Investigating Multi-Player Online Video Games for Brain-Injured People

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Structured Abstract

Purpose

This paper reports a pilot experiment to test if multi-player online video games could provide a measurable cognitive therapeutic benefit for brain-injured people.

Design

Single-subject research design with $n=3$ brain-injured participants. Four alternating intervention and non-intervention weeks. Battery of cognitive tests taken at the start of the experiment and at the end of each week.

Findings

Widely varying results with large standard deviation overall.

Research limitations

The experimental design was heavily reliant on multiple participants logging in at the same time. Server logs showed that this happened relatively rarely.

Practical implications

Implications for the next iteration of the experiment are to refine the game design to avoid the need to synchronise the participants. The findings presented may be of practical use to other researchers in this area.

Social Implications

Acquired brain injury has been described as an epidemic, and is rising, with stroke being a leading cause. Traumatic brain injury (e.g. due to road traffic accident) has increasing prevalence in low-middle income countries. This research aims to provide a form of therapy to people for whom physical access to rehabilitation services is limited.

Originality/value

The use of multi-player online video games as rehabilitation is a relatively unexplored area. A positive result in an experiment of this nature would indicate the potential for a new, complimentary form of cognitive therapy for brain-injured people.

Abstract

This paper describes a pilot investigation into the potential for multi-player online video games to be used as a form of therapy for people who have an acquired brain injury. The experimental design is a single-subject research design in “ABAB” form. Participants ($n = 3$) played a multi-player online video game and periodically took cognitive tests (reaction time, Stroop tests and trail-making tests). Results showed an improvement in reaction time but were inconclusive for the other measures. Difficulties with conducting this type of experiment are discussed and future work described.

1 Introduction

This paper describes a pilot investigation into the potential for multi-player online video games to be used as a form of therapy for people who have an acquired brain injury. Brain injury is complex and multi-faceted, and this research is investigative and exploratory in nature. An initial study has been completed, and the results are here presented and discussed. The results and issues uncovered may be a useful guide for further work in this area.

A number of issues make it difficult to design an experiment around brain-injured people. Every brain injury is different, affecting each person's abilities in a unique way; and there is potential for spontaneous recovery. There are many forms of brain injury. This research concentrates on stroke and traumatic brain injury. This is due to the participant groups involved, and because these injuries are non-degenerative: other type of brain injuries may not respond to the proposed interventions in the same way.

1.1 Acquired brain injury

Acquired brain injury (ABI) is defined as “a non-degenerative injury to the brain occurring since birth” (Beecham *et al.*, 2009), and is one of the most common causes of disability and death in adults (Feigin *et al.*, 2010). The leading causes of acquired brain injury are stroke and traumatic injury (Feigin *et al.*, 2010). In the UK, there are an estimated 152,000 strokes every year, and 1.1 million stroke survivors (Townsend *et al.*, 2012, pp. 57-58).

Worldwide, the World Health Organisation has estimated that 15 million people per year suffer a stroke (Mackay & Mensah, 2004). Globally, ten million people are affected by traumatic brain injury (Hyder *et al.*, 2007). Acquired brain injury (ABI) is thus described as a global disease of “epidemic” proportions (Theodoros *et al.*, 2001). Cognitive deficits experienced after brain injury include problems with communication, memory and planning. The goal of rehabilitation for a cognitively impaired person is to function safely, productively and independently (Mateer, 2005), and to improve his or her function in areas relevant to their everyday lives (Cicerone *et al.*, 2000).

According to Sohlberg & Mateer (2001), a basic assumption underlying cognitive rehabilitation is that cognition cannot be treated in isolation: “Brain damage affects cognitive, social, behavioural and emotional functioning.” Ben-Yishay & Daniels-Zide (2000) suggest that acceptance of the disability leads to a life which is more emotionally satisfying than one in which comparisons with pre-injury abilities are constantly being made. This is interpreted by Sohlberg & Mateer (2001) as implying that cognitive and emotional recovery for a brain injured person are inseparable.

In addition, Jones *et al.* (2010) assessed 630 individuals with an acquired brain injury, and found a surprising positive relationship between injury severity and life satisfaction. These authors showed that the strengthening of personal identity and social relationships are beneficial for ABI survivors, and conclude “...individuals can be protected from the negative impact of more severe head injury by receiving support from social networks and by strengthening personal identity”. Some evidence has suggested that perceived social isolation – loneliness – has a dramatic effect on social animals, including man (Cacioppo & Hawkley, 2009). Loneliness is a risk factor for cognitive decline, and isolation is common following brain injury (Murdoch & Theodoros, 2001).

The aforementioned findings suggest that an improvement in social interaction could produce an increase in the subjective measures of quality of life; and that correspond to improvements in cognitive skill functions. There remains, however, limited evidence as to the role of technology upon social and emotional wellbeing in the stroke survivor. Most recent finds from the ATRAS stroke (Demain *et al.* 2013) support the view that technology can be used to assist and produce

beneficial effects upon physical and possibly emotional and cognitive functioning post acquired brain injury, but the actual dose and type and form of the technology is yet to be fully established.

Given this information, it is possible to suggest that an improvement in social interaction utilising multiplayer led technology could be used to improve physical, social and emotional interaction, thus leading to an improvement in the subjective quality of life measure and producing a corresponding improvement in cognitive skills as a result of using the technology in acquired brain-injured people.

1.2 Video game therapy

Video games have been shown to provide therapeutic benefits in many contexts (Griffiths, 2005), and video games such as the Nintendo Wii have been successfully used to promote physical rehabilitation after stroke. Interestingly, a study which investigated the potential for cognitive therapy for traumatic brain injury survivors (Malec *et al.*, 1984) found that playing a single player video game did not provide any such benefit, beyond an improvement in reaction time. Nevertheless, Bavelier *et al.* (2012) review evidence showing that players of action video games have improved abilities in some aspects of vision, cognitive function, decision making and attention.

Massively multi-player online games (MMOs) are a combination of video game and virtual environment where social interaction with other players is the norm. Griffiths *et al.* (2004) conducted a survey of 540 *Everquest* players and found that the favourite features were the social aspects of playing online, such as social contact, and helping others. Wang & Wang (2008) studied prosocial behaviour in a Taiwanese online game, finding that the players help each other, engaging in altruism and reciprocity.

The therapeutic potential of MMOs is exciting but relatively unexplored. Playing an MMO provides a social experience, even for those who play alone (Ducheneaut *et al.*, 2006), and McGonigal (2011) states “social network games make it easier and more fun to maintain strong, active connections with people we care about”.

1.3 Neuroplasticity

Neuroplasticity is the ability of neurons in the brain to make new connections and to reorganise existing ones. Dubin (2002) states that plastic changes in the cortex are ongoing throughout adulthood, suggesting that carefully designed rehabilitation exercises might reduce the effects of acquired brain injury. Pascual-Leone *et al.* (2005) state that plasticity is an intrinsic property of the nervous system, retained throughout the lifespan. Similarly, studies by Hummel *et al.* (2005) have produced evidence using functional imaging that neuronal tissues undergo plastic changes, in healthy and brain injured people. More recently it is has become evident that the extent of neuroplastic change can be augmented (Vines *et al.*, 2008).

With the development of affordable technology, studies have shown that gaming has the potential to be used to enhance the neuroplasticity change of undamaged neuronal tissue in both healthy and (acquired) stroke survivors (Gillespie *et al.*, 2012; Bodak *et al.*, 2014), in order to improve physical function in injury. However, the use of video gaming in relation to cognitive function in acquired brain injury remains under debate (Lange *et al.*, 2010). It is known that cognitive function can be increased in healthy individuals utilising video gaming (Kramer & Erickson, 2007). The aforementioned study provides support to suggest that gaming could be used for cognitive improvement thorough neuronal plasticity through video gaming technology.

Bavelier *et al.* (2012) review the many cases where players of action video games have improved abilities in some aspects of vision, cognitive function, decision making and attention. Furthermore, playing such games may enhance the ability to learn, through the mechanism of enhancing neuroplasticity. This is in contrast to other training scenarios where, rather than a general improvement, only an improvement in the specific training task tends to be found.

1.4 Linking cognitive recovery, social relationships, loneliness and multi player online gaming

In this section we explore links between the topics reviewed above, forming a conceptual model which is the basis for a hypothesis. From Sohlberg & Mateer (2001), cognitive deficits resulting from brain injury are inseparably accompanied by social and emotional deficits; moreover, improvements in cognitive and emotional abilities will proceed in tandem, not independently. Certainly, in the general population, a link is seen between the emotionally damaging effects of loneliness and cognitive decline (Cacioppo & Hawkley, 2009). Video games have a long history of being used therapeutically, with multi-player online video games fostering altruistic, prosocial behaviour. There is thus a link from the social, emotional therapeutic benefits of MMOs to counteracting the negative effects of isolation, to cognitive improvements which an improvement in quality of life may bring.

The foregoing has led to the hypothesis that playing a multi-player online video game could provide a form of cognitive therapy for a brain injured person, due to the social interaction it fosters. Neuroplasticity is the mechanism for learning, growth and development, and is the process by which the hypothesised cognitive improvements would take place.

2 Method

This section describes the experimental method designed to test the hypothesis. Participants engage in playing a prototype multi-player online video game, designed to encourage cooperation and collaboration. The players periodically take cognitive tests which are built into the game software. The tests have been chosen as broad measures of executive function. The experimental hypothesis is that the cognitive test scores would improve over time due to playing the multi-player online game. The null hypothesis, that playing such a game would have no effect, could be rejected if positive changes to the cognitive test scores could be ascribed to playing the video game.

Malec *et al.* (1984) performed a study with a small group of brain-injured people, to determine if playing a video game provided a form of cognitive therapy. The game was single-player only (*Target Fun* on the Atari VCS game console). Cognitive improvement was measured using Stroop tests (described in more detail below), letter cancellation tests, and a reaction time test. An improvement in reaction time was found, but not for the other measures.

The design of the current study has been based to some extent on the Malec study, allowing a comparison between that study (which evaluated a single-player game) and the present study (evaluating an online multi-player game).

2.1 Experimental design

A single-subject research design (SSRD, or “n=1” design) was employed. In this type of design, time series data is collected for each participant as they experience different interventions or activities. Effectively, each participant provides their own control. In an “A-B-A” design, a baseline of the dependent variable is collected in the first phase (A). The intervention is introduced (B),

where a change in the time series data is expected. The intervention is then withdrawn (A), upon which the change should stop or reverse. This step is required to refute rival hypotheses for any changes to the dependent variables (Christensen, 2004). In an “A-B-A-B” study, the intervention is introduced for a second time. In this study, the dependent variables are the results from cognitive tests. The independent variable is whether or not the participant has played the multi-player game in the week of the test.

2.2 The participants

Brain-injured people from two support groups, Different Strokes (www.differentstrokes.co.uk), and Headway (www.headway.org.uk), were invited to take part in this research project. Different Strokes and Headway are UK organisations which support survivors of stroke and other brain injuries. The experiment commenced in August 2013 with a cohort of three brain-injured participants. Additionally, thirteen non-brain-injured volunteers were recruited from a higher education college in East London, to increase the number of players. Prior to taking part, all participants were given an information sheet and were able to ask the researcher questions. A website provided additional information.

2.2.1 Inclusion and exclusion criteria

In this section we list the inclusion and exclusion criteria for recruiting participants. The inclusion criteria for all participants were the following:

- Capable of granting/withholding consent
- Adult
- If a brain injury survivor, beyond the acute care and rehabilitation stage
- Medical needs do not preclude playing video games
- Able to read
- Able to physically control the game using an appropriate interface
- Access to suitable apparatus: personal computer with Internet access

The exclusion criteria for the brain-injured participants were as follows:

- Unable to give or withhold consent
- Any history of seizure due to photosensitive epilepsy
- Any history of ill effects due to playing video games
- Fails other medical assessment, or on advice of carer
- Is already regularly playing a multi-player online video game

The exclusion criteria for non-brain-injured participants were less stringent, as their role was primarily to populate the game world. It was considered acceptable if they had already played an online multi-player game, as the hypothesis was being tested with the brain-injured participants only.

2.2.2 Participant details

Details of the three brain-injured participants are given in table 1. The thirteen non-brain-injured participants were students, recruited from a games programming degree course, and invariably had had experience of multi-player online video games, in contrast to the brain-injured participants. Twelve of these thirteen participants were male, with ages ranging from 20-32.

Participant	Brain injury	Sex	Age	Prior experience of online multiplayer video games
M	Stroke (haemorrhage) 2001	F	56	None

Participant	Brain injury	Sex	Age	Prior experience of online multiplayer video games
P	Stroke, 2010	M	55	None
A	Strokes, cerebral vasculitis, 2010-2011	M	45	None

Table 1. Brain-injured participants.

2.3 Procedures

Participants were asked to engage in activities using software provided by the researchers, for a number of sessions as detailed in table 2. On five consecutive Fridays, the participants were asked to take a short battery of cognitive tests. The participants were asked to play the multi-player online game on each day from Monday to Thursday, after the second and fourth Friday of tests. Participants used their own computer, in their own home. The intention was to maximise the number of participants by removing geographic location and mobility as barriers.

2.3.1 Session duration

Lerdal *et al.* (2009) state that fatigue is a common complaint following a stroke, but knowledge regarding post stroke fatigue is limited. In the current study, session length was intended to be kept as short as possible, to minimise fatigue. This had to be balanced with the need to keep the sessions long enough for any potential effects to develop, and for the participants to complete the weekly cognitive tests. In an unstructured interview with one participant, it was found that 15 minutes may be the maximum acceptable duration, but this is expected to be widely variable. Session lengths were recorded in this study, which will be used to guide future iterations of the experiment.

2.3.2 Participant training

Participants were not given explicit training on how to play the game. It was found during play test sessions that participants were comfortable with the point and click mechanic. The cognitive tests which are also part of the game software had a practice mode for each test. This allowed the participant to test his or her understanding of the test. The correct response is shown after the participant has made their response.

Saturday	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday
						23 August Take tests
24	25	26	27	28	29	30 Take tests
31	01 September	2 Play game	3 Play game	4 Play game	5 Play game	6 Take tests
7	8	9	10	11	12	13 Take tests
14	15	16 Play game	17 Play game	18 Play game	19 Play game	20 Take tests

Table 2. Calendar for the experiment. "Game weeks" are shaded.

2.4 Measures

This section describes the dependent variables, which were the test scores in a battery of cognitive tests taken weekly. For each test, participants were given instructions within the game software, and were allowed a practice attempt.

2.4.1 Reaction time test

A reaction time test is included in the present study. Many studies have found that playing video games improves the reaction time of the player (Griffiths, 2005), including brain-injured participants (Malec *et al.*, 1984). Participants are asked to click an on-screen button as quickly as they can after a prompt is given, as per Malec *et al.* (1984).

2.4.2 Stroop tests

The Stroop tests are comprised of three tasks. The first two are the Stroop colour test, and Stroop word test. The third, the Stroop colour-word test, is more difficult than the first two.

In the Stroop colour test, the participant is asked to identify the colours of rectangles by clicking on the correct button. The colour of the rectangle is chosen at random from four possibilities. The button positions do not change. This design follows the Stroop tests implemented in PEBL, the Psychology Experiment Building Language (Mueller, 2012). There is a time limit of 45 seconds. Figure 1 (a) shows this test.

In the Stroop word test, the participant is asked to select the button with the correct word, corresponding to the larger text. Figure 1 (b) shows this test. Again, there is a time limit of 45 seconds.

In the Stroop colour-word test, the participant should choose the button naming the colour of the word, not the word itself. For instance, in figure 1 (c), the correct response is to press the “blue” button – not “yellow” – because the colour of the word displayed on screen is blue. The difficulty of this task was discovered by Stroop (1935), and is ascribed to interference between the two separate cognitive tasks of identifying a colour and reading a word. Homack & Riccio (2004) point out that there are numerous variants of the Stroop tests and no “official” version. The validity of using computerised Stroop tests is supported by the findings of Hepp *et al.* (1996), who compared a computerised Stroop test with a manually administered version, and recommend that “computerized versions of the Stroop task should be used.”

2.4.3 Trail-making tests

In the manual version of these tests, the participant uses a pencil to connect randomly distributed numbered or lettered circles in a stipulated order. In the simpler case, the circles contain numbers and must be connected in sequential numeric order. In the second task, the circles contain alternating numbers and letters. The circles should be joined in the order 1-A-2-B-3-C, etc. These are commonly called tasks “A” and “B” (Zakzanis *et al.*, 2005).

In the current trail-making tests, the participant moves the mouse cursor over circles in order. There are two varieties of the test. The first is to select the circles in ascending numeric order. The second test is to select the circles in an alternating pattern of ascending numbers and letters. Figure 1 (d) shows the sequential test. In the alternating version of the trail-making test, the participant starts on '1', then moves to 'A', then '2', then 'B', etc.

Figure 1. The cognitive tests integrated into the game software.

2.4.4 Quantitative data

Data from the cognitive tests was recorded, per participant, per test session, as follows:

Reaction time test

- Reaction test time, measured in milliseconds. (Test is repeated three times.)

For each Stroop test

- Number of correct choices;
- Number of incorrect choices.

For each trail-making test

- Number of correct circles;
- Number of incorrect circles;
- Time taken to complete the trail, in seconds.

2.5 Design and development of the game software

A prototype multi-player online video game comprising integrated cognitive tests was developed in an iterative, participatory process. Brain-injured personnel from Headway East London provided input into the game design process, and participated in play testing, and user testing of the cognitive tests. Figure 2 shows a screenshot of the game.

Figure 2. Screenshot of game prototype in multi-player game mode

Developing bespoke software allowed for all aspects of the game experience to be customised to the requirements of the experimental design and the special needs of the participants.

2.5.1 Game design

The game developed is a multi-player online adventure game, intended as a much simplified example of an MMO. This genre was chosen because of its popularity – there are millions of MMO players. In the game, players inhabit a shared environment containing food, treasure, and harmful enemies which deplete the players' health. Health is restored by eating food, but players can only eat food given to them by other players, and are thus reliant on each other to stay alive. It is a “socially significant” situation as described by Ray (2004), intended to heighten the emotional involvement for players. Players can communicate with each other by typing text into a shared chat window. Text is also displayed to indicate the location of other players and their recent actions. This design is intended to foster communication, collaboration, and cooperation.

2.5.2 Accessibility features

During the development process, feedback from potential participants guided the inclusion of the following accessibility features.

- The game was initially envisaged as being 3D. This was changed to 2D as it was found that some brain-injured personnel would find this difficult to process and could feel “sea-sick” viewing it;
- Text-to-speech was incorporated for all in-game instructions;
- A soft keyboard allowed for mouse-only operation.

2.5.3 Development language and libraries

The game client was developed using C++ and OpenGL, initially running on Windows PCs. This choice allowed the authors to leverage pre-existing game code and assets. There is potential for porting to different platforms such as tablets, which may be advantageous for future iterations of the experiment. The game server is implemented as Perl scripts which talk to a database (MySQL). Client-server communication is over HTTP. The client sends RESTful requests to the server, which responds with XML. The project is open source, and is freely available (for details, go to <http://www.amju.com/mygame/dev.html>).

2.5.4 How the game design relates to the cognitive tests

The game design is intended specifically to foster altruistic and collaborative behaviour, by placing the players in a shared, adverse situation. Andras *et al.* (2007) note that in many contexts, cooperation between individuals improves as adversity and uncertainty increases in the environment. It is therefore the aim that the game design will have the effect of improving cooperation, counteracting feelings of loneliness and isolation.

Green & Bavelier (2006) point out that as all video games are different, the potential gain in perception or cognition from a given game is hard to predict. The essential ingredients of games which lead to improvements in a particular domain are not known. Therefore, broad tests of cognitive function were chosen as the measures.

The Stroop colour-word test is a commonly used measure of executive function. It measures the ability to shift cognitive set, and is believed to measure cognitive inhibition (Homack & Riccio, 2004) - the ability to suppress a learned response in favour of an unusual response. Trail-making tasks are widely used to measure cognitive flexibility and attention, as well as visual capabilities (Zakzanis *et al.*, 2005).

Studies have consistently found that playing action video games improves reaction time (Green & Bavelier, 2006). The current game is not an action game, but there are time-sensitive aspects to it, and it is played in real time. It was therefore hypothesised that an improvement in reaction time would be seen. If no improvement in reaction time was seen, this may indicate that a parameter of the experiment needs adjustment – e.g. the session duration has not been long enough to cause any improvement.

2.6 Ethical considerations

This section describes the risks to the participants identified. Following this risk assessment, institutional ethical approval was granted by the Faculty of Technology Ethics Committee at the University of Portsmouth.

Approximately 1 in 4000 people in the general population suffer from photosensitive epilepsy (PSE), in which a seizure may be triggered by video games, amongst other causes (Harding and Jeavons, 1994). The incidence of epilepsy is higher in the brain-injured population. Minor risks are the possibility of aches and pains; eye strain; and stress caused by extended periods of vigilance. These risks are mitigated by limiting play to short sessions. Other issues to consider when using video games as therapy are video game “addiction”; violent content; and the offensive nature of some games (Colman & Gnanayutham, 2010). Gaggioli *et al.* (2007) caution that using virtual environments for online therapy exposes participants to risks arising from the anonymous and open nature of virtual environments. This risk is averted by using a private server. Only invited participants were allowed to log in.

2.6.1 Informed consent

Potential participants were given an information sheet providing a summary of the experimental protocol, including potential risks, and a link to the project website which provides full details of the project. In this run of the experiment, all participants were physically able to sign the consent form.

3 Results

For each brain-injured participant, a time series of test scores were recorded. The tests were taken weekly, in a total of five sessions. One participant was taken ill, and did not complete the final

round of tests. There are a total of 15 test scores for each week, as each cognitive test has multiple measures.

3.1 Cognitive test scores

The mean of the results for the three brain-injured participants are reported in table 3 and plotted in figure 3.

For each participant, for each test score, percentage change from the first to final measurement was calculated as $(\text{final score} - \text{first score}) / \text{first score} * 100$. Mean and standard deviation of these values for each test are shown in table 4. Positive change is an improvement for correct test scores, but negative change is an improvement for reaction time, trail-making time taken, and incorrect test scores.

Figure 3. Weekly cognitive test scores for the three brain-injured participants.

Test	Measure	23 August	30 August	06 Sept	13 Sept	20 Sept
Stroop word	Correct	22	22.67	19.67	23	23
Stroop word	Incorrect	1.33	0.67	1	1	3
Stroop colour	Correct	21.33	22.33	19.67	22.67	23.5
Stroop colour	Incorrect	1.33	1.33	1.33	1	3.5
Stroop colour-word	Correct	13.67	12.33	13.67	15	13.5
Stroop colour-word	Incorrect	3.33	4.67	5.67	3	8.5
Reaction time	Mean	1019.4	1068.6	925.4	571.9	681
Trail making (sequential)	Correct	25	25	25	25	25
Trail making (sequential)	Incorrect	4.67	4.67	9	8.33	1
Trail making (sequential)	Time	81.59	85.62	80.19	82.86	96.9
Trail making (alternating)	Correct	25	25	25	25	25
Trail making (alternating)	Incorrect	8	6	9.67	10	13
Trail making (alternating)	Time	59.28	67.82	54.01	46.31	74.06

Table 3. Mean of results for ABI participants

Test name	Measure	Mean % change	S.D.
Stroop word	Correct	9.14	10
Stroop word	Incorrect	16.67	23.57
Stroop colour	Correct	35.4	38.2
Stroop colour	Incorrect	25	35.36
Stroop colour word	Correct	7.44	46.16
Stroop colour word	Incorrect	62.96	44.75
Reaction time		-29.04	18.76
Trail making (sequential)	Correct	0	0
Trail making (sequential)	Incorrect	108.33	277.14
Trail making (sequential)	Time	1.76	4.48
Trail making (alternate)	Correct	0	0
Trail making (alternate)	Incorrect	215.19	272.47
Trail making (alternate)	Time	-0.57	49.79

Table 4. Percentage change for each test score, from first to last measurement, for the three ABI participants.

3.2 Log in data

Server logs were analysed to find the typical session duration (time between logging in and logging out or closing the software), and how many players were logged in at any given time. There were a total of 281 distinct log in sessions. The mean session duration was just under 15 minutes. The number of players logged in at the same time varied between 0 and 10, with a median value of 1. In other words, for most of the time, there was only one person online at a time. This is shown graphically in figure 4.

3.3 Discussion

In this experiment, the hypothesis would be supported by an improvement in cognitive test scores following the weeks in which the multi-player online game was played by the participants. From inspection of the results for each participant, there is not an unambiguous improvement in the test scores at the end of the game weeks.

An overall improvement in reaction time was seen between the start and end of the study. This is in agreement with results of previous studies which have found that playing video games improved reaction time (Green & Bavelier, 2006). However, the game was only played for one-half of the overall experimental schedule, and so much improvement in reaction time could be due to simple practice effects. Week to week, the change in reaction time does not depend on whether or not the game was played.

Improvements were seen in some other test scores (e.g. the Stroop test correct scores), but other measures were worse at the end of the study (e.g. trail-making test incorrect scores). For all measures, the standard deviation in percentage change is large.

Running this pilot study has identified issues which may explain the negative result. Server logs were analysed to find the extent of interaction between the players, as this is the proposed intervention under test. Figure 4 shows a plot of the number of players logged in over the course of the experiment. It can be seen that, for much of the experiment, the participants did not play at the same time. The most important element of the intervention under test is that participants log in at the same time and play together, in order to gain the proposed benefits of social gaming. The results do not fully reflect the effect of playing together in a shared, multi-player environment.

Figure 4. Number of players logged in over the course of the experiment.

The number of participants in this study is of course small, and taking this pilot as an indication, unequivocal results for all participants is not a realistic expectation. In future studies, more participants can build up a richer picture, and contribute to greater external validity of the results.

4 Conclusions and future work

In this paper, the hypothesis has been presented that playing a multi-player online video game could provide a measurable cognitive therapeutic benefit for brain-injured people. A pilot study has been conducted. The results of this study did not find consistent cognitive improvements which could be ascribed to the effects of a multi-player online game, and so the hypothesis is not supported at this stage. This is in line with the findings of an earlier study which investigated the effects on cognitive skills of a single-player video game (Malec *et al.*, 1984). This pilot has been valuable in highlighting difficulties in conducting research of this nature. The next steps in this research are to refine the experimental design and the multi-player online game design in the light of these findings.

4.1 Future work

The main problem found with the experimental design has been that it is too reliant on the participants all logging in at the same time. When the participants are geographically dispersed, it is

difficult to ensure this happens. One solution to this problem would be to recruit many more participants, so that there would be more chance of some number of participants online at any given time. Another approach is to modify the game design so that the players have a social experience without needing to be online at the same time. For example, it is proposed to add a trading mechanic to the game, where players can swap items with each other. This can be done in a turn-based style, with players leaving messages for each other, so removing the need to be logged in concurrently.

4.2 Other potential lines of research

There are other game designs and genres which may give therapeutic benefits due to their social component. We have had conversations with brain-injured people who enjoy playing other types of online games, such as word and card games, including poker, which can involve potentially sophisticated social interactions (bluffing). Games which are turn-based do not require the players to be online at the same time, but can still provide a socially enriching experience.

To conclude, the difficulties inherent in this research area are described by Green and Bevelier (2006), who stress that it is not easy to produce perceptual or cognitive changes through video games, due to the many potentially confounding factors. We believe that it is worth attempting to address these challenges, as the potential gain is a new, complimentary form of therapy for brain-injured people.

5 References

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