A Prototype Virtual Reality Rehabilitation Game for Complex Regional Pain Syndrome

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Abstract:

A prototype virtual reality (VR) game for use in rehabilitation programmes for complex regional pain syndrome (CRPS) has been developed. The game uses a 'catch and throw' mechanic with a transposed 'handiness' control system. The game activities reflect 'mirror therapy' which is used to help patients learn to re-use their affected limbs. The game was developed with the Unity game engine and is played with the HTC Vive VR system. It was evaluated by thirty members of staff and students (age range 18-40+) form Birmingham City University (UK) using the System Usability Scale (SUS). The volunteer testers were differentiated into two groups, regular gamers (n=11) who played several times of day, daily or several times a week and less frequent gamers (n=16) who only played a few times a month or once a month. One person did not provide this information and two could not be classified clearly into either group and were therefore exclude from the analysis. Each group was standardized with results presented based upon the percentage of respondents within each group who answered either 'agree/strongly agree' or 'disagree / strongly disagree' to the SUS statements. Less frequent gamers (63%) said they would play the game frequently whereas 45% of the regular gamers said they would. Less frequent games (63%) thought the game was easy to use where as only 36% of regular gamers thought so. Ninety one percent of regular gamers and 75% of less frequent gamers said they thought people would find the game easy to learn. Seventy-five percent of less frequent gamers and 64% of regular gamers did not think the game was unnecessarily complex. Fifty-six percent of less frequent gamers and 36% of regular gamers said they did not find the game very cumbersome to use however the current control system should be refined as some found collecting the virtual balls difficult. This study records the systematic development of a prototype for a virtual reality based rehabilitation game. Despite some initial minor usability issues the game is playable and can be used to facilitate usability evaluations with CRPS patients.

Keywords: Virtual Reality, Game, Rehabilitation, Therapy, Complex Regional Pain Syndrome

1. Introduction

Clinical management of long term medical conditions is complex and does not rely solely on the use of drug therapies but involves a wide range of educational and behavioural interventions aimed at improving the quality of life of the individual. One long term medical condition that is very challenging to manage is complex regional pain syndrome (CRPS). It is relatively uncommon with an incidence of approximately 26 per 100,000 person years with females more likely to be affected than males (de Mos et al., 2007). For those that are affected it is a debilitating condition that affects a person's limbs. It is thought to occur as a result of damage to or from abnormal functioning of the peripheral and central nervous systems for example when a person suffers a stroke. The condition can persist and be resistant to a range of treatments. This can result in patients exhibiting a range of additional conditions including pain, swelling and a reluctance to move the affected limb. Treatments include the use of a range of education and self-management strategies, physical rehabilitation, pain relief and psychological support. Exercise programmes are used to improve issues associated with the circulatory system as well as helping with mobility, strength and function in the affected limb.

The rehabilitation process in CRPS is guided by health care professionals for example occupational and physio-therapists. They provide the patient with appropriate activities in order to help them recover, adapt and learn new ways of working and performing their daily tasks. Given that CRPS requires both physical and psychological interventions, therapies that combine both are important. One approach used is 'mirror therapy' where the affected limb is concealed behind a mirror and the unaffected limb is positioned so that its reflection is superimposed to where the affected limb should be (Pollard, 2013). Initially the patient is required to perform activities with their unaffected limb in the mirror giving their brain the perception that their affected limb is being used. Over time both limbs are used so that the patient feels both movement and also observes the reflection of the normal limb moving.

Rehabilitation exercises can be routine and not always fun especially when they have to be done repeatedly. In order to make these types of programme more enjoyable virtual reality (VR) and game-based approaches have been explored. Luque-Moreno et al (2015) reviewed a range of studies where VR had been used to support rehabilitation of lower body extremities in stroke patients. Their findings showed that VR had the potential to make a positive impact on a patient's balance and gait recovery. A review by Lohse et al (2014) also identified positive benefits of VR on body function when compared to conventional therapy. There was some evidence that commercial exergames could also benefit rehabilitation too but the authors of that report argued that the cohort sizes used in these studies were often too small to make any strong prediction based upon their analysis of the published work. Computer games and VR have also been used to assist with the management of pain with positive effects being reported when used in burn wound care as well as in both actual and experimentally induced pain (Hoffman et al, 2000; Jones et al, 2016; Malloy & Milling, 2010).

Successful health outcomes are associated with adherence to treatment plans. This can be difficult to manage outside of the clinical settings as lack of unsupervised activities over time can lead to reduced motivation to continue with treatment(s). It has been noted that the entertainment value of games can help with patient adherence to their therapies (Rose et al, 2018) meaning that they have the potential to help with poor motivation. The importance of social interaction in rehabilitation games has also been identified too. In a study by Ballester et al (2011) higher levels of improvement in stroke patients' hand mobility where identified when they played a multiplayer VR game when compared to the single player version. In their interviews with patients, who had previously played their games for stoke rehabilitation, Alankus et al (2010) recommended that the social side of the gaming could be a way of motivating their patients to continue to engage with their rehabilitation. The social aspect of games is therefore an important consideration when designing rehabilitation activities requiring regular repetition as in CRPS, as success in reversing the maladaptive changes in pain perception that patients experience requires continued and repeated practice of limb movement over time (Sato et al., 2010). The authors of this paper felt that the VR game should be fundamentally playable by anyone. By doing so both the patients, family members and friends could all play together introducing this important social support with a view that this should help the patient continue with their therapy.

In order to identify the effects of treatment and therapies on patients many clinical disciplines use specialised assessments to help with this. They are developed with the intention of providing a standardized and consistent mechanism for analysis which covers a range of possible health outcomes for example quality of life, physical and mental wellbeing, perceptions of pain as well as patient satisfaction with their care. This evidence-based approach identifies best use of current practice and then applies it to the care of individual patients (Sackett et al., 1996). Therefore these types of health outcome assessments play an important part of monitoring health care processes leading to improved doctor-patient interactions (Velikova et al, 2002; Snyder et al, 2011). The authors' game is designed with the intention of teaching patients how to regain the use of their affected limbs. Therefore in order to monitoring this health outcome measures had been incorporated into it.

This paper will describe:

- The development of the virtual reality game
- The health outcome assessments used
- The game and its levels
- Usability evaluation of the game by healthy volunteers
- The advantages and disadvantages of the current approach used

2. Development

2.1. Hardware and Software

The VR game was developed using Unity version 2017.3 incorporating the SteamVR plugin v1.2.3. The game was developed and tested on an Alienware gaming laptop (CPU: Intel i7-7700HQ @2.8 GHz; RAM: 16GB, Graphics: NVIDIA GTX1070) running the Windows 10 (64) bit Operating System. The game is played through the HTC Vive VR system. The minimum area used to play the game is 2.9m by 1.5m.

2.2. The Virtual Reality Game

The game is a simple casual based one which was designed so it could be played both by the patients as well as family and friends with a view to facilitating a communal approach to the rehabilitation process.

The game comprises a data room to record patient pain scores and their range of arm motion. The game has seven levels with the first one being the tutorial which is used to teach the player how to play the game. A menu system allows the user to navigate to either the data room or the game.

2.2.1. Data Room – Range of Motion Test and Visual Analogue Pain Scale

Before playing the game the user is asked to record their current level of pain using a built-in visual analogue scale (Figure 1). This graphical scale uses a series of different coloured icons expressing a range of facial expressions from very happy to very sad. The player selects the icon which closely matches how they feel about their level of pain resulting in a numerical value being recorded which ranges from zero (no pain) to 10 (unimaginable pain).

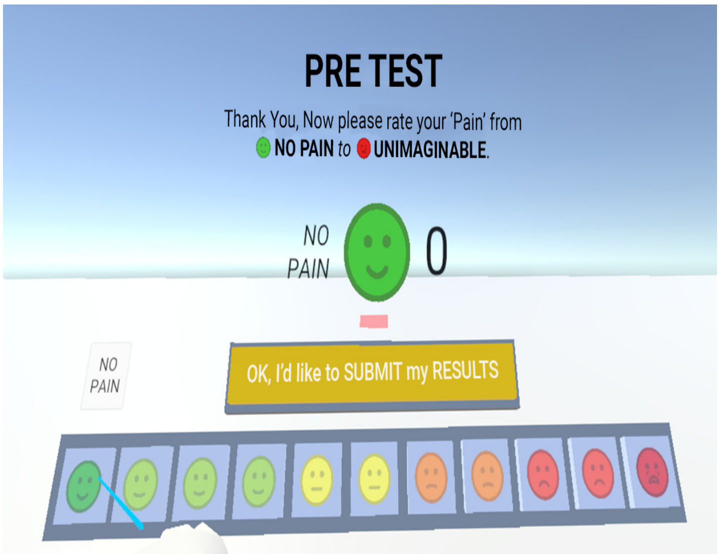

Figure 1. Visual analogue scale for pain. The player selects the icon which closely matches their feeling.

The player is also asked to complete a simple test which is used to determine their range of motion in their arm. At the start of this test the player uses the VIVE's controller to click on a button that appears within a rectangular area of the screen (Figure 2).

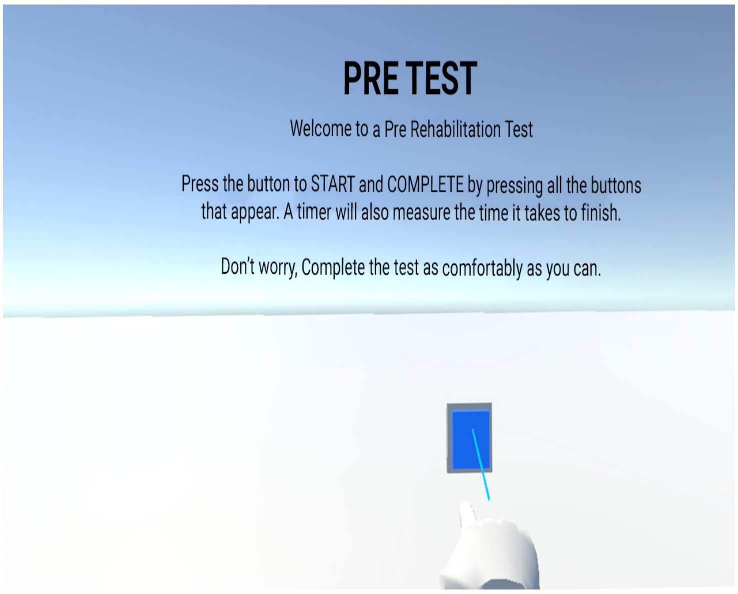

Figure 2. Range of motion test. The user clicks on buttons that appear in a set sequence in an increasingly larger area.

Once successfully 'clicked' another button will appear. In order to determine how these appear an algorithm was created that generates them in the following sequence: centre, top right, bottom right, bottom left and top left. The test repeats a total of three times, each time the size of the rectangular area increases. In this test, data are recorded on how many buttons were pressed, the time taken in-between pressing each of the buttons and the total time it took to press all of them.

Once these tests have been completed the player can then play the game. After successfully completing the game (levels) the user is again asked to complete both the range of motion test and the pain scale, in order to assess any potential effects the game had on these parameters.

The game anonymously stores the date and time that the tests were conducted; information on the range of motion the player was able to perform as well the rating of their current level of pain, both before and after playing.

2.2.2. The Game

The player uses their unaffected hand to play the game however they will see both left and right virtual hands in the game as this approach is used to encourage the brain to visual both limbs as being unaffected and functional. The mirroring effect is achieved by changing the HTC Vive controller's position and rotation relative to the Unity game camera's position. Secondly the Vive controller's velocity, which is used to throw the ball, is also mirrored so that when the balls are thrown they move in the correct direction.

The game has a total of eight levels each of which become increasingly more difficult as the user successfully completes them. Level 1 is the tutorial level which requires the player to collected coloured balls and throw them into a colour matched tiled area. They will gain a score each time they successfully achieve this. If they successfully complete the game by achieving the pre-set target score (6 in this level) then they can progress onto the next one. The subsequent levels become progressively more difficult by increasing the value of the pre-set target score. In the non-tutorial level the player can score in the game whenever the colour key of the Graphical User Interface (GUI) is black. However in advanced levels there is a specified random chance that the colour key of the GUI will change whilst playing the game (Figure 3). When this occurs the player can only score if they collect balls that match that specific colour and successfully throw them into the appropriate matching coloured tile. Also in each of the higher levels the surface area of the tile also decreases increasing the challenge of the game. For example at level 2 the probability that the colour key will change is 10% each time the player successfully scores; the surface area of the tile is set in the Unity game engine to a size of 1 unit. In level 7 there is a 50% chance that each time the player successfully scores the key colour will randomly change; the surface area of the tile decreases to 0.65 units.

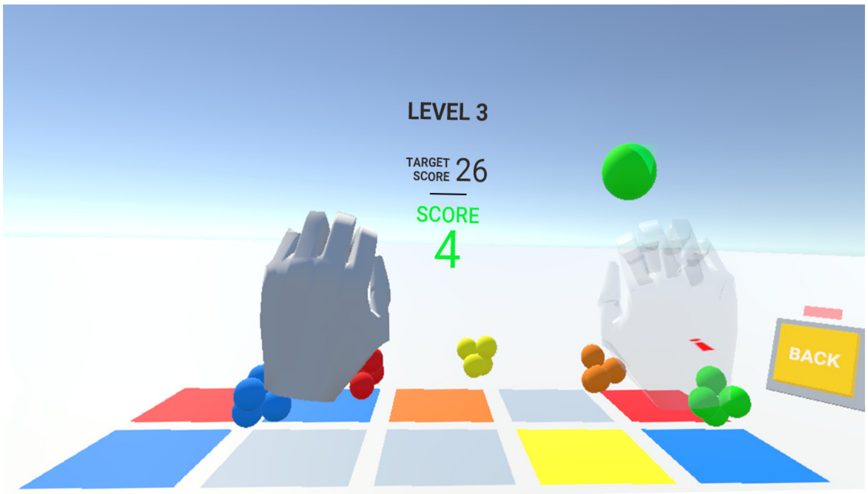

Figure 3. The game. The player will use the Vive controllers to coordinate how the virtual hands to throw the balls into appropriate matched tiles.

2.2.3. User Experience

The game has been developed so that it can assist the user in understanding how to play it. Each level has written instructions to help the player. Interactive areas, for example on the buttons have tool tips which provide instructions on playing the game and guidance on what to do (Figure 4).

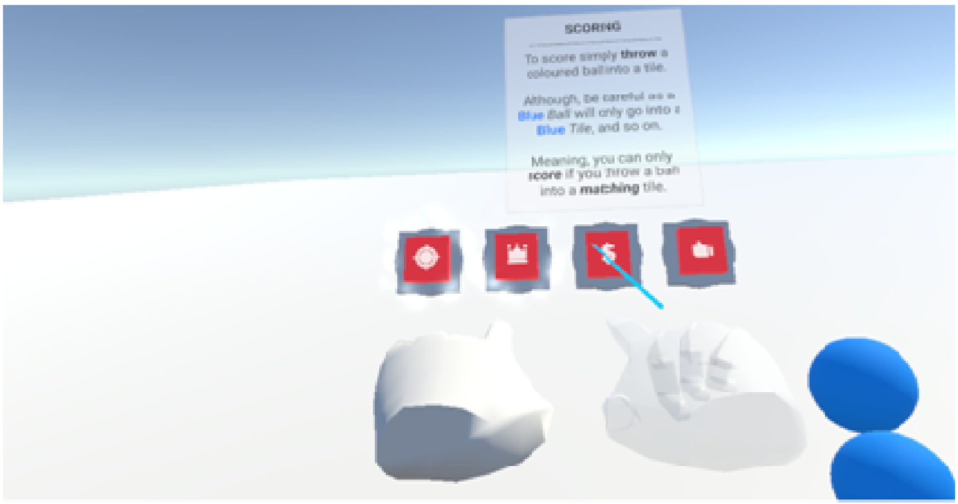

Figure 4. Feedback system in virtual reality providing instructions, information and guidance for the player

In order to preserve the logical flow of data collection the player cannot play the game before completing the pre-tests. They cannot complete the post-test until after playing the game.

2.2.4. Evaluation

Thirty staff and students from Birmingham City University (UK) were asked if they would like to assess the VR game. Demographic information was collected from them which included their age range (18-21, 22-25, 26-30, 31-40 and 40+); how often they play games (ranging from several times a day, daily, a few times a week, once a week, a few times a month or once a month). Each volunteer was given information about the game and what the study entailed prior to their agreement to participate and completion of an informed consent form.

Each participant played the game with no direction from the developers in order to gauge their ability to play it. After the game had been played they were asked to complete an evaluation using the System Usability Scale

(SUS) (Brooke, 1996). This scale has ten statements relating to a person's perception of the ease of use of the system. Each question is scored on a 5 point Likert scale.

Table 1. System Usability Scale statements

Statement number	SUS Statement
S1	I think that I would like to use this system frequently.
S2	I found the system unnecessarily complex.
S3	I thought the system was easy to use.
S4	I think that I would need the support of a technical person to be able to use this system.
S5	I found the various functions in this system were well integrated.
S6	I thought there was too much inconsistency in this system.
S7	I would imagine that most people would learn to use this system very quickly.
S8	I found the system very cumbersome to use.
S9	I felt very confident using the system.
S10	I needed to learn a lot of things before I could get going with this system.

For statement S1: "*I think that I would like to use this system frequently*" and S3. "*I thought the system was easy to use*" players were asked to add additional comments in order to clarify their responses. Two additional questions were also asked which included "*I found the game enjoyable to play*" rating it from 1 (strongly disagree) to 6 (strongly agree) and "*Would you pay this game with family or friends?*" responding as either yes or no. The volunteers were also asked as to their opinions on the following: "*Were there any particular areas that you found difficult to understand?*", "*Is there anything you 'liked' about the application or want to see more of?*" and "*Is there anything you 'disliked' about the application or would like to be fixed?*"

All thirty volunteers agreed to participate. Twenty-nine responded to the demographic questions. Age breakdown was 18-21 (n=17), 22-25 (n=7), 26-30 (n=2) and 31-40 (n=2), 40+ (n=1) and one no response. Of the twenty-nine respondents asked about their game playing habits, these were several times of day (n=1), daily (n=3), a few times a week (n=7), once a week (n=2), a few times a month (n=5) or once a month (n=11). Thirty people completed the SUS (Figure 5).

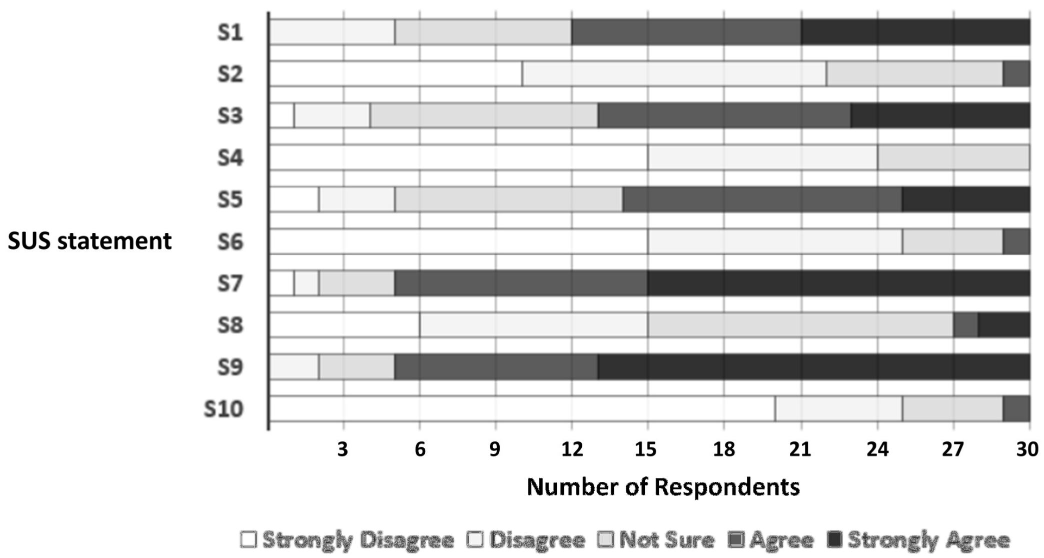

Figure 5. System Usability Scale (SUS) for the VR game. S1 to S10 are the individual SUS statements as presented in Table 1. Data are presented as number of respondents that answered either strongly disagree, disagree, not sure, agree or strongly agree with the respective SUS statement. Data are based upon thirty respondents.

Combining the ‘agree / strongly agree’ answers it was identified that players agreed with the following SUS statements S1: “*I think that I would like to use this system frequently*” (n=18: 60%), S3: “*I thought the system was easy to use*” (n=17:57%), S5: “*I found the various functions in this system were well integrated*” (n=16: 53%), S7: “*I would imagine that most people would learn to use this system very quickly*” (n= 25:83%) and S9: “*I felt very confident using the system*” (n=25:83%).

Combining the ‘disagree / strongly disagree’ answers it was found that players disagreed with the following SUS statements S2: “*I found the system unnecessarily complex*” (n=22:73%), S4: “*I think that I would need the support of a technical person to be able to use this system*” (n=24:80%), S6: “*I thought there was too much inconsistency in this system*” (n=25:83%), S8: “*I found the system very cumbersome to use*” (n=15:50%) and S10: “*I needed to learn a lot of things before I could get going with this system*” (n=25:83%).

Seventeen out of the twenty-nine respondents said the game was enjoyable to play with ten being unsure as to their views on it. Twenty-two of the twenty-nine respondents said that they would play the game with family or friends.

When respondents were asked why they would play the game again seven said it was because it was fun. Reasons for not playing were cited as too simple (n=2) and repetitive (n=3). When the players were asked which parts were the most difficult to use some of the gameplay elements such as picking up the balls were a little too difficult for them (n=8), five respondents felt that the mirrored hands were confusing to use and four did not understand the rules of the game.

Two sub groups were created from the total cohort. Regular players (n=11) were classified as those who play several times of day (n=1), daily (n=3) and several times a week players (n=7). Less frequent gamers (n=16) were those that play a few times a month (n=5) or once a month (n=11). Those who played once a week (n=2) were not included in either group. One person did not supply this information and so could not be assigned to either group. Within each new group the data were combining for all ‘agree/strongly agree’ (positive) or ‘disagree / strongly disagree’ (negative) responses to the SUS statements. The data were subsequently standardized as a percentage of the total number of volunteers, within each group, who either responded positively or negatively to the respective SUS statement.

It was found that within the less frequent gamers group 63% would play the game frequently (S1) whereas 45% of the regular gamers said they would. Less frequent games (63%) thought the game was easy to use (S3) where as only 36% of regular gamers thought so. In terms of how the various functions in the game were integrated (S5) 64% of regular gamers and 44% of less frequent gamers thought they were. In statement S7: “*I would imagine that most people would learn to use this system very quickly”,* 91% of regular gamers and 75% of less frequent gamers said they thought it would be. Eighty-eight percent of less frequent gamers and 72% of regular gamers felt very confident when playing the game (S9).

When the volunteers were asked if they found the system unnecessarily complex (S2), 75% of less frequent gamers and 64% of regular gamers did not think it was. Eighty-one percent of both regular gamers and less frequent gamers did not feel that they needed technical support to be able to play the game (S4). Eighty-eight percent of less frequent gamers and 82% of regular gamers did not feel that there was too much inconsistency in the game (S6). Fifty-six percent of less frequent gamers and 36% of regular gamers said they did not find the system very cumbersome to use (S8). Eighty-one percent of both regular gamers and less frequent gamers felt that they did not need to learn a lot of things before they could play the game (S10).

When the volunteers were asked whether there were any particular areas that they found difficult to understand nineteen of the respondents said there were not, three said it confusing having the two hands visible (two of which were less frequent gamers) and three found it difficult to collect the balls (all less frequent gamers). When asked was there anything they 'liked' about the game or want to see more of, eleven volunteers said they would like more complexity and game features (7 non-gamers (44%) and 4 gamers (36%)) and two of them would have liked to have seen better aesthetics. Finally when all were asked if there was anything they 'disliked' about the game or would like to be fixed 14 respondents said no. Seven said the hand controls needed to be easier (two gamers (18%) and 5 non gamers (31%)).

As the age range of the volunteers was predominantly below 25 with few over 30 no analyses was performed against any potential age related affects on the system usability scale responses.

3. Discussion

With the development of any health technology it is important to engage with both the doctors and patients to ensure the product accurately reflects the clinical needs and is what is wanted leading to a better chance that the users will be satisfied with it. This can be challenging as access to both health care professionals and patients is limited by their availability. CRPS in itself is relatively uncommon making working with patients even more difficult. The first stage in this longer term project was to systematically develop a prototype VR game which would be initially evaluated by healthy volunteers. The System Usability Scale (Brooke, 1996) was used as quick determinant for satisfaction with the game and to identify any immediate issues and problem before engaging with patients. Fixing bugs and rudimentary usability and game play issues during meetings with doctors and patients would not be conducive to productive talks and would waste valuable time with them. The initial evaluation would also help the authors gauge how fun and playable the game was to a more general audience, an important consideration given that the social aspect of this rehabilitation game was posited as a way of potentially maintaining the patient's adherence to their therapy.

There were relatively positive responses to the game with testers feeling that they would play it again. Less frequent gamers were more likely to do so. The less frequent gamers were more likely to find the game easier to play where as regular gamers were more likely to understand how it all worked. Both groups felt people would be able to learn how to play it quickly as it did not require much learning how to play it, and it was not so difficult that it would require technical support to help play it. The testers thought the game was not unnecessarily complex albeit perhaps cumbersome in places. The hand control system, used in the mirroring effect, was cited by some as being not quite refined as of yet.

Table 2. Summary of identified issues during the approach used

Item	Issue	Potential Resolution
HTC Vive	Expensive equipment. The cost of both a specialised PC / Laptop capable of running the Vive and Vive can exceed £1000.	Review alternative VR headsets - Oculus and Windows Mixed Reality are cheaper but still require high specification machines. Use Google cardboard or similar head mounted displays for mobile phones. They have less functionality but are more affordable.
HTC Vive	Despite the game only needing a limited playing area the Vive's light houses require a relatively large space which may not be suitable in all family homes.	Review alternative standalone VR headsets.
Game play	The current game play is not appealing to all users.	Continual play testing and review will be used to make the game fun and challenging for both gamer and non gamers.
The game	Game play can be difficult for some users with the current control system.	Refine control system without compromised the mirror effect and the therapeutic activities.
Player data	Player data is anonymized but stored on PC. Data needs to be available for review by the clinical staff.	A system of private and secure data transmission to clinical staff needs to be implemented.

The development processes described in this paper have shown that it is possible to make a VR game that reflects the therapeutic activities used by occupational therapists. The evaluation identified both positives and negatives of the game, and areas for improvement. Although this usability data cannot be extrapolated to suggest that the approach would be appealing to patients, it was encouraging that less frequent gamers were positive about the game and in some instances their responses were more so than regular gamers. Therefore there is indication that the game does appeal to a general audience, which is something the authors were trying to achieve in order to facilitate the social aspect of the game. During the development of the game the authors identified areas for consideration which could impact on the adoption of the system in the clinical or home setting (Table 2).

4. Conclusion

This study is one of the first that the authors are aware of that has recorded the systematic development of a prototype for a VR based rehabilitation game for complex regional pain syndrome which is based upon mirror therapy. During the development of the prototype game the authors identified some potential issues with the overall system as well as with the game, which were highlighted by the use of the System Usability Scale. Despite this, there were generally positive responses from the testers indicating that the current game was playable and therefore could be used to facilitate further development and usability evaluations with CRPS patients. The processes described in this paper will be of interest to others who are exploring the development, use and evaluation of virtual VR games for rehabilitation in clinical settings.

5. Ethics

Ethics approval to conduct this study was sought from Birmingham City University's Faculty of Computing, Engineering and the Built Environment Faculty Research Ethics Committee.

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References

Alankus, G., Lazar, A., May, M. and Kelleher C. (2010) “Towards Customizable Games for Stroke Rehabilitation”, CHI 2010, Atlanta, Georgia, USA, April.

Ballester, B.R., Badia, S.B.I. and Verschure, P.F.M.J. (2011) "The effect of social gaming in virtual reality based rehabilitation of stroke patients", International Conference on Virtual Rehabilitation, Zurich, Switzerland pp 1-2.

Brooke J (1996) *SUS: a quick and dirty usability scale*. *Usability Evaluation in Industry*, Taylor and Francis, London.

De Mos, M., De Bruijn, A.G.J., Huygen, F.J.P.M., Dieleman, J.P., Stricker, B.H.C. and Sturkenboom, M.C.J.M. (2007) “The incidence of complex regional pain syndrome: a population-based study”, *Pain*, Vol 129, No. 1-2, pp 12-20.

Hoffman, H.G., Doctor, J.N., Patterson, D.R., Carrougher, G.J. and Furness, T.A. (2000) “Virtual reality as an adjunctive pain control during burn wound care in adolescent patients”, *Pain* Vol 85, No. 1-2, pp 305-309.

Jones, T., Moore, T. and Choo, J. (2016) “The Impact of Virtual Reality on Chronic Pain”, *PLoS One*, Vol 11, No. 12, pp e0167523.

Lohse, K.R., Hilderman, C.G.E., Cheung, K.L., Tatla, S, and Van der Loos, H.F.M. (2014) “Virtual Reality Therapy for Adults Post-Stroke: A Systematic Review and Meta-Analysis Exploring Virtual Environments and Commercial Games in Therapy”, *PLoS One* Vol 9, No. 3, pp e93318.

Luque-Moreno, C., Ferragut-Garcías, A., Rodríguez-Blanco, C., Heredia-Rizo, A.M., Oliva-Pascual-Vaca, J., Kiper, P. and Oliva-Pascual-Vaca, Á. (2015) ”A Decade of Progress Using Virtual Reality for Poststroke Lower Extremity Rehabilitation: Systematic Review of the Intervention Methods”, *BioMed Research International*, Vol 2015, No. 342529.

Malloy, K.M. and Milling, L.S. (2010) “The effectiveness of virtual reality distraction for pain reduction: a systematic review”, *Clinical Psychology Review*, Vol 30, No. 8, pp 1011-1018.

Pollard, C. (2013) “Physiotherapy management of complex regional pain syndrome”, *New Zealand Journal of Physiotherapy*, Vol 41, No. 2, pp 65-72.

Rose, T., Nam, C.S. and Chen, K.B. (2018) “Immersion of virtual reality for rehabilitation – Review”, *Applied Ergonomics*”, Vol 69, pp 153-161.

Sackett, D.L., Rosenberg, W.M.C, Gray, J.A.M., Haynes, R.B. and Richardson, W.S. (1996) “Evidence based medicine: what it is and what it isn't”, *British Medical Journal*, Vol 312, pp 71.

Sato, K., Fukumori , S., Matsusaki, T., Maruo, T., Ishikawa, S., Nishie, H., Takata, K., Mizuhara, H., Mizobuchi, S., Nakatsuka, H., Matsumi, M., Gofuku, A., Yokoyama, M. and Morita, K. (2010) “Nonimmersive virtual reality mirror visual feedback therapy and its application for the treatment of complex regional pain syndrome: an open-label pilot study”, *Pain Medicine*, Vol 11 No. 4, pp 622-629.

Snyder, C.F., Aaronson, N.K., Choucair, A.K., Elliott, T.E., Greenhalgh, J., Halyard, M.Y., Hess, R., Miller, D.M., Reeve, B.B. and Santana, M. (2012) “Implementing patient-reported outcomes assessment in clinical practice: a review of the options and considerations”, *Quality of Life Research*, Vol 21, No. 8, pp 1305-1314.

Velikova, G., Brown, J.M., Smith, A.B. and Selby, P.J. (2002) “Computer-based quality of life questionnaires may contribute to doctor-patient interactions in oncology”, *British Journal of Cancer*, Vol 86, No. 1, pp 51-59.