Quantifying the experience of immersion in games

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Abstract

Games are undoubtedly the most successful computer application yet it is not easy to attribute their success to any one particular feature. Nonetheless, when talking about games, gamers and reviewers frequently refer to the immersive experience of the game as an important aspect to be attained. However, it is not clear what immersion is and even if it is a comparable experience between different players and different games. This paper aims to develop more quantifiable and therefore objective measures of immersion. We describe a study into switching from an immersive gaming experience to another task, not in the game world. Though the degree of immersion does seem to have an impact on the ability to perform the task, the experimental approach is complex and possibly quite fragile. We therefore set out hypotheses for a similar experiment with the aim of exploring whether eyetracking and body motion provide better indicators of the degree of immersion.

Immersion in Games

Engaging with media such as computer games, virtual reality, cinema and even books has been described as giving rise to experiences of feeling deeply involved with that particular medium. In software research, numerous terms have been developed to try to account for these experiences, such as flow, presence and immersion (Csikszentmihalyi, 1990; Slater, Usoh & Steed, 1994; Witmer & Singer, 1998). Within game reviews, the term usually used is that of immersion (for example, TTLG, 2005) but it is not clear if this corresponds to immersion in other contexts or the extent to which it relates to other involving experiences.

Even within the term immersion, there are competing definitions. Coomans and Timmermans (1997) describe immersion as "a feeling of being deeply engaged where people enter a make-believe world as if it is real" whilst Menetta and Blade (1998) describe it with respect to the emotional response presented by a virtual world. Radford (2000) describes immersion as being related to the ability to enter a game through its controls, although it is unclear how this relationship affects or gives rise to immersion.

Approaching the concept from a different perspective, Slater et al. (1994), defined immersion with respect to the technology rather than the human experience. Immersion is described as how far the system delivers an environment that creates a sense of "presence". The experiences of the user are related to presence which is "a sense of being there" in a mediated environment and the experience is confined to virtual reality (VR) domains, where one perceives themselves to be surrounded by (particularly visual) stimuli. In this sense, presence in VR would seem to correspond to immersion in games though clearly Slater et al. make it clear that non-VR games could not lead to presence.

However there is a paradox, Schubert and Crusius (2002) argue that an individual reading a book may feel just as present in that medium as they might be engaging in a VR setting, even though they are not completely surrounded by stimuli. This is supported by other work where immersion as understood by gamers (Brown and Cairns, 2004) is found to be comparable to immersion in reading and film (Cairns et al., under review).

Definitions are further hindered by overlaps of the underlying concept of immersion, according to the gaming community's usage, with themes from related constructs. For example, flow (Csikszentmihalyi, 1990) is described as an optimal experience achieved in the pursuit of intrinsically rewarding physical or symbolic activities where "individuals are so involved in an activity that nothing else seems to matter". Similarly, Agarwal and Karahanna's (2001) construct of cognitive absorption (CA) is intended as a state of deep involvement with software. Their study highlights the discrepancy between studies as to what constitutes antecedents and features of constructs such as flow and cognitive absorption, and the consequences of being in these states. Also, it is worth noting that CA is better understood as a personality trait rather than an immersive state since the instrument used to measure CA questions general experiences of using software rather than any particular experience.

These differing approaches within and across domains create a certain level of confusion as to what exactly is immersion, whether or not it is a common experience of gamers, or whether it is so different from related constructs.

In an attempt to classify immersion Brown and Cairns (2004) investigated gamers' own understandings of immersion using grounded theory (Strauss & Corbin, 1998). The theory supported immersion as the degree of involvement with a computer game and also identified barriers that could limit the degree of involvement. These barriers arose from a combination of human, computer and contextual factors. The type of barrier suggested different levels of immersion which were dubbed engagement, engrossment and total immersion. This last, most involved state was equated by the gamers to a sense of presence, which may overlap with the virtual reality concept or even flow, in achieving an optimal state — although total immersion may be more fleeting and be mediated by negative elements such as guilt.

Given that gamers are able to identify immersion for themselves but that the concept is currently rather under-defined, the aim of this paper is to consider player's subjective experiences of immersion and to attempt to relate these to more quantitative, objective measures. The first study is 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 could be impaired in proportion to the degree of immersion. The study does 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. The second part of the paper therefore considers other types of objective measures and hypotheses about how they relate to immersion.

Experiment on Immersion

Overview of the experiment

The goal of this experiment is to relate the experience of immersion to a more objective measure. Immersion is measured with a questionnaire based on previous work and the more objective measure is the time taken to complete a task. 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.

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.

Figure 1: A screenshot from Half_Life

Method

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

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 . This game resembles the format of virtual reality games, see Figure 1, which according to Slater et al. (1994) is the only interface capable of generating presence. 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 minutes 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 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 Figure 2. It was again per-

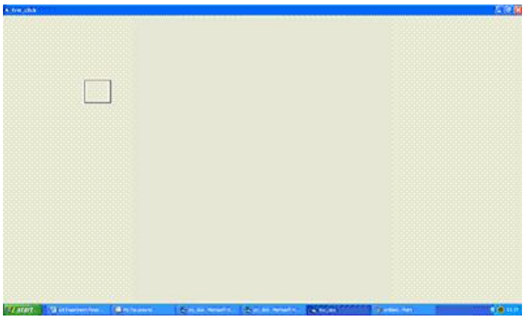

Figure 2: The Control Task

formed 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 by 9 grid, for which the coordinates were generated randomly, to create the pattern that they would follow.

Immersion questionnaire The questionnaire is developed from findings of previous studies into related areas. Included are Agarwal and Karahanna's (2000) five dimensions of CA, these areas are: temporal dissociation; focused immersion; heightened enjoyment; control; curiosity. However, unlike the standard CA questions, these questions relate to the particular experience of the given task rather than general experience of using software.

Other questions were also derived from Brown and Cairns' (2004) study, namely: emotional involvement (empathizing with a game's purpose or characters, wanting to speak out loud to the game, suspense about the games events), transportation to a different place (how far was disbelief about the game was suspended and how far 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 traveling somewhere and interacting with a world).

Two questionnaires were developed, with two pairs (positive and negative version) of related questions developed for each target area. These were then counterbalanced so that both questionnaires contained a question from each pair. In the control task, the questionnaire was exactly the same, except the word "game" was replaced with "task".

The questionnaire asked how far participants agreed with statements describing their possible experiences before they were interrupted. Answers for each question were marked on a five point scale: disagree, partially disagree, neither agree/disagree, partially agree, agree, where 1 is disagree and 5 is agree.

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.

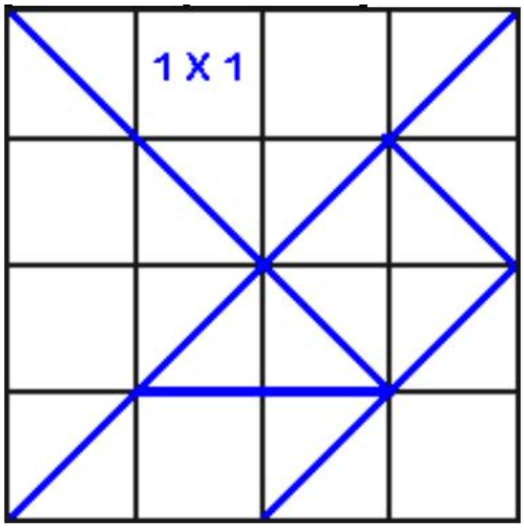

Figure 3: Tangram pieces arranged as a square

The tangram task was chosen for both its cognitive and physical elements. A solution can only be achieved by moving pieces, Figure 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 positioon of pieces can be used to indicate partial solutions in the manner of distributed cognition ToDo: Ref. 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 Figure 4, took on average four minutes to complete in the pre-testing.

Procedure The basic structure of the procedure is that participants are given the tangram task to do first, they then perform either the control or experimental task for ten minutes when they are interrupted to fill in the immersion questionnaire. They then continue for a further ten minutes when they carry 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

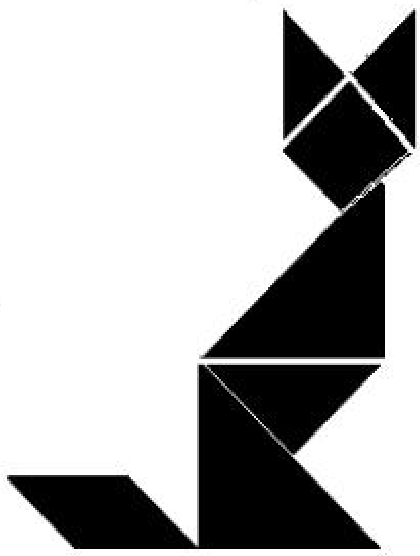

Figure 4: The fox figure

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 Figure 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 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 ten minutes 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 ten minutes 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 ten minutes, 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 either the questioning before the task would 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.

Results

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 positive or negative version of the immersion 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. 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 $\rho = -0.45$, $p = 0.003$). 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 4.2s 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.

Discussion

The hypotheses of the experiment are supported by the results of the experiment.

The relationship between task time change and immersion score only appears to exist in the experimental condition, it demonstrates that a proportion of variability in time change in the experimental condition can be accounted for by variability in immersion score, but not in the control condition. The results suggest that being increasingly immersed in a game decreased one's ability to reengage 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 is 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 have a greater impact on performance.

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.

Another interpretation of the second hypothesis would be that, due to lower immersion, the control condition task time differences should be higher than the experimental condition's. However, this was not found. Thus, 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.

The experiment also has some unsatisfactory features. Whilst immersion and the second task attempt are performed at separate times for a good reason, it is still possible that the immersion at the end of the playing experience is not the same as the point at which it was measured. Also, the very interruption used to measure immersion may lead to reduced immersion in the remainder of the experimental activity.

The task also still takes quite a long time. The average task completion time in the second condition was still 61s and a standard deviation of 33s. It is not clear if any effect of immersion could be considered to be present after a minute of working on the task. Thus, perhaps what is being measured is more about how much learning has gone on from the first time to the second time the task is done. 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.

To help address some of these concerns, a second experiment was devised with a cube arranging task as the intended way to objectively measure immersion. The idea was that the time at which different cube arrangements were generated would give a cross section of times as the participants emerged from an immersed state. However, this task whilst cognitively demanding in the long run showed no differences between participants in the first few arrangements. This suggests that the experimental task is highly interlinked in finding this sort of world transition effect but without a better knowledge of immersion justifying which tasks are best to use may be post hoc and convenient rather than rigorous and insightful.

Thus, 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 and body motion.

Exploring eye-tracking and body motion during games

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 & Cox, 2006) and attentional paradigms such as inattentional blindness (Koivisto, Hyona & Revonsuo, 2004; Memmert, 2006; Pappas et al, 2005) and change blindness (Hollingworth, Williams & Henderson, 2001; Triesch et al. 2003). However, when it comes to how people perceive computer games, very little is known.

In Brown & Cairns (2004), gamers described total immersion as "you feel like you're there" and "when you stop thinking about the fact that you're playing a computer game and you're just in a computer." These quotes strongly suggest that gamers actually feel as if they are viewing a real scene when they are immersed. In a review of eye-tracking studies investigating scene perception, Rayner (1998) reports that the gist of a static scene is extracted from the first few fixations, and then the remainder of the fixations are more focused on particular objects, to fill in the details. Similarly, in the attention literature Styles (1997) reviews a number of studies and 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.

However, whereas the scenes talked about in this past literature are static, in a computer game the scene is always changing (like real life). Therefore, rather than eye movements becoming more fixed as time progresses 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 eye movements will increase. In contrast, for a non-immersive game 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.

As well as eye movements, bio-physical sensors and non-verbal expressions provide an alternative, non-intrusive source of information on the cognitive and affective state of the user. While quite a few studies have focused on the use of bio-physical sensors (Ravaja et al, 2005), very little attention has been given to posture despite ample evidence that it provides a very reliable window on the affective states of the user. De Silva and Berthouze (2003) and Coulson (2004) for example reported very high classification rates for human subjects recognizing emotions from body postures of avatars, either from ad-hoc body postures or avatars postures reconstructed from human motion data. Moreover, Berthouze and Kleinsmith (2003) demonstrated that a simple kinematic description of the posture was sufficient to automatically construct a classification model for affective postures. More directly related to the states of interest for gaming, Mota and Picard (2003) showed how postural information detected by pressure sensors mounted on a chair provided information pertaining to the levels of interest in students. We therefore believe that motion-capture and in particular, postural information, might provide us with interesting ways in which to measure the degree of immersion experienced.

Posture may also integrate well with eye-tracking. Indeed, as pointed out by Gibson (1986), "one sees the environment not with the eyes but with the eyes-in-the-head-on-the-body-resting-on-the-ground" and therefore constraints imposed on body postures by the affective state, or the cognitive load, of the user also impose constraints on how the gamer (actively) perceives the gaming environment. For instance, Sennersten's (2004) study of eye fixations during an action game suggests as much when it reports a significant disparity between observed behaviour and reported behaviour. While subjects reported getting salient information from looking at the face of the visual stimulus, fixations revealed a much greater focus on body areas which was more consistent with the physical constraints of the game, such as, the fact that time pressure results in a head-down posture.

Hypotheses on eyetracking, body motion and immersion

Given the potential offered by eyetracking and body movement, we propose here hypotheses that builds 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 and body motion 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.

In an another attempt to test the validity of the behavioural measures, it is predicted that participants that have high ratings of absorption or openness to experience (two personality traits closely related to immersion) will exhibit eye movements and body movements associated with immersion sooner and for a longer period of time than participants that have low ratings of absorption or openness to experience.

Overall, the proposed study has four main hypotheses:

1. Participants in an immersive condition will show a greater increase in the number of fixations and saccades, and a greater decrease in fixation length, than participants in a non-immersive condition.

2. Participants in an immersive condition will exhibit body motions that are different to the body motions exhibited by participants in a non-immersive condition.

3. Subjective self-reported immersion ratings will correlate with these objective behavioural measures of immersion.

We are currently running an experiment to test these hypotheses and we hope to report the first analyses of our data at the workshop.

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