course or at any point when they felt comfortable to proceed further. All game configurations were displayed on a paper placed in front of participants so all controls were instantly accessible to them, causing minimum disruption whilst playing. The game sound was played through speakers placed either side of the monitor, which helped to create an immersive atmosphere.

The control task was designed to be as minimally engaging as possible, whilst still being interactive with a computer interface. This was to demonstrate whether it was the computer game that created a sense of immersion or any form of computer interaction. The simple program was developed on Visual Basic 6.0, which presents a series of squares that appear and disappear in a regular pattern, as in Fig. 2. It was again performed on a Dell Inspiron laptop. Participants respond to the squares by clicking on them with the left mouse key when they appear, the square then disappears and reappears elsewhere on the screen. The squares appear at any point on an invisible 9×9 grid, for which the coordinates were generated randomly, to create the pattern that they would follow. The non-immersive task had no sound accompanying it.

Fig. 1. A screenshot from Half Life.

Fig. 2. The control task.

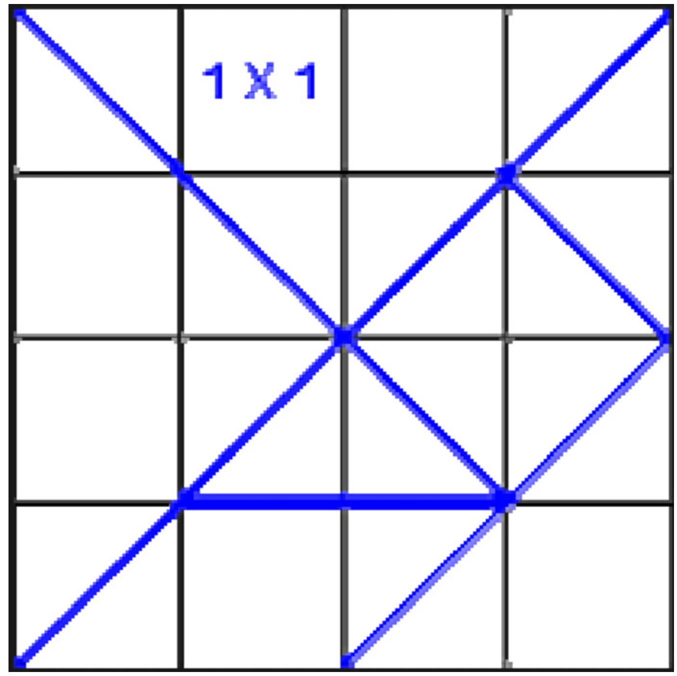

Fig. 3. Tangram pieces arranged as a square.

6.3. Tangram task

In principle the tangram task was selected as a task centred in and engaging with the "real world" as much as possible; which could contrast with the "computer game (or task) world". If there is a transition period just after breaking out of immersion as one re-engages with the real world, then the tangram task should cause the transition to take place. Assuming this transition period is prolonged by an increased level of immersion, this would imply that the time taken for an individual to complete the tangram task would reflect the extent to which that individual was immersed.

The tangram task was chosen for both its cognitive and physical elements. A solution can only be achieved by moving pieces, Fig. 3, around physically in the real world, and seeing the way in which shapes relate to each other. Though a solution could be achieved by purely reflecting on the task, the participants would still have to manipulate pieces to present the solution. Also, if participants do start to move pieces around, the repositioning of pieces can be used to indicate partial solutions. Participants are therefore required to directly engage physically and mentally in the real world and the physical engagement can aid in achieving the task.

Numerous tangram figures can be generated from tangram shapes, all of varying difficulty. Pre-tests were conducted to select an appropriate figure for construction that would be appropriately challenging and take a modest amount of time to complete. This would avoid swamping the transition time with problem solving ability or motivation. The final figure chosen, a fox as in Fig. 4, took on average 4 min to complete in the pre-testing.

6.4. Procedure

The basic structure of the procedure was that participants were given the tangram task to do first. They then performed either the control or experimental task and were interrupted after ten minutes to fill in the immersion questionnaire. They then continued for a further 10 min, after which they carried out the tangram task for a second time. The details are as follows.

Before beginning the computer game or task, participants were first presented with the tangram task that they would then re-perform after the computer task. This involved constructing the tangram figure from the tangram shapes. Pilots demonstrated that tangram task performance is affected by familiarity with tangrams so how the pieces can be used was demonstrated to give the participants some idea of what was required.

When presented with the tangram task at the beginning of the experiment, the tangram pieces were arranged into a square in front of participants, to give them an insight into how the pieces can be rotated and aligned to form new figures. From the square, participants were presented with the fox figure, which they were told they had to construct by rearranging the square to make the new figure. It should be noted that the fox figure shown participants was not quite like Fig. 4 in that the white lines outlining the pieces were omitted.

The time taken for participants to construct the new figure was recorded. Participants were told that they would return to the tangram task later. Participants were then presented with the computer game or task, depending on if they had been assigned to the control or experimental condition. When presented with the computer game, participants were introduced to the game's purpose and explained its format. The first essential movement controls were demonstrated to them and they were then told that the rest of the controls they would need were on the paper

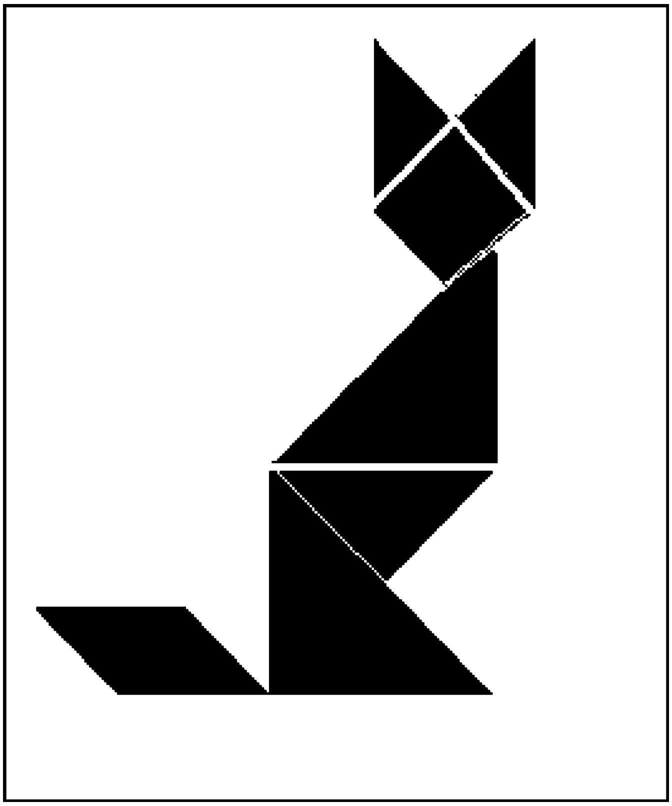

Fig. 4. The fox figure.

in front of them. Participants first played the hazard training course but could move straight to the game at any point. This allowed participants to control their own development through the game, reducing the barrier of access (Brown and Cairns, 2004) which is affected by interest, investment and usability of controls. Therefore less advanced players were not overwhelmed by difficult controls and more advanced players would not be bored by over-simplicity. It also avoided any external interruptions not part of the world created by the game.

Participants given the control task were told that they would have to follow a square that would appear and reappear elsewhere on the screen once they responded to it by pressing it. In order to minimally engage participants, they were also told to be as accurate as possible whilst playing. Participants were told that they would have to perform the computer game or control task, for 10 min after which time they would be interrupted. The warning avoids startling participants and so the interruption has less impact on the task in hand (Trafton et al., 2003).

After 10 min of engaging with the task, participants were interrupted and made to fill in the immersion ratings questionnaire. Basing their responses on the moment just prior to interruption, participants rated how far their own experiences matched with those described in the questionnaire. Participants then resumed the game or task, again they were warned that they would be stopped after 10 min, following which participants were made to return to the tangram task.

On the second attempt, the tangram square was preconstructed from which they were made to reconstruct the tangram figure made earlier, the time taken to do so was recorded. Participants were not questioned on immersion at the same time as doing the task, as the questioning before the task may result in loss of the effect of immersion, and questioning after the task may mean that their experience of immersion is moderated by their ability to do the task.

7. Results

All statistical analyses were performed using SPSS 11.0. The immersion scores were calculated based on 0 for a strongly disagree to an immersion question and 4 for strongly agree. This was also adjusted appropriately for the positive or negative versions of the questions. As predicted in the first hypothesis, the experimental mean was higher than the control mean: 69.6 and 52.5, respectively (and corresponding standard deviations of 18.2 and 17.2). As there was no requirement on the immersion scores to be normal, these were compared non-parametrically and found to be significantly different (Mann–Whitney $U = 96$, $p = 0.005$). As it happened, the data across both conditions did fit well with a normal distribution and the corresponding t-test gave identical probabilities.

To test for the effect of immersion on task performance, the difference between the pre-test and post-test times was found. As expected, apart from two participants, the time to complete the task the second time was less than the first time. It is not clear why these two participants failed to improve their task time so they were not included in all subsequent analysis. The hypothesis predicts that the more immersed a person is, the smaller the difference between the two task times (i.e. they would improve less in the tangram task). As the experimental and control conditions should only affect immersion, the differences and immersion scores were correlated across both conditions and a significant correlation was found (Spearman's $\rho = -0.45$, $p < 0.005$). That is, as predicted, the time difference is less the greater the immersion.

Using regression to consider the effect size, a one point change in immersion corresponded to a 4.2 s reduction in the time difference. Thus, the effect is appreciable on the range of immersion scores found in this study. Surprisingly, when divided into the two conditions, the correlation between immersion and task time difference was not significant in the control condition. The second tangram task completion times between the two conditions were also compared but again there was no significant difference.

8. Discussion

The hypothesis, that the level of immersion in playing the game would be higher than the level of immersion in the control activity, was supported. The immersion score obtained in the experimental condition was significantly higher compared to that of the control condition. The questionnaire was generally successful in obtaining an immersion score, and demonstrated normal distributions in the level of immersion reached in either of the two conditions. Therefore, one can conclude that as a first attempt at developing a questionnaire to measure immersion, Experiment 1 was successful.

The second hypothesis, that the improvement in task performance (as measured by task completion time) would be less in the experimental condition than in the control condition, was also supported. As predicted, the relationship between task time change and immersion score was found in the experimental condition only, demonstrating that a proportion of variability in time change in the experimental condition could be accounted for by variability in immersion score. Therefore the results suggest that being increasingly immersed in a game decreased one's ability to re-engage with the "real world", supporting to some extent the idea of a transitional period between coming out of immersion in the "world of the game", and returning to the "real world".

This effect however was not observed in the simple computer task, perhaps because any immersive effects are diluted by other factors unaccounted for by the model. It also suggests that the computer game enabled a higher level of immersion to be reached and potentially had a greater impact on performance.

Another interpretation of the second hypothesis would be that, due to lower immersion, the control condition task time differences should have been higher than the experimental condition's. However, this was not found. Therefore, it is possible that the effects observed by the computer game may be due to other unknown factors which have influenced task performance on the tangram task and that also correlated with the immersion questionnaire, rather than immersion itself.

Whilst measuring immersion (half way through gameplay) and measuring the second task attempt (at the end of gameplay) were performed at separate times for a good reason, it is still possible that the immersion at the end of the playing experience was not the same as the point at which it was measured. Also, the very interruption used to measure immersion might have led to reduced immersion in the remainder of the experimental activity.

Furthermore, the tangram task took quite a long time. The average task completion time in the second condition was 61 s and a standard deviation of 33 s. It was not clear whether any effect of immersion could be considered present after a minute of working on the task. Therefore, perhaps the measured time difference in completion times is caused by how much learning has taken place from a person's first try to their second try, rather than a person's ability to re-engage with the real world. Immersion may be interfering with the "mulling over" of the tangram task which may explain why it is having an effect in the experimental condition but no effect in the control condition, as in the latter there is plenty of time for consideration.

Thus, one can conclude that whilst this experimental approach offers hope that some sort of objective measure of immersion is feasible, it is clear that there are many problems in setting up a dual task situation of this sort. Instead, we turn to consider non-intrusive measures that can be taken during an immersive activity, namely eye tracking.

9. Experiment 2

9.1. Background of the experiment

The human gaze reveals information about the user's intention and attention, providing a porthole into his/her current cognitive processes (Toet, 2006). As a result eye tracking has become an increasingly popular methodology for measuring attention, and with recent developments in technology it is becoming increasingly reliable too. In the past eye tracking has been used to analyse how people read, perceive scenery, artwork, and films (Duchowski, 2003). Recently, eye tracking has also been used to investigate how people perceive websites (Silva and Cox, 2006) and attentional paradigms such as inattentional blindness (Koivisto et al., 2004; Pappas et al., 2005; Memmert, 2006) and change blindness (Hollingworth et al., 2001; Treisch et al., 2003). However, when it comes to studying how people perceive computer games, very little is known.

El-Nasr and Yan (2006) explain that part of the difficulty in studying eye tracking in relation to computer games lies in the complexity of the 3-D game environment: the content of the screen is changing all the time. Furthermore, comparing visual attention patterns between two games is difficult because one would naturally expect them to differ due to their differing content. For example, in games with a first person perspective (i.e. your character is "invisible", the screen content changes as a result of your character's movement) the player paid attention only to the centre of the screen, where the cross of their gun was located. On the other hand, in games with a third person perspective (i.e. your character is a small part of the screen) the player's visual pattern is quite different, covering more area of the whole screen. In Experiment 2, we decided to avoid these problems by investigating how eye movements changed over time within games (immersive and non-immersive), rather than comparing eye movements between games. As immersion is a gradual process, it seemed reasonable to expect that immersion would be associated with a change in visual attention, and hence a change in eye movements.

There are two main types of eye movements: saccades and fixations. Saccades are the fast movements that redirect the eye to a new part of the surroundings. Fixations are the intervals between saccades in which gaze is held almost stationary. Land (2006) explains that it is during fixations that people take information in: during saccades we are effectively blind. Measures of fixation include two attributes: the fixation duration (i.e. the time spent investigating a local area of the visual field) and the number of fixations (i.e. the number of times the eye stops on a certain area of the visual field). Longer fixation duration implies more time spent on interpreting or processing a target (Toet, 2006). If one chooses to study fixation change over time however, it is inevitable the fixation duration and the number of fixations will be inversely related, i.e. a high number of fixations per second imply fixations are of a short duration, whereas a low number of fixations per second imply that fixations are of a long duration. Therefore one can choose to report either fixation measure in such a method. In Experiment 2, number of fixations per second will be reported.

Past research suggests that when participants are in a low alertness state they have slower saccades (i.e. participants are slower to redirect their eyes to new parts of their surroundings) and there is a decrease in pupil diameter, suggesting that less information is perceived (Ueno and Uchikawa, 2004). During computer tasks with a high cognitive workload on the other hand, pupil dilation increases (Takahashi et al., 2000; Marshall, 2005) and saccadic eye movement time increases (Takahashi et al., 2000), suggesting that more information is perceived. Furthermore, blinks are inhibited during periods where information is expected, presented and processed (Fukada et al., 2005) and fixation duration increases upon detection of a critical stimulus (Velichkovsky et al., 2000). In accordance with such findings, Styles (1997) suggests that visual attention can be compared to a zoom lens: initially attention is widely distributed over all elements of the display, but then attention is narrowed down and becomes more fixed. Therefore, one might predict that for an immersive game an individual's number of fixations per second will decrease, as their attention becomes more focused. In contrast, for a non-immersive task an individual's number of fixations per second might increase, as they are more likely to become distracted.

Due to the complexity of computer games however there is also rationale for the exact opposite: rather than eye movements becoming more fixed as time progresses, alternatively one might predict that as a gamer becomes more immersed in the game and attempts to take in the whole scene while meeting the demands of the task their number of fixations will increase. In contrast, for a non-immersive task one might predict that an individual's eye movements will decrease over time; not necessarily because the person is focusing in on the task but because they are more likely to "drift off" as they become bored.

9.2. Hypotheses

Given the potential offered by eye tracking, we propose here hypotheses that build on the first experiment in trying to find objective measures of the degree of immersion experienced by people as they play games. The hypotheses address these ideas by considering participants' changes in eye movement (i.e. number of fixations) while they engage in either the immersive or non-immersive task. The immersion questionnaire used above will still be used to assess the validity of these behavioural measures in relation to immersion. For example, one might predict that participants who exhibit changes in eye movements associated with immersion should have higher self-reported ratings of immersion than participants that did not exhibit such changes in eye movements.

Overall, the study has three main hypotheses:

1. The level of immersion in playing in the immersive condition will be higher than the level of immersion in the non-immersive condition.
2. Participants in the immersive condition will show a different change in eye movements (i.e. number of fixations) over the time than participants in the non-immersive condition.
3. Subjective self-reported immersion ratings will correlate with these changes in eye movements.

10. Method

10.1. Design

The experiment was an independent measures design. Participants completed one of two tasks: a non-immersive task (simple graphics, clicking boxes) or an immersive task (complex graphics, exploring a virtual environment). In both tasks eye tracking was used to explore how the participants' eye movements changed during the task (i.e. the number of fixations, fixation duration). The participants' level of self-reported immersion was also measured.

10.2. Participants

Overall 41 participants took part in the study, 21 in the non-immersive condition and 20 in the immersive condition. In terms of gender, 19 were female (46.3%) and 22 were male (53.7%). Ages ranged from 18 to 39 years, the mean age being 25.39 years. Participants were recruited through an opportunity sample. They were all fully debriefed at the end of the experiment and paid £6 for taking part.

10.3. Immersion questionnaire and experimental tasks

The immersion questionnaire previously described was used to measure self-reported levels of immersion after the task (see Section 4 for more details). Both a multiple measure of immersion (consisting of 32 questions) and a single measure of immersion (consisting of 1 question) were calculated for each participant.

The non-immersive task and the immersive task were also the same as used in Experiment 1. Both the immersive and non-immersive task were run for a duration of 10 min each (not including practice time).

10.4. Eye tracking equipment and other apparatus

Eye movements were recorded using a Tobii 1750 eye tracker, set up as a double computer double screen configuration. Data was collected by Clearview 2.4.1. A web camera (connected to the eye tracker) and a video camera (positioned on a tripod) were also used to track the participants' body motion during the tasks. The cameras were placed anterior and lateral, in order to record both a front view and a side view of the person's head and torso. These results were part of a separate analysis and were reported in a separate analysis (Bianchi-Berthouze et al., 2006).

10.5. Procedure

First participants were assessed for two personality traits that were thought to be linked to immersion: absorption and openness of experience (part of a separate analysis, not to be reported in this paper). Then the experimenter explained to the participants that their eye movements and body motion would be recorded while they engaged with a task/game. Participants were instructed to sit close enough to the monitor so that their eye movements could be calibrated on the eye tracker. The experimenter also checked that from this position the two cameras were able to get a good picture of the participant (anterior and lateral).

Upon completion of calibration, participants were then presented with either the non-immersive task (clicking squares) or the immersive task (playing the first person shooter Half Life). Allocation to each condition was random for all participants. Instructions and practice for each task were the same as Experiment 1.

In both conditions participants were told beforehand that they would have 10 min to perform the task, after which time the experimenter would re-enter the room. Participants were then asked to fill out an immersion questionnaire rating their experiences in the task. After completing the questionnaire, all participants were fully debriefed and received payment.

11. Results

11.1. Overview of results

Statistical analyses were performed using SPSS 11.0. As well as analysing eye gaze data trends within the conditions, we thought it would also be informative to compare the eye gaze data of participants that scored highest on immersion and participants that scored lowest on immersion, in a short qualitative analysis. Therefore results will be presented in the following order: eye gaze data trends within conditions, subjective immersion ratings, and qualitative analysis.

11.2. Eye gaze data trends within conditions

When analysing the mean fixations for the control and experimental tasks, we decided to analyse eye data from 300 to 600 s (5–10 min into the task), as we hoped that participants would be reasonably adjusted to the controls and if they were to become immersed, now would be the time. Four participants were excluded from this analysis as there was not enough fixation data, i.e. the majority of their eye gaze was not recorded during the specified time period of 300–600 s. These were P4, P24, P25 and P29 ("P" is used to denote "Participant Number" in this context).

In order to display the results of the analysis, two graphs were created. Each point on the graph represents the mean number of fixations calculated for a second of the task, e.g. the 300th second, the 301st second, etc.

As can be seen in Fig. 5, the mean number of fixations for participants in the non-immersive condition increased over time. The Spearman's correlation between time and the mean number of fixations in the non-immersive condition was 0.518 and significant (Spearman's $\rho = 0.518$, $p < 0.001$). The R-square value indicated that 26.4% of the variability could be accounted for by the regression model.

The mean number of fixations for participants in the immersive condition on the other hand decreased over time, see Fig. 6. The Spearman's correlation between time and the mean number of fixations in the immersive condition was -0.191 and significant (Spearman's $\rho = -0.191$, $p < 0.05$). The R-square value indicated that only 4.3% of variability could be accounted for by the regression model.

11.3. Subjective immersion ratings

The immersion questionnaire used included both a single question measure of immersion (i.e. "rate how immersed you felt from 1 to 10...") and a multiple question measure of immersion (consisting of several questions about emotional involvement, transportation,

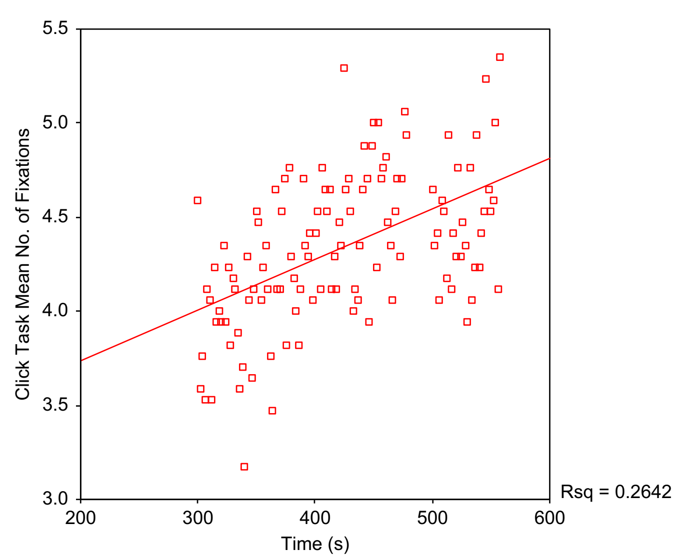

Fig. 5. Mean number of fixations per second for the non-immersive condition.

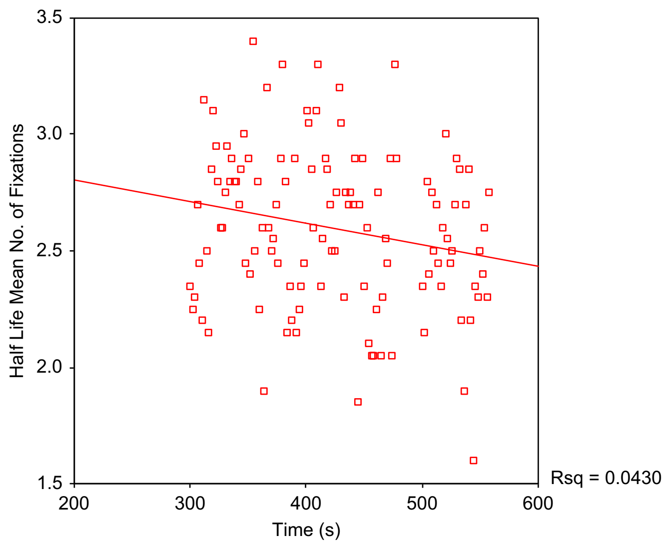

Fig. 6. Mean number of fixations per second for the immersive condition.

control and autonomy, etc.). For the single question measure of immersion, participants in the immersive condition rated it as significantly more immersive than participants in the non-immersive condition (Mann–Whitney $U = 89.5$, $p < 0.005$), the mean immersion ratings being 6.3 (SD = 1.69) and 3.9 (SD = 2.30), respectively. For the multiple question measure of immersion, participants in the immersive condition also rated it as significantly more immersive than participants in the non-immersive condition (Mann–Whitney $U = 60$, $p < 0.001$), the mean immersion ratings being 66.0 (SD = 13.55) and 44.9 (SD = 15.20).

Spearman correlations were carried out on the two immersion measures and they were found to be significantly positively correlated with one another (Spearman's $\rho = 0.724$, $p < 0.001$), within both the immersive condition, (Spearman's $\rho = 0.753$, $p < 0.001$), and the non-immersive condition (Spearman's $\rho = 0.580$, $p < 0.01$).

These findings appear reliable, as confounding variables such as the participants' age, gender, personality questionnaire order, immersion questionnaire version, and testing location, were all found to have non-significant correlations with both single and multiple question measures of immersion.

For the single question measure of immersion, in the immersion condition immersion ratings ranged from 3 to 10, while in the non-immersive condition immersion ratings ranged from 1 to 8. Similarly, for the multiple question measure of immersion, in the immersive condition immersion ratings ranged from 39 to 96, while in the non-immersive condition immersion ratings ranged from 13 to 68.

As a result of such variance, one can question why some participants found the experimental task immersive, while others did not. Similarly, why did some participants find the control task engaging, while others did not? Would a comparison of eye gaze data between such participants be useful in helping us to understand these questions? Choosing the four participants that had the highest and lowest immersion scores from each condition, fixation data were analysed again for the time period 300–600 s.

The mean number of fixations for low immersed participants in the "non-immersive" condition (P1, P3, P27, P29) significantly increased over time (Spearman's $\rho = 0.724$, $p < 0.001$). The R-square value indicated that 53.8% of variability could be accounted for by the regression model. In contrast, the mean number of fixations for highly immersed participants in the "non-immersive" condition (P2, P6, P23, P28) showed no significant change over time (Spearman's $\rho = -0.105$, $p > 0.05$).

For the immersive condition however a different pattern of results was found. Whereas the mean number fixations for low immersed participants in the "immersive" condition (P19, P33, P36, P38) showed no significant change over time (Spearman's $\rho = -0.037$, $p > 0.05$); the mean number of fixations for highly immersed participants in the "immersive" condition (P12, P17, P18, P41) significantly decreased over time, Spearman's $\rho = -0.312$, $p = 0.001$). A regression analysis was also significant, $F(1,118) = 10.953$, $p = 0.001$. The R-square value indicated that 8.5% of the variability could be accounted for by the regression model.

It was decided that a qualitative analysis should be carried out to add to this comparison.

11.4. Qualitative analysis

For the non-immersive condition, watching the eye tracking footage of the participants revealed very little. P6, P23 and P28 (all highly immersed) had eye paths that seemed much straighter when travelling from one target to another compared to P1, P3 and P29 (low immersion), but P2 (who was also highly immersed) failed to show this similarity.

After the task, some participants had commented that they had made the non-immersive condition a game for themselves by trying to see how quick they could click the targets, seeing whether they could predict where the target would appear next, etc. Following this lead, we carried out Spearman correlations on the mouse click data. The Spearman correlation between the mean number of mouse clicks and the mean number of fixations in the non-immersive condition was 0.140 and non-significant. As can be seen in Fig. 7, regression lines reveal that the number of mouse clicks fail to increase to the same extent as the number of fixations.

For the immersive condition, the qualitative analysis was a bit more revealing. P17 and P12 (high immersion) seemed to find it much easier to control their movement in the task, while P19, P36 and P38 (low immersion) sometimes walked into walls and had more jerky movements. In the practice session, it was also noted that P12 was one of the only participants to attempt to use the mouse (which controlled motion of the head) and the keyboard (which controlled motion of the body) at the same time (most participants choosing to only use the keyboard until the mouse was

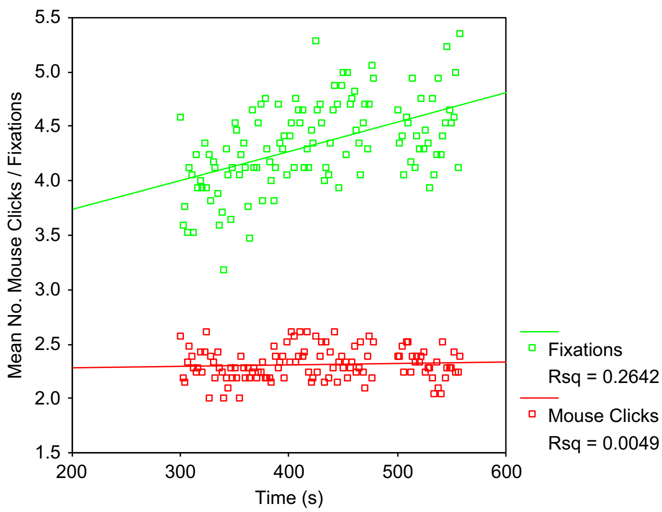

Fig. 7. Mean number of mouse clicks per second and mean number of fixations per second in the non-immersive condition.

necessary), which led to a more natural movement when travelling around the virtual environment.

P17 noticeably made rather quick progress in the game—he was one of two participants in the sample that mentioned they had played the computer game Half Life before. Previous gaming experience had not been considered when recruiting participants in Experiments 1 and 2, but will definitely be considered in future studies. One could suggest that this prior experience gave P17 an advantage in the task, as he had a good idea of what he had to do. In contrast, other participants who had not played the game before such as P19 commented "I just didn't get it."

However, prior experience cannot be all that matters as P12 had never played the game before but yet had the third highest immersion rating in the overall sample. Watching his gaze replay revealed that compared to P19 and P36 (low immersion), P12 was much more exploratory from the outset. In entering the first room in the building, P12 was one of the only participants that did a full circle in order to scan the whole room, looking at maps and signs on the walls. P12 also tried speaking to characters, and when entering new rooms again explored them fully, as if looking for clues.

In contrast to P17 (also highly immersed), P12 did not progress as far but did show a lot of perseverance. In one part of the game in which the player must access a special suit that is locked in a transparent box, P17 could be seen making a number of different attempts to access the suit, before finally reaching the right one. Therefore, like P19 (low immersion) who "just didn't get it", one could suggest that P12 was also unsure at times in the game. However, rather than viewing it as bad experience P12 viewed it as a chance to do some problem solving and persevered through.

12. Discussion

The hypothesis, that the level of immersion in the immersive condition would be higher than the level of immersion in the non-immersive condition, was supported. The immersion scores obtained in the immersive condition (both multiple and single question measures) were significantly higher compared to that of the control condition. Therefore like Experiment 1 again it would appear that the immersion questionnaire developed was a successful indicator of immersion, and people can reliably reflect on their own immersion in a single question.

The second hypothesis, that participants in the immersive condition would show a different change in eye movements over the time than participants in the non-immersive condition, was also supported. Fixation data revealed that participants' eye movements significantly increased over time in the non-immersive condition. In contrast, participants' eye movements in the immersive condition significantly decreased over time.

These findings support the idea that for a non-immersive game an individual's eye movements will increase, as they are more likely to become distracted by other items in the visual display irrelevant to the game. In contrast, for an immersive game, an individual's eye movements will decrease as their attention becomes more focused on visual components relevant to the game. Similar decreases in eye movements have been found in studies in the visual attention literature (e.g. Velichkovsky et al., 2000), therefore visual attention can be compared to a zoom lens (Styles, 1997).

The third hypothesis, that subjective self-reported immersion ratings would correlate with these changes in eye movements, was somewhat supported. Analysing data from participants that had the highest and lowest immersion scores in the non-immersive condition (clicking task), it was found that the eye movements of the four participants with the lowest immersion scores significantly increased over time; whereas the four highest immersed participants showed no significant change in eye movements over time.

Some participants had commented that they had made the non-immersive condition a game for themselves by trying to see how quickly they could click the targets, if they could predict where the target would appear next, etc. However, a further analysis comparing fixation data and mouse click data revealed that the increase in fixations in the non-immersive condition was not a result of participants clicking the target square quicker. Therefore, again one might suggest that the increase in eye movements shown in the four lowest immersed participants was a result of them becoming restless and growing distracted.

When analysing data in the immersion condition (Half Life) however, a different pattern of results was found. This time it was the four lowest immersed participants' eye movements that showed no significant change over time. In contrast, the four highest immersed participants' eye movements significantly decreased over time.

The tasks within the two conditions are clearly very different and so it is difficult to make direct comparisons in terms of why such different patterns of eye movements were found in each. One might suggest that even though some people rated themselves as highly immersed in the clicking task, it is unlikely that they were immersed to the same extent as those playing Half Life (hence no significant decrease in eye movements). Similarly, even though some people rated themselves as having low levels of immersion when playing Half Life, it is unlikely that they were non-immersed to the same extent as those in the clicking task (hence no significant increase in eye movements). However, it must be emphasised that these proposals are only tentative.

Another problem is that one could easily imagine a situation where a person carries out a task requiring their eye movements to decrease over time, but yet they are not immersed. Therefore, one can conclude that although eye tracking is a more objective measure of immersion, it is unlikely to always be a reliable measure of mental states.

However, this does not necessarily mean that eye tracking does not have its benefits for immersion research. In Experiment 2 we found the ability to replay a person's eye gaze and watch how they travelled through the virtual environment particularly useful. Progression through the game, exploration of the environment and perseverance were highlighted as key behaviours exhibited by the four highly immersed participants in the immersive condition. From such findings the question arises why is it that some participants might take a certain attitude towards game playing while others do not? Also, one could question whether the participants' attitudes were specific to this game or are representative of their immersive experiences in general (e.g. perhaps P19 just does not like problem solving games)? In a follow-up study, it could be interesting to replay the eye gaze footage back to participants after testing, asking them to talk through their thoughts. What were they thinking during the different stages of the game? Which moments did they feel really immersed?

Overall it is evident that Experiment 2 was valuable as an exploratory study, raising a number of issues for future study. One of the most interesting findings, not predicted in terms of immersion ratings, was the amount of variability within each condition. Researchers were surprised to find that some participants actually rated the clicking task as immersive, rating it as high as 8 out of 10 in the single question measure of immersion. Similarly, for the multiple question measure of immersion, in the immersive condition immersion ratings ranged from 39 to 96, while in the non-immersive condition immersion ratings ranged from 13 to 68. Although the clicking task might have led to participants experiencing some aspects of immersion, again we would argue that it is unlikely that true immersion could have occurred in such a task. Instead participants might have experienced some of the features associated with immersion (e.g. high concentration, loss of time). We suspected that this could be due to the speed of interaction with the interface in the clicking task. Investigating this further was the impetus for Experiment 3.

13. Further refinement of the questionnaire

In Experiments 1 and 2 the mixture of negative and positive wording of questions was found to be confusing to participants at times. Therefore a new questionnaire was developed with simpler wording.

The questionnaire was divided into six sections in total. The first three sections were concerned with varying degrees of attention to the task: basic attention (e.g. To what extent did you feel you were focused on the game?), temporal dissociation (e.g. To what extent did you lose track of time?), and transportation (e.g. To what extent was your sense of being in the game environment stronger than your sense of being in the real world?). These factors were drawn from past work on flow, CA, presence and Brown and Cairns's (2004) grounded theory of immersion. Although the clicking task does not have the features necessary for presence to occur we believe that some form of transportation, feeling that you are no longer attached to the real world (although not feeling that you are in an alternate world), would be the next closest thing possible to experience in such a task.

As well as attention, there are a number of task factors that are likely to influence whether immersion is experienced. In flow theory, Csikszentmihalyi (1990) emphasises that there needed to be a balance between ability level and challenge. Similarly, we would predict that a game that is too difficult and leads to too much anxiety would not be immersive. Emotional involvement is another important factor, highlighted by Brown and Cairns (2004) as a barrier to total immersion: gamers who did not feel total immersion talked of lack of empathy and the transfer of consciousness. Also, Brown and Cairns (2004) report that immersive experiences are thought to be enjoyable experiences, by reviewers and gamers alike. As a result, the next three sections were concerned with factors that could influence a person's motivation during the task: challenge (Did you find the task too difficult?), emotional involvement (Did you care if you won or lost?), and enjoyment (Did you like the task?).

The questionnaire consisted of 31 items overall: basic attention (4 questions), temporal dissociation (6 questions), transportation (6 questions), challenge (6 questions), emotional involvement (5 questions) and enjoyment (4 questions). Participants are asked to rate from a scale of 1 to 5 how they felt at the end of the game (where 1 = not at all and 5 = very much so). The majority of questions are marked positively; only 6 are subjected to negated marking (Q6, Q8, Q9, Q10, Q18, Q20). Immersion scores are computed by summing participants' answers to all 31 questions.

13.1. Validation of the questionnaire

In order to validate and analyse the questionnaire and to ensure that the questions fall in to factors similar to those from which they were originally drawn the questionnaire was administered to a large sample and a factor analysis was conducted on the results.

13.2. Participants and sampling

Two hundred and sixty participants were recruited via adverts posted on Internet message boards and forums. The adverts contained a simple description of the task and a link to the study homepage. Here participants were informed that in order to participate they should be over the age of 18 and have played a computer game in the last week. In order to collect a wide sample that included gamers used to a variety of genre preferences and platforms, adverts were posted in all of the top 10 most popular gaming forums and in forums dedicated to the top 10 games (by sales) of 2006. Of the 260 respondents 16 filled in the form incorrectly or failed to answer a sufficient number of questions, these were removed from the final analyses. Two hundred and thirty of the remaining 244 were male (94.3%) and only 14 female (5.7%). Respondents were not rewarded for their participation.

13.3. Procedure

The survey was performed on an online form that consisted of 3 pages; the first was an introduction containing the requirements for participation in the study, further information about the researcher, confidentiality and ethics. By agreeing to take part in the study the participants were taken to a second page which collected demographic information and the questionnaire data. Responses were made by typing in demographic information, e.g. number of hours spent playing games per week, or by selecting the most appropriate response from a drop down list of Likert scale responses situated next to each statement from the questionnaires. When responding to the immersion questionnaire it was made clear that responses should be made based on their most recent gaming experience. When the end of the page was reached participants submitted their information by clicking on a button, this sent their data to the researcher via an email, informed the user of this and provided some debriefing information about the study.

13.4. Results

The data were checked for sampling adequacy, which showed that the overall KMO value was 0.845 and individual values ranged from 0.926 to. 0.590. Bartlett's test of sphericity was also found to be highly significant ($p<0.001$). Therefore the data were deemed fit for factor analysis.

An initial principal components analysis (PCA) revealed one omnibus factor that included all but 6 of the 31 questions, along with 7 other factors with eigenvalues greater than 1. The size of the omnibus factor indicated that the questionnaire as a whole measures the same underlying concept, although there are several underlying components which should be investigated.

Five main factors were identified, using Cattell's scree plot method. These five factors accounted for 49% of the total variance. The direct oblimin rotation provided a far more interpretable solution than the varimax rotation. Based on this rotation, two matrices were produced, a pattern matrix and a structure matrix. The difference between the high and low loadings was far more apparent in the pattern matrix, and it also had fewer complex variables and simpler structure. Therefore the pattern matrix was interpreted (see Foster et al., 2006 for more information on interpreting a factor analysis).

The five factors produced were seen to have common themes in the questions they contained and as such were given the tags *Cognitive Involvement, Real World Dissociation, Challenge, Emotional Involvement* and *Control*. Therefore the questionnaire appears to be measuring a mixture of person factors (cognitive involvement, real world dissociation, emotional involvement) and game factors (challenge, control).

14. Experiment 3

14.1. Background of the experiment

In this experiment we decided to investigate the effect of a person's pace of interaction with the computer interface. The motivation behind this research direction comes from the findings of Experiment 2, in which researchers were surprised to find that some participants actually rated the supposedly non-immersive task as highly immersive. We suspect this result could be due to the pace of the non-immersive task itself. Being self-paced, this meant that as soon as the participant clicked one box another would appear, leading to the user having a fast interaction with the computer interface. Some participants even reported liking the task, as they tried to see how fast they could click each box. In contrast, if there was a time delay between how fast one box appeared after another no matter how fast the participant clicked it (i.e. speed being externally paced rather than self-paced), we doubt that such high ratings of immersion would have been experienced.

The importance of speed has also been highlighted in other studies. For example, Ip and Jacobs (2004) carried out a quantitative study in which they analysed various game characteristics of rally games. They found that games rated as "good"/"average" had stage times of around 2 min, whereas games rated as poor had stage times of roughly 3.5 min. Similarly, games rated as "good" had a typical loading times of 15 s between stages, whereas games rated as "poor" had a typical loading time of around 40 s. Therefore, it would appear that the quicker the game, the more enjoyable it is. One possible reason that quicker games might be more immersive is because they require the gamer to use high-attentional resources. By requiring a fast speed of interaction, gamers are presented with a challenge which involves higher levels of concentration and effort. As a result, they must focus on the computer interface more in order to progress in the game, which distracts them from their real environment.

On the other hand, one can argue that slow games require high levels of concentration too. For example, in testing for attention deficit disorder (ADD) the Test of Variables of Attention (TOVA) analyses children's responses to a boring repetitive task with infrequent stimuli. Such a task is slow-paced and attentionally demanding, which is why the TOVA provides a good measure of ADD. However, it is extremely unlikely that such a task would lead to immersion. Therefore it is evident that although attention is an important factor, immersion in fast computer games is caused by more than attention alone.

Instead, a second (more likely) reason that quicker games might be more immersive is because they lead to higher levels of anxiety, as well as requiring high levels of attention. Renaud and Blondin (1997) found that when completing an attentionally demanding task, state anxiety scores increased only for participants in the self-paced and fast externally paced groups (not the slow externally paced group). Expanding upon this, one can suggest that when playing fast computer games the challenge of keeping up with the pace allows the gamer to become more emotionally involved in the game. The gamer is more likely to feel anxious about failure, leading to more effort and attention, and hence more immersion. However, with this anxiety also comes certain benefits—if a gamer is able to make progress in the game (i.e. overcoming a particularly difficult stage) they are more likely to experience joy, as they feel that they have accomplished something difficult.

14.2. Hypotheses

This study aims to investigate the relationship between immersion and pace of interaction with the computer interface by comparing the subjective ratings of immersion and state anxiety of participants within four speed conditions: slow externally paced, fast externally paced, increasing externally paced, and self-paced (speed emphasised). The task used is very similar to the "non-immersive task" used in Experiments 1 and 2, except with the relevant speed modifications. As well as state anxiety, the Positive and Negative Affective Scale-X (PANAS-X) will also be used to explore whether any other emotions are effected by speed.

Overall there are three main hypotheses:

1. Participants in the four speed conditions will vary in terms of the amount of immersion they experience. Participants in the fast externally paced condition will rate themselves as more immersed than participants in the self-paced condition, who in turn will rate themselves as more immersed than participants in the slow condition. The increasing pace condition will be the most immersive of all, as the user has a feeling of progression and the task is not too challenging.
2. Participants in the four speed conditions will also vary in terms of the amount of state anxiety they experience (measured by the State Anxiety Questionnaire). Participants in the fast externally paced condition will rate themselves as more anxious than participants in the self-paced condition, who in turn will rate themselves as more anxious than participants in the slow conditions. Participants in the increasing pace condition will report a moderate level of anxiety.
3. As well as state anxiety, participants in the four speed conditions will differ in levels of other affective states (measured by the PANAS-X), namely positive affect and negative affect.

15. Method

15.1. Participants

There were thirty-six participants in total, nine in each condition. The majority of participants were university students, recruited through an opportunity sample. In terms of gender, 19 were female (52.8%) and 17 were male (47.2%). Ages ranged from 17 to 42 years, the mean age being 24.6 years.

15.2. State questionnaires

The State Anxiety Questionnaire (Spielberger et al., 1970) was used to measure state anxiety. It consisted of 20 statements (e.g. "I felt calm") and asked participants to rate on a scale from 1 to 5 how they felt at the end of the game (where 1 = not at all and 5 = very much so).

The PANAS-X (Watson and Clark, 1994) was used to measure other affective states, namely positive and negative affect. It consisted of 60 items (e.g. "I felt alert") and asked participants to rate on a scale from 1 to 5 how they felt at the end of the game (where 1 = not at all and 5 = very much so).

As well as questionnaire measures, two video cameras were used to record the participants' body motions during the task (positioned the same as Experiment 2) and biosensors were used to measure participants' stress levels. Again, these results were part of a separate analysis and will not be reported in this paper.

15.3. Experimental task

The task was run on a Gateway laptop and was the same clicking boxes task used in Experiment 1 and 2, except with the relevant pace modifications. In the self-paced condition clicking one box led to the immediate appearance of the next box. In comparison, the other conditions were externally paced (i.e. the task continued at a designated pace whether or not you clicked the target button, and the speed of your clicking has no effect). In the slow condition each box appeared and then disappeared every 3 s for the full 10 min. In the fast condition each box appeared and disappeared every 0.7 s. In the increasing paced condition on the other hand, the boxes appeared and disappeared every 3 s in the first minute, increasing by 0.26 s every minute so that by the 10th minute the boxes appeared and disappeared every 0.7 s. So in essence, the increasing pace condition is increasing from same speed as the slowest condition to the same speed as the fastest condition).

15.4. Procedure

The experiment was an independent measures design. Participants were randomly assigned to one of four conditions: self-paced, slow-paced, fast paced and increasing pace. Participants were informed that they would be playing a simple clicking game for 10 min. As extra motivation, the experimenter instructed the participant to click the boxes as quickly as they could, as the participant that performed the best would receive a prize. After 10 min, participants were asked to fill out the immersion questionnaire, the State Anxiety Questionnaire and the PANAS-X. Questionnaires were counterbalanced to avoid order effects. After completing the questionnaire all participants were fully debriefed and thanked for their participation.

16. Results

All statistical analyses were performed using SPSS 11.0. The mean immersion, state anxiety, positive and negative affect experienced by participants in the four pace conditions are shown in Table 1.

The increasing pace condition had the highest mean immersion score, followed by the fast condition, the slow condition, and then the self-paced condition last of all. The non-parametric Jonkheere-Terpstra test was used to investigate the directional hypothesis for immersion: θ Slow $<\theta$ Self-Paced $<\theta$ Fast $<\theta$ Increasing. The differences between the conditions were not significant in the direction predicted (observed J-T statistic = 302.500, $p>0.05$).

The mean state anxiety experienced by participants in the fast and increasing speed conditions was higher than the mean state anxiety experienced by participants in the slow condition. The non-parametric Jonkheere-Terpstra test was used to investigate the directional hypothesis for state anxiety: θ Slow $<\theta$ Self-Paced $<\theta$ Increasing $<\theta$ Fast. The differences between the conditions were significant in the direction predicted (observed J-T statistic = 359.500, $p=0.001$).

Table 1
Descriptive statistics for immersion, state anxiety, positive and negative affect, within the four pace conditions

	Pace condition means (and standard deviations)			
	Slow	Self-paced	Fast	Increasing
Immersion	78.78 (22.10)	74.78 (18.47)	86.22 (12.79)	90.33 (17.89)
State Anx.*	38.22 (12.87)	43.78 (9.48)	55.11 (11.49)	57.11 (5.75)
P. affect	23.44 (6.60)	28.44 (13.33)	28.22 (5.83)	26.56 (8.85)
N. affect*	12.00 (1.80)	13.78 (3.78)	17.56 (6.19)	19.89 (5.42)

*The difference is significant at the 0.05 level.

Positive and negative affect means were also calculated. The self-paced condition has the highest positive affect score, followed by the fast condition, the increasing condition, and then the slow condition. A Kruskall–Wallis test revealed that there was no significant difference between the positive affect experienced by participants in the four speed conditions ($\chi^2_{(3)}=1.644$, $p>0.05$).

In terms of negative affect, the increasing pace condition was rated the highest, followed by the fast condition, the self-paced condition, and then the slow condition. A Kruskall–Wallis test revealed that there was a significant difference between the negative affect experienced by participants in the four speed conditions ($\chi^2_{(3)}=13.512$, $p<0.01$). A Kruskall–Wallis follow-up test revealed that participants in the increasing condition experienced significantly more negative affect than participants in the slow condition (critical difference = 16.821, exceeding the critical value of 12.912).

In order to investigate the relationship between affect and immersion, Spearman correlations were also carried out between the affect measures and immersion scores. Only positive affect was correlated with overall immersion (Spearman's $\rho=0.711$, $p<0.001$).

17. Discussion

The hypothesis, that participants in the four speed conditions would vary in terms of the amount of immersion they experienced, was not supported. Although the increasing pace condition did have the highest mean immersion score (as expected) the mean differences between the four pace conditions were not significant.

We suspect that the lack of significance is largely due to the game not being "game-like" enough. Even in the increasing pace condition, although the task had some qualities we believe are related to immersion, such as a fast paced interaction with the computer interface and a sense of progression, participants still regarded it as a task rather than a game. One reason for this could be that in the task's simplicity other interface elements which are likely to play an important role in game immersion, such as graphics and sound, were absent. In future research it would be interesting to investigate further why users perceive some computer interactions as games and not others. What are the necessary features for an interaction to be perceived as a "game"?

The second hypothesis, that participants in the four pace conditions would vary in terms of the amount of state anxiety they experienced, was partially supported. State anxiety experienced in the fast externally paced condition was significantly higher than state anxiety experienced in the slow condition. However, rather than being somewhere in-between with a moderate level of anxiety as expected, participants in the increasing pace condition were found to experience the highest state anxiety of all.

As a result of these findings one can suggest that emotional involvement appears to be a key factor in immersion, supporting Brown and Cairns (2004). Not only do people get caught up in tasks which steadily get more difficult over time, but they become highly anxious too. They feel more pressure to win, perhaps because they have developed a certain level of proficiency in the game, and so they have higher expectations and their game play is emotionally charged.

The third hypothesis, that participants in the four speed conditions would differ in levels of other affective states, was also supported. Participants in the increasing condition experienced significantly more negative affect than participants in the slow condition. Again these findings suggest that a key part of immersion in games is that they are provoking: not only are they viewed as positive experiences, but negative emotions and uneasiness run high. This is also a way in which immersion in games differs from flow: whereas Csikszentmihalyi (1990) claims that flow involves a serene mindset, immersion is much more emotionally charged.

Regarding the motivation behind this experiment, although it is clear that the increasing condition was more enjoyable and emotionally charged than the self-paced condition, reasons why the self-paced condition might have been perceived as immersive in Experiment 2 are still unclear. One could argue that the self-paced condition demonstrated more serene qualities (i.e. monotonous, repetitive) compared to its quicker counterparts, which could have potentially led to participants experiencing some form of flow (although not quite immersion).

However again it must be noted that such proposals are tentative. Although the simplicity of the experimental design has been beneficial in trying to identify the effect of one game factor (i.e. pace of interaction) on user experience, this same simplicity also has its downfalls. The nature of the task makes it difficult to compare this situation to real computer games as computer games are much more complex.

18. General discussion

18.1. Summary of findings

In this paper we have discussed a number of issues in defining and measuring immersion, and we have reported the findings of three experiments investigating these issues. Immersion is a concept which we argue is important to gaming, transcending existing cognitive theories of flow, CA and presence. Immersion is an experience in one moment in time and graded (i.e. engagement, engrossment, total immersion). Immersion involves a lack of awareness of time, a loss of awareness of the real world, involvement and a sense of being in the task environment. Most importantly, immersion is the result of a good gaming experience.

Given that gamers are able to define immersion for themselves, yet the concept is rather under-defined, one aim of this paper was to develop an immersion questionnaire. The first questionnaire developed was generally successful in obtaining an immersion score, the level of immersion reported in the immersive condition (playing a computer game) being significantly higher than the level of immersion reported in the non-immersive condition (clicking task) for both Experiments 1 and 2. A shorter second questionnaire with simpler wording was developed for Experiment 3. A validation study identified 5 clear factors underlying the immersion experience questionnaire. These are a mixture of person factors (cognitive involvement, real world dissociation and emotional involvement) and game factors (challenge and control). In Experiment 3 this questionnaire showed that although the immersion scores between the conditions were in the direction predicted, the differences were not significant.

Another aim of this paper was to relate the subjective experience of immersion to more quantitative objective measures. Experiment 1 investigated the relationship between immersion and task completion time. The more immersed a person was when playing a game, the longer it took them to complete a tangram task afterwards that was not related to the game. Therefore one can suggest that being increasingly immersed in a game decreased one's ability to re-engage with the "real world".

Experiment 2 investigated the relationship between immersion and changes in the number of eye fixations over time. Fixation data revealed that participants' eye movements significantly increased over time in the non-immersive condition. In contrast, participants' eye movements in the immersive condition significantly decreased over time. Similar decreases in eye movements have been found in the visual attention literature, in which visual attention is compared to a zoom lens (Styles, 1997). Therefore one can suggest for an immersive game an individual's eye movements will decrease, as their attention becomes more focused on visual components relevant to the game.

Due to the surprising amount of variability in immersion ratings in Experiment 2 (i.e. some participants rating the clicking task as highly immersive), a further aim of this paper was to investigate how altering one component of a task alters the immersive experience. Experiment 3 was designed to investigate the relationship between immersion and the pace of interaction with the computer interface. The results indicated that although the immersion scores between the conditions were in the direction predicted (i.e. increasing pace condition being the most immersive), the differences were non-significant.

Pace of interaction with the interface did however lead to participants experiencing significantly different levels of affect. Participants in the increasing pace condition experienced the highest level of state anxiety and negative affect. Therefore one can suggest that emotional involvement appears to be a key factor in immersion, supporting Brown and Cairns (2004).

Overall, it is evident that our research has covered a broad range of issues. Through these experiments we have demonstrated that immersion can be measured subjectively (through questionnaires) as well as objectively (i.e. task completion time, eye movements). Furthermore, immersion is not only viewed as a positive experience: negative emotions and uneasiness (i.e. anxiety) also run high. However, it is clear that this work is only the beginning of such research, and so we would like to highlight some directions for the future.

18.2. Directions for future research

As of yet, the findings of Experiments 1 and 2 suggest that immersion is occurring. However, it is evident that we need to also carry out investigations with computer games that are more directly comparable (e.g. equal levels of complexity). Furthermore, our immersion questionnaires still need more testing and further refinement. We plan to develop our immersion questionnaire further through the use of qualitative measures, by interviewing gamers.

The development of an objective measure of immersion might also be a useful way of finding out more about immersion. In this paper we have already discussed measures such as reaction times and eye tracking (Experiments 1 and 2). These studies did indeed have hopeful results, but neither of them is completely concrete. As a result, we are currently in the process of working with data gathered from other objective measures, such as biosensors and body motion analysis, to see what benefits these offer.

Although it is likely that game factors are the major reason why immersion occurs, personality factors are also likely to be important. We are currently in the process of investigating whether there is a relationship between immersion and the personality traits absorption and openness to experience. Such research could help explain why some people become more addicted to games than others.

Another feature of our paper is that we studied a mixture of gamers and non-gamers in all three experiments. It might be useful to keep these two groups of people separate and just study gamers in the future. Similarly, although we purposefully controlled for gender in Experiments 2 and 3, having nearly an equal number of males and females in each condition, research into gender differences in gaming might also be fruitful.

Altogether it is evident that this research into immersion is still a work in progress, but we believe this paper has outlined some very useful first steps. Through the development of such research, we hope to gather evidence that our concept of immersion allows researchers to describe a person's experience playing computer games better than flow or any other existing concept, giving our argument considerably more strength. We also hope that such research would be of potential value to game designers, helping them to develop games with features to enhance the user's immersive experiences. Although it is very early to tell, one might suspect that understanding immersion might also prove useful in understanding game addiction too.

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Appendix A. Immersion questionnaire used in Experiments 1 and 2

Your personal experience of the game

Please rate how far you would agree with the statements below just before you were interrupted.

SD = strongly disagree; D = disagree; N = neutral; A = agree; SA = strongly agree.

I felt that I really empathised/felt for with the game.
SD D N A SA

I did not feel any emotional attachment to the game.
SD D N A SA

I was interested in seeing how the game's events would progress.
SD D N A SA

It did not interest me to know what would happen next in the game.
SD D N A SA

I was in suspense about whether I would win or lose the game.
SD D N A SA

I was not concerned about whether I would win or lose the game.
SD D N A SA

I sometimes found myself to become so involved with the game that I wanted to speak to the game directly.
SD D N A SA

I did not find myself to become so caught up with the game that I wanted to speak to directly to the game.
SD D N A SA

I enjoyed the graphics and imagery of the game.
SD D N A SA

I did not like the graphics and imagery of the game.
SD D N A SA

I enjoyed playing the game.
SD D N A SA

Playing the game was not fun.
SD D N A SA

The controls were not easy to pick up.
SD D N A SA

There were not any particularly frustrating aspects of the controls to get the hang of.
SD D N A SA

I became unaware that I was even using any controls.
SD D N A SA

The controls were not invisible to me.
SD D N A SA

I felt myself to be directly travelling through the game according to my own volition.
SD D N A SA

I did not feel as if I was moving through the game according to my own will.
SD D N A SA

It was as if I could interact with the world of the game as if I was in the real world.
SD D N A SA

Interacting with the world of the game did not feel as real to me as it would be in the real world.
SD D N A SA

I was unaware of what was happening around me.
SD D N A SA

I was aware of surroundings.
SD D N A SA

I felt detached from the outside world.
SD D N A SA

I still felt attached to the real world.
SD D N A SA

At the time the game was my only concern.
SD D N A SA

Everyday thoughts and concerns were still very much on my mind.
SD D N A SA

I did not feel the urge at any point to stop playing and see what was going on around me.
SD D N A SA

I was interested to know what might be happening around me.
SD D N A SA

I did not feel like I was in the real world but the game world.
SD D N A SA

I still felt as if I was in the real world whilst playing.
SD D N A SA

To me it felt like only a very short amount of time had passed.
SD D N A SA

When playing the game time appeared to go by very slowly.
SD D N A SA

How immersed did you feel? (10 = very immersed; 0 = not at all immersed)
1 2 3 4 5 6 7 8 9 10

Appendix B. Immersion questionnaire used in Experiment 3

Your experience of the game

Please answer the following questions by circling the relevant number. In particular, remember that these questions are asking you about how you felt at the end of the game.

To what extent did the game hold your attention?
Not at all 1 2 3 4 5 A lot

To what extent did you feel you were focused on the game?
Not at all 1 2 3 4 5 A lot

How much effort did you put into playing the game?
Very little 1 2 3 4 5 A lot

Did you feel that you were trying you best?
Not at all 1 2 3 4 5 Very much so

To what extent did you lose track of time?
Not at all 1 2 3 4 5 A lot

To what extent did you feel consciously aware of being in the real world whilst playing?
Not at all 1 2 3 4 5 Very much so

To what extent did you forget about your everyday concerns?
Not at all 1 2 3 4 5 A lot

To what extent were you aware of yourself in your surroundings?
Not at all 1 2 3 4 5 Very aware

To what extent did you notice events taking place around you?
Not at all 1 2 3 4 5 A lot

Did you feel the urge at any point to stop playing and see what was happening around you?
Not at all 1 2 3 4 5 Very much so

To what extent did you feel that you were interacting with the game environment?
Not at all 1 2 3 4 5 Very much so

To what extent did you feel as though you were separated from your real-world environment?
Not at all 1 2 3 4 5 Very much so

To what extent did you feel that the game was something you were experiencing, rather than something you were just doing?
Not at all 1 2 3 4 5 Very much so

To what extent was your sense of being in the game environment stronger than your sense of being in the real world?
Not at all 1 2 3 4 5 Very much so

At any point did you find yourself become so involved that you were unaware you were even using controls?
Not at all 1 2 3 4 5 Very much so

To what extent did you feel as though you were moving through the game according to you own will?
Not at all 1 2 3 4 5 Very much so

To what extent did you find the game challenging?
Not at all 1 2 3 4 5 Very difficult

Were there any times during the game in which you just wanted to give up?
Not at all 1 2 3 4 5 A lot

To what extent did you feel motivated while playing?
Not at all 1 2 3 4 5 A lot

To what extent did you find the game easy?
Not at all 1 2 3 4 5 Very much so

To what extent did you feel like you were making progress towards the end of the game?
Not at all 1 2 3 4 5 A lot

How well do you think you performed in the game?
Very poor 1 2 3 4 5 Very well

To what extent did you feel emotionally attached to the game?
Not at all 1 2 3 4 5 Very much so

To what extent were you interested in seeing how the game's events would progress?
Not at all 1 2 3 4 5 A lot

How much did you want to "win" the game?
Not at all 1 2 3 4 5 Very much so

Were you in suspense about whether or not you would win or lose the game?
Not at all 1 2 3 4 5 Very much so

At any point did you find yourself become so involved that you wanted to speak to the game directly?
Not at all 1 2 3 4 5 Very much so

To what extent did you enjoy the graphics and the imagery?
Not at all 1 2 3 4 5 A lot

How much would you say you enjoyed playing the game?
Not at all 1 2 3 4 5 A lot

When interrupted, were you disappointed that the game was over?
Not at all 1 2 3 4 5 Very much so

Would you like to play the game again?
Definitely not 1 2 3 4 5 Definitely yes

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