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CMP6200/DIG6200

Individual Undergraduate Project 2024–2025

**A1: Proposal**

Gamifying movements BENEFICIAL for upper limb stroke rehabilitation



Course: Computer Games Technology

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# Introduction

## Background and Rationale

Upper limb stroke rehabilitation typically sees heightened implementation after patients are discharged from the hospital. After returning home a patient should undertake home therapy programmes to further recover and better their quality of life.

Having a range of home therapy options is vital, crucially due to patient travel limitations. Almost 10 million people in England live in rural areas. (Gov.Uk, 2024:7) In these areas there are more people aged 50-59 years than any other age group with one in four people being over 65 (Gov.Uk, 2024:8). This correlates with the ages statistically vulnerable to having a stroke. According to the GRASP instructor manual (The University of British Columbia, 2021:9) the risk of stroke doubles every 10 years after age 55, with the typical age at the time of stroke being 70 – 75 and 25% of strokes occurring in individuals below the age of 65.

The brain has the most ability to repair itself in the first 3 months’ post stroke (The University of British Columbia: 2021: 5) therefore it is vital that the patient completes as much therapy in this time as possible to maximise recovery. Currently there are home therapy programmes such as the GRASP manual. However contemporary home therapy programmes do not provide high levels of motivation to the patient, this can cause the therapy to be neglected leading to sub-optimal recovery or potentially other implications such as learned non-use syndrome (The University of British Columbia, 2021: 13).

Therefore, it is important to explore ways to provide more motivation to the patient. Gamification and even more so multiplayer gamification is one such way this goal can be achieved. Being able to play the game alongside family members, friends or caregivers may provide higher levels of motivation and reduce the neglect of home therapy, increasing its effectiveness.

This paper is the first stage of the experiment and will be tested on healthy adults to verify the intended movements are being performed in the correct repetition ranges and to test the user experience and motivation using the game.

## Key Themes/Topics

Key Words:

* Games for rehabilitation – The design decisions made for the artefact will be made through the lens of providing effective rehabilitation
* Upper extremity – arm, wrist and hand movement and flexion will be targeted
* Stroke
* Multi-player – multiplayer games often cause a game to have increased replay ability which is vital for a rehabilitation game as it will be used very frequently
* Gamification – Gamification will be employed to create a therapy which gives the user greater motivation to use the therapy.

Key Themes:

* Production of a gamified treatment to encourage beneficial movements
* Game design, especially game design pertaining to serious games and stroke rehabilitation
* User centred design
* Multiplayer game design
* Motivation and willingness to use the game created

# Project Planning

## Initial Project Plan

An Agile methodology specifically scrum will be used during development. At a high level there will be a planning phase, followed by implementation and then evaluation. In the planning phase the different requirements of the project will be considered to create an exhaustive list of tasks which need to be completed.

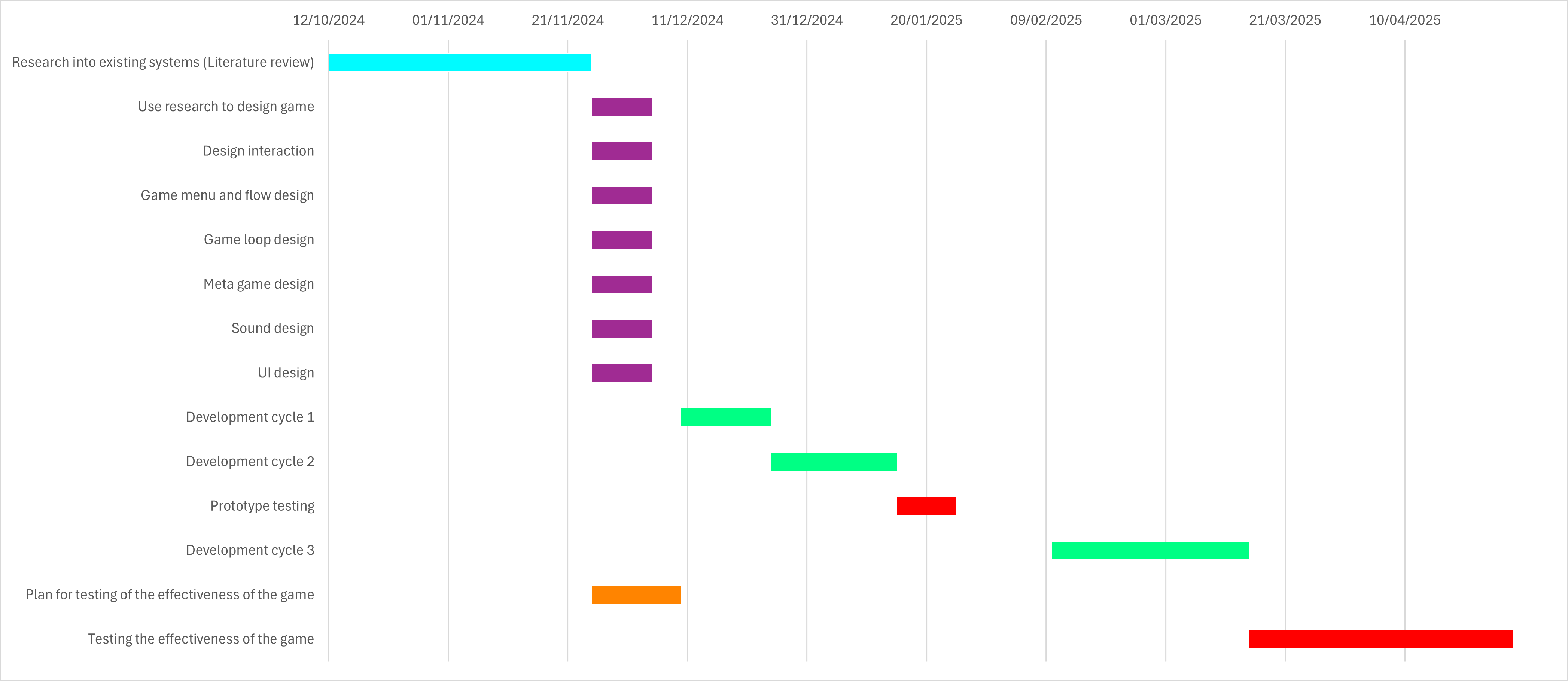
Then the implementation phase will be split into three cycles, the exhaustive list from the previous phase will be used to plan what work will be completed in the next cycle. After the second cycle a pilot test will be conducted, and the third cycle will address issues found.

Finally, once the project is complete it can be tested and its effectiveness evaluated.

Table 1 below outlines the tasks which will need to be completed for the project.

Table 1 high level tasks to complete

|  |  |  |  |
| --- | --- | --- | --- |
| Task Name | Task Description | Date Start | Date End |
| Research into existing systems (Literature review) | Research looking at conventional therapy options and what movements/exercises they use. Additionally, investigation into game design of upper limb rehabilitation serious games will be conducted | 12/10/2024 | 25/11/2024 |
| Use research to design game | A small design document will be produced. Additionally, an exhaustive task list will be created. Each task having a cost and priority ranked 1 – 3 break each task down into its atomic elements | 25/11/2024 | 05/12/2024 |
| Design interaction | This will require consideration to be taken into how the user will interact with the game, utilizing etee controllers, in a simple and effective way. | 25/11/2024 | 05/12/2024 |
| Game menu and flow design | What menus will be present in the game will be designed as well as the flow of using the system. | 25/11/2024 | 05/12/2024 |
| Game loop design | Design in the moment-to-moment gameplay will be considered | 25/11/2024 | 05/12/2024 |
| Meta game design | This design focuses on the gameplay of an entire game/ play session | 25/11/2024 | 05/12/2024 |
| Sound design | What sounds will be needed | 25/11/2024 | 05/12/2024 |
| UI design | Each menu and UI will have to be designed. | 25/11/2024 | 05/12/2024 |
| Development cycle 1 | Development cycle 1 will consist of setting up the multiplayer and etee controls. Basic menus and placeholder UI will be created. A prototype White box level will be created along with some simple interaction. | 10/12/2024 | 25/12/2024 |
| Development cycle 2 | The gameplay will be completed in this phase. Game interaction will be continuously tested for ease of use. 3d art will be added to the game. | 25/12/2024 | 15/01/2025 |
| Prototype testing | The prototype will be tested to see if users can use the game easily and if it is encouraging the movements intended | 15/01/2025 | 25/01/2025 |
| Development cycle 3 | The final phase of development will be dedicated to polishing the game, this includes responding to tester feedback, adding in art, sound effects and complete menus. | 10/02/2025 | 15/03/2025 |
| Plan for testing of the effectiveness of the game | Time will need to be taken to consider how the testing will be conducted and preparing resources for the testing such as printing off resources such as how to use the controllers, how to play the game etc… | 25/11/2024 | 10/12/2024 |
| Testing the effectiveness of the game | The actual testing of the game will look to gather adult participants to test the game. The success of the project can then be evaluated. | 15/03/2025 | 28/04/2025 |

Figure 1 tasks to complete visualised as a Gantt Chart

## Resources

* Computer (with internet connection), mouse and keyboard
* Access to someone knowledgeable in the field of upper limb stroke rehabilitation
* Unity game engine
* Version/source management software (GitHub)
* An integrated development environment (IDE) such as JetBrains Rider
* Access to adults with a varying prior experience with videogames for the final testing
* Home stroke rehabilitation items currently being used to compare the project artefact to
* A pair of etee controllers for development, testing and playing the game
* Access to someone knowledgeable with unity in case implementation issues and bugs arise
* Information such as the grasp manual to identify beneficial movements and/or exercises
* New people to playtest the game during development to check for quality, fun and usability
* Access to copyright free music and sound effects to put into the game
* Access to copyright free art assets to use in the game
* Software to create art assets when needed for the game (visual and auditory)
* Word for creating design and planning documents
* Access to a printer to print off resources such as guides on how to play the game/the structure of the testing session to be shown to participants in testing.

## Risk Assessments

|  |  |  |  |
| --- | --- | --- | --- |
| Risk assessment issue | How it will be mitigated | Likeliness (1-3) | Severity (1-3) |
| Hygiene issues | Antiseptic wipes | 3 | 1 |
| Controller damage | Controllers will be transported in their original packaging. | 2 | 3 |
| Hardware issues | GitHub source control and computer transport bag | 2 | 2 |
| Limited access to field specialists | Information will mostly be gathered independently. | 3 | 1 |
| Inexperience using unity networking solution | Unity has very good documentation and community to aid learning. | 3 | 2 |
| First time developing using etee API | Reaching out to members/developers at etee for support if issues arise. | 3 | 2 |
| No access to contemporary home therapy equipment | Use non equipment therapies to compare against for user motivation. | 3 | 1 |
| Implementation issues | Tasks will be well planned and broken down. This will allow the scope of the project to be realistic at conception and will allow the scope to be intelligently adjusted to ensure the project finishes on time. | 3 | 2 |
| Unable to access or create art assets for the game | By keeping the game world small the art assets required are limited decreasing the probability of missing assets. | 2 | 2 |
| Use of copyright material | Any third-party assets will be checked for copyright. | 3 | 3 |
| External responsibilities (work and other modules) | Same as implementation issues. | 3 | 3 |

# Project Review and Methodology

## Critique of Past Final Year Projects

(Goff, 2020) starts his paper by acknowledging the current issue of global warming and environmental damage. Goff (2020: 9) asserts “The tourism/travel industry is a significant contributor to worldwide pollution”. The project produces a mobile application to be part of a solution to this problem. The application is designed to gamify tourism in a way that encourages walking to destinations rather than taking a car or bus. This is done using gamification techniques such as, statistics (score, steps, landmarks visited, routes, distance travelled and time spent), awards and a level attached to the account. These are effective gamification techniques. In the evaluation Goff (2020:38) remarks that according to feedback obtained through questionnaires these techniques were effective and lead to more engagement in the experiment group.

Goff’s (2020) project is relevant to this one as it employs gamification techniques to encourage certain behaviours. In this case using sustainable travel. Gamification in the design of this project should be considered to drive user motivation.

To critique this project, the decision to develop the application for IOS systems was a large risk. Goff (2020: 12-13) had little experience developing for iOS and its multitude of difficulties. It was later remarked in the challenges and issue’s part that “The most significant issue during the project was underestimating the time needed to learn the new system and programming language being used to develop the artefact” (Goff, 2020: 21). This led to features not being completed. Taking these lessons learnt and applying them to this project means that Unity, a familiar game engine, will be used to develop the project. This will help reduce the time spent learning and troubleshooting new technologies. One of the reasons this learning process was such a hindrance was the lack of documentation and guidance. (Goff, 2020:21) Fortunately, programmers at etee will be able to answer questions regarding the API for development with etee controllers.

(Day, 2018) seeks to examine the efficacy of the use of VRET when used to treat anxiety disorders, specifically public speaking. Day (2018) recognises the studied effectiveness of exposure therapy as a treatment for irrational fears and positions this paper to be an extension of that knowledge. Achieve the aim of the project a bespoke environment was produced to mean VRET standards. The project overall met its objectives. As for the efficacy of the system the test showed “The results of the experiments show that participants who performed the interview within VR showed a greater decline in heartrate by the end of the mock interview than those who performed outside VR” (Day, 2018:52) therefore the system was deemed as overall effective.

This paper is linked to this project as it details the development of a serious game designed to be used as a treatment.

One thing that was done very well was the effective use of a user centred design methodology. This manifested itself as a set of playtests. The first playtest uncovered a negative response to the environment created. With testers reporting of an uncanny valley feeling. After receiving this feedback Day (2018) was able to make the appropriate changes to the environment such that the testers no longer felt that the environment was distracting.

However, due to the nature of the project some complex ethical considerations must be made. This would have increased the complexity of the project. Considerations must be made regarding exposing users to a VRET environment and considerations into the wellbeing of users with diagnosed social anxiety disorder included in the study. For reasons like those previously described this paper will focus on nondescript adults.

**A2: Literature Review**

# Report introduction

This report will investigate previous gamified therapies, their methods, and their effectiveness. This information will be crucial to the design of the artefact.

# Aim and Objectives

## Project Aim

The aim of this project is to produce a multiplayer game, utilizing etee controllers, which encourages movements beneficial to Upper Limb (UL) stroke rehabilitation and provides more motivation than conventional home therapy treatments.

## Project Objectives

* Identify characteristics of effective rehabilitation treatments.
* Identify movements beneficial to providing effective rehabilitation treatment.
* Use knowledge gained from objectives 1 and 2 to design, scope and plan the development of the serious game
* Develop the game using the designs and plans produced in the previous objective using agile project management techniques
* Test the game with a group of adults to observe the repetitions of the intended motions and motivation to play the game relative to other therapy options.
* Use the knowledge learned from testing to evaluate the projects outcomes.
* Summarize and report writing

# Literature Search Methodology

To find relevant and useful papers which will inform this literature PICOC in conjunction with PRISMA will be used to find and screen papers. PICOC as defined on its website is “a method used to describe the five elements of a searchable question” (CEBMa). PICOC will be used to help think about and create searchable terms which will be used to find and screen papers as per the PRISMA guidelines.

The PICOC acronym stands for, Population, Intervention, Comparison, Outcome and Context. Below is each of these acronyms expanded in relation to this paper.

|  |  |
| --- | --- |
| PICOC element | Expanded acronym |
| Population (Who?) | General population sample |
| Intervention (What or How?) | A bespoke multiplayer gamified software solution designed to facilitate and encourage upper limb movements conducive to stroke rehabilitation |
| Comparison (Compared to what?) | Conventional physical therapy techniques used for upper limb rehabilitation (e.g. traditional exercises) |
| Outcome (What are you trying to accomplish / improve?) | Users perform therapeutic upper limb movements with increased motivation compared to conventional therapy. |
| Context (in what kind of organization / circumstances?) | Using the software for rehabilitation in a home setting. |

Using this PICOC structure, keyword search terms and permutations can be generated and used in databases to find potentially useful literature.

|  |  |  |  |
| --- | --- | --- | --- |
| Search term permutation | Input to database search | Searched database | Literature retrieved count |
| (Population) AND (Intervention) | (general AND population OR stroke AND patients) AND (gamified AND rehabilitation OR virtual AND therapy) | Scopus | 2 |
| (Outcome) AND (Context) | (upper AND limb AND movements OR patient AND engagement) AND (home-based OR in-home) | Scopus | 19 |
| (Intervention) AND (Comparison) | (game-based AND software OR digital AND therapy) AND (traditional AND rehabilitation OR conventional AND therapy) | Scopus | 4 |
| (Intervention) AND (Outcome) AND (Context) | (gamified AND rehabilitation OR virtual AND therapy OR game-based AND software OR digital AND therapy) (motor AND improvement OR adherence) AND (home AND rehabilitation) | Scopus | 1 |
| (Population) AND (Intervention) AND (Outcome) AND (Context) AND NOT (Exclusions) | (general population OR stroke patients) AND (gamified rehabilitation OR virtual therapy OR Serious Games) AND (upper limb movements OR patient engagement) AND (home-based OR in-home) NOT (lower limb) NOT (clinical) AND (multiplayer OR multi-user) | Google Scholar | 247 |

These searches retrieved a total of 273 pieces of likely relevant literature. These results will then be screened using inclusion and exclusion criteria.

PRISMA provides a set of guidelines ensuring systematic reviews and meta-analyses are comprehensive, transparent and reproducible. Prisma guidelines will be used in the selection process of relevant papers.

Inclusion and exclusion criteria will be used to screen the papers found from the database searches.

|  |  |
| --- | --- |
| Inclusion Criteria | Exclusion Criteria |
| Literature focused on gamified or digital interventions for UL rehabilitation | Studies not related to stroke or upper limb rehabilitation |
| Studies evaluating repetitions or engagement as outcomes | Interventions not utilizing gamified or digital methods |
| Research involving at-home or remote-based rehabilitation | Studies with a focus solely on lower limb |
| Papers published in peer-reviewed journals | Research involving clinical settings exclusively |
| Studies that compare interventions to traditional rehabilitation methods | Result past the second page of google scholar |
|  | Research focusing on robotic intervention |

Records identified from\*:

Databases (n = 273)

Registers (n = 0)

Found personally through arbitrary searches (7)

Backward snowballing (3)

Records removed *before screening*:

page of google scholar (n = 227)

records added which were used in the project proposal (n = 3)

duplicates removed (n = 1)

Records screened

(n = 52)

Records excluded\*\*

(n = 18)

Reports sought for retrieval

(n = 37)

Reports not retrieved

(n = 7)

**Identification of studies via databases and registers**

**Identification**

**Screening**

**Included**

Reports assessed for eligibility

(n = 27)

Reports excluded:

Literature focuses on robotic rehabilitation (n = 3)

Literature did not focus on non-digital based interventions (n = 2)

Studies included in review

(n = 25)

Reports of included studies

(n = x)

# Themes

The following themes were extracted from the literatures…

|  |  |
| --- | --- |
| Theme | Relevance |
| Gamified rehabilitation in stroke | See what gamification techniques have been applied in other projects to inform the approach to gamification in this project. |
| Digital application to enhance motivation of the therapy | The goal of this project is twofold, to create a therapy application where the user performs an adequate amount of movement while experiencing more motivation to do so. Knowing what game elements users respond well to will be important in creating an experience that users enjoy more than non-game therapies. |
| Digital application to enhance upper limb movement | Linked to the previous theme it is important to know what movements are beneficial to inform the design of the game and what it asks the user to do. |
| Haptics for rehabilitation game | Haptics is an implicit form of feedback correlated with effective rehabilitation and user experience. |
| Multiplayer games for stroke rehabilitation | A relatively new and exciting topic for exploration which may provide large boosts to motivation. |

# Review of Literature

## Gamified Rehabilitation for Stroke

Gamification is the application of elements typically found in commercial games. It is a technique which, when applied, results in greater levels of user motivation when completing a task.

After reviewing relevant literature in the field of post stroke therapy gamification, (Tamayo-Serrano et al, 2018) identified a set of features commonly used in gamified rehabilitation applications. Some features which seem highly relevant to this project include meaningful play and feedback, social interaction, simple interaction devices and motivational rewards.

(Guo, 2024) discusses gamification and how it can be employed to create a gamified learning experience. The process of gamification is not a process of injecting game elements to the target context but instead requires systematic thinking to design game elements which help enhance and achieve the design goals (Guo, 2024).

The FRAGGLE framework, as presented by (Guo, 2024), is utilized to design the game which includes four iterative phases. A declaration phase where learning resources and teaching methodologies are reviewed to create different learning objectives. A Creation phase where the game elements such as mechanics and user interactions are designed. An Execution phase where the game prototype is implemented and finally a learning phase which includes product evaluation and test and feedback data collection. (Guo, 2024) uses this framework and was able to design the product and produce an MVP ready for user testing.

### Meaningful Play and feedback

(Tamayo-Serrano et l, 2018) describes Meaningful play as the ability for the player to perceive the immediate effects of his/her actions which must have an impact in the game at some point in the future. The authors go on to state that the decisions made by the player will shape the outcomes of the game.

Under the line of thinking of (Tamayo-Serrano et al, 2018) feedback is part of meaningful play and is the extra stimulus given to the player to inform them about the result of their actions.

This feedback can be used to guide the player into taking the correct action and discourage them from taking incorrect actions. Other literature also recognizes the importance of feedback. (Maier et al) cited by (Doumas et al, 2021), established a list of neurorehabilitation principles, implicit feedback, that being feedback on the user’s performance in real time, was one of the identified principles in this list.

### Social Interaction

(Tamayo-Serrano et al, 2018) consider social interaction to be “the important motivational aspect to be implemented in a rehabilitation system”. Social interaction has been widely used in the video game entertainment industry and has seen massive success. The ability for players to cooperate or compete among themselves, competition in particular, are driving forces for motivation. Additionally, the ability to communicate for example share high scores or information is also classified as social interaction.

Theoretically social interaction is a very useful form of motivation which can be used in rehabilitation, (Tamayo-Serrano et al, 2018) expanded by also adding, nevertheless the use of social interaction in stroke rehabilitation is rarely used. Of the studies included in the review only 7% used social interaction to increase the effectiveness of the therapy.

Literatures which have used social interaction include Towards Customizable Games for Stroke Rehabilitation and an Integrated Low-Cost System for At-Home Rehabilitation both found via backwards snowballing from Gamified In-Home Rehabilitation for Stroke Survivors: Analytical Review. As well as Development of a 3D, networked multi-user virtual reality environment for home therapy after stroke, found via searches on google scholar. These literatures will be reviewed under 4.5.5 Multiplayer Games for Stroke Rehabilitation.

When talking about gamification (Toledo-Delgado et al, 2013: 2) states “Gamification works to satisfy some of the most fundamental human desires”. One interesting desire identified was the desire for self-expression. Social interaction may work to boost this desire and make it more alluring to be able to customize an in-game avatar.

### Simple interaction devices

The simplicity and usability of hardware device interfaces should be considered. (Tamayo-Serrano et al, 2018) states that older patients may struggle with learning complex interfaces and there is no guarantee that post stroke survivors will be able to effectively use the hardware should it be too complex.

Particularly for older people using the therapy application the ease of hardware interaction should be considered.

Below is a table detailing the interaction devices used by applications included in the literature review.

|  |  |  |
| --- | --- | --- |
| Interaction device name | Number of literatures used in | References to literatures |
| etee controller | 1 | [21] |
| Microsoft Kintect / other vision-based camera input | 8 | [20, 8, 19, 13, 25, 5, 2, 1] |
| Mobile device secured to patient | 1 | [4] |
| Immersive VR headset and Controllers | 3 | [3, 16, 14] |
| Tactile buttons | 1 | [18] |
| Haptic device (Novint Falcon, Omni Phantom) | 1 | [2] |
| Wii balance board | 1 | [2] |
| Nintendo Wii remote | 1 | [1] |

As shown by the table the most common interaction device is a vision-based camera input. This is most commonly a Kinect device but can also be other vision-based input devices like the PlayStation 3 eye [2].

This is due to the low cost of the hardware required. (Tamayo-Serrano et al, 2018) identified low-cost solutions as being another feature of rehabilitation applications. This is due to the therapy being designed for home use, therefore must be affordable. It was also found that patients were willing to pay costs ranging from 300 to 1500 dollars.

Studies [3, 16 and 14] all used VR headsets and controllers as the interface for their applications. (Chen et al, 2022) states that as VR technology is advancing it is becoming more cost effective and accessible to the public. This likely explains why the second most studied interaction device is immersive VR technologies.

One study [21] used etee controllers. etee controllers, designed to work in VR gaming applications have also been used in non-immersive VR contexts to create therapy applications. (Strong et al, 2022) were able to utilize the controllers capacitive sensing technology to be able to record the patients hand position. This data was used to create a gamified experience where users would have to match the hand gestures showed on the screen.

The use of haptic devices as mentioned by (Borghese et al, 2012) is interesting and novel and may be effective in UL rehabilitation due to the haptic feedback they provide to the user. However, the devices cost is likely what has caused them to be infrequently used in studies.

### Motivational Rewards

This is referring to points or ranking systems, and they are regarded by (Tamayo-Serrano et al, 2018) as effective ways of generating motivation. An interesting point made by (Toledo-Delgado et al, 2013) and referenced by (Tamayo-Serrano et al, 2018) is that a motivational rewarding system in conjuncture with the ability to share these features with others (for example a leaderboard system) can be so effective it can actually generate addiction in the players.

If a rehabilitation application was able to addict its players into using it, then the problem of noncompliance due to lack of motivation could be solved. This is important as according to (Gelineau et al, 2022: 2) “many people do not feel motivated to engage in new habits”.

## Digital application to enhance motivation of the therapy.

(Koutsiana et al, 2020) explored the technologies used for UL rehab. It was found that researchers prefer to use commercial hardware over development of new hardware (62.7% of studies). This is likely due to the difficulty of creating new hardware as well as the cost of commercial sensors being lower making them better suited to in home rehabilitation systems. The literature also studied the game target, which was found to be usually task driven 62.1% of reviewed material, it was also common to see score driven games 41.1%.

When discussing the gameplay approaches for increased engagement and motivation, (Hadjipanayi et al, 2024), highlights the significance of the visual aspects of exergames. Exergames in this context referring to a “subcategory of serious games which incorporate physical activity into their gameplay mechanics” (Hadjipanayi et al, 2024: 1). Patients appreciate beautiful environments and respond positively to them regardless of the level of sensory immersion (Hadjipanayi et al, 2024).

Regrading the art style of the game (Hadjipanayi et al, 2024) commented on the realism of the graphics regarding the effect of realistic graphics on player investment and motivation. While (Hadjipanayi et al, 2024) agrees that the visual aspects of an exergame are important they also state “it is crucial to consider that beautiful scenery can be highly subjective” (Hadjipanayi et al, 2024: 6). They also go on to reference (H.-T. Jung, et al, 2020) and (G. Burdea et al, 2021) stating that highly detailed and photorealistic graphics may cognitively overwhelm and cause discomfort to patients with neurological impairments.

Providing on screen visual feedback, for example a virtual character which performs similar movements to the patient can activate mirror neurons potentially aiding in stroke recovery. (A. Warland et al, 2019) as referenced in (Hadjipanayi et al, 2024). Better yet virtual kinematic representation of an upper limb synchronised to the paretic limbs movement can help strengthen the control of the paretic limb providing instant neural modulation. (J. Rong et al, 2021), (H. -S. Choi et al, 2019) as cited in (Hadjipanayi et al, 2024).

(Hadjipanayi et al, 2024) also mentions the significance of in game achievements and their impact on the neurophysiology of the brain during these interventions. Another interesting point is that VR exergames can be inherently more engaging compared to traditional rehabilitation intervention but can become monotonous and laborious when repetitive or when the game rewards lose their value (Hadjipanayi et al, 2024). It is possible social gameplay elements may help to offset this.

## Digital application to enhance upper limb movement.

(Doumas et al, 2021:1) aimed to “assess the efficacy of serious games, implemented on diverse technological systems, targeting UL recovery after stroke”. The paper was a meta-analysis and collated the findings of 42 trials including 1760 participants. The study concluded that “rehabilitation through serious games, targeting UL recovery after stroke, leads to better improvements, compared to conventional treatment”. (Doumas et al, 2021:1) The outcome of this literature gives feasibility to this project as it evidences that bespoke games designed to aid in UL rehabilitation are indeed effective and overall, more effective than conventional therapy. As recognised by (Amorim et al, 2020) game-based therapies are a valid solution for telerehabilitation (rehabilitation conducted remotely). (Amorim et al, 2020) acknowledges the use of game therapies to bring rehabilitation exercises into a patient’s home during the chronic stage to empower the patient to manage their health while being monitored by physicians.

Additionally, this piece of literature highlighted essential design features that this project must cater for. Those being the eleven neurorehabilitation principles established by (Maier et al). The literature claimed that for the gamified therapy to be more effective than traditional therapies it must implement at least 8 of these principles. “Indeed, only interventions that met 8 or more principles showed significant impact of moderate effect size on upper limb motor function” (Doumas et al, 2021: 5). While this project is more focused on encouraging the correct movements to be performed in a motivational way, rather than the actual clinical effectiveness of the game, the findings of this study relating to these principles is still influential and will be considered in the game design of the game.

(Vieira et al, 2021) was also focused on the clinical outcomes and efficacy of serious games when used in therapy in motor impairment patients with stroke, multiple sclerosis or cerebral palsy. Unlike the previous however this review took “a closer look at video game design features” (Vieira et al, 2021:1) described in the literatures reviewed. These features being “game genre [GG], game nature [GN], and game development strategy [GDS]” (Vieira et al, 2021: 1). These features were assessed on “how they may contribute toward improving health outcomes” (Vieira et al, 2021: 1). The study agreed with the previous that bespoke made games “tends to give better clinical results although the latter are perceived as more motivating and engaging” (Vieira et al, 2021:2), the latter here referring to commercial off the shelf games.

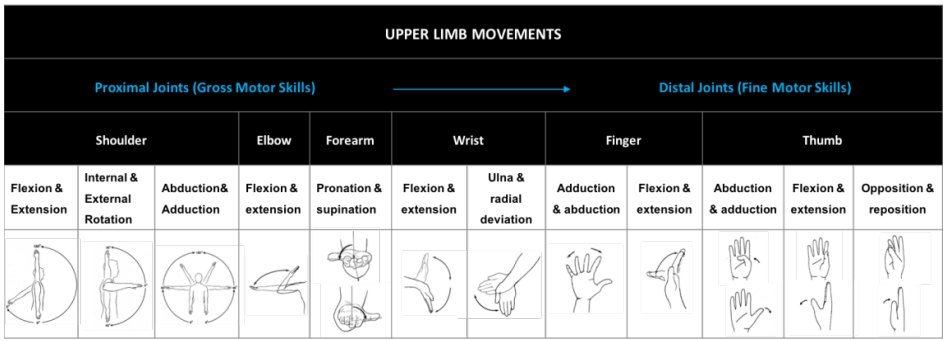
This review will be useful when designing the game as it will allow informed decisions to be made about the design of the game.

(Triandafilou et al, 2018)) produced a 3d networked multiuser Virtual Environment for Rehabilitative Gaming Exercises (VERGE) (Triandafilou et al, 2018:1). Users could control the game through measurements made with a low-cost Kinect device. The study found that “85% of the subjects found the VERGE system to be an effective means of promoting repetitive practice of arm movement” (Triandafilou et al, 2018:1). The study tested the quantity of useful movement and the motivation to use the system against current therapies. This paper, due to its similarities to this project will play a critical role in the approach of this project.

Upper limb functions can be separated into gross and fine motor skills. (Pan, W, 2018). Fine motor skills refereeing to small muscle movements like the hands and gross movements being larger, for example the coordination of the proximal joints such as the shoulder and elbow (Pan, W, 2018).

(Pan, W, 2018) organised common movements in UL rehabilitation into a series of groups of movements, each group requiring more fine motor control. The groups described are as follows Shoulder, elbow, forearm, wrist, finder and thumb. This information is succinctly presented by (Pan, W, 2018) using the following figure.

Figure 1 UL stroke movements, original author (Pan, W, 2018: 21)



Due to the hardware being used and its sensing capacities the following movements will be omitted in this project. Wrist movements, finger adduction and abduction and thumb extension. It is likely the etee controllers will be able to track the other movements and so can be incorporated into the games design.

## Haptics for rehabilitation game

Implicit feedback is an especially important feature in stroke rehabilitation games. Haptic feedback is one such way that this feedback can be provided. (Ning et al, 2022) considers haptic feedback to be one of three types of feedback. Visual, haptic and auditory. (Ning et al, 2022) goes on to state that the different forms of feedback contribute to different cognitive functions. Haptic feedback can provide more cognitive skills training than visual feedback while using less cognitive bandwidth. (Ning et al, 2022) states that when developing games for rehabilitation researchers should pay attention to the choice of feedback they can provide as well as the degree of feedback.

(Baur et al, 2018) states increasing haptic support can be used as a means of enhancing the individualization of a virtual reality therapy game. (Baur et al, 2018) also states “The benefit of social interaction could be increased by integrating visual, auditory/verbal, and haptic elements.”. The haptic elements here likely help to immerse the player in the game world and as stated earlier help to give implicit feedback.

## Multiplayer Games for Stroke Rehabilitation.

It is well known that patients undergoing stroke rehabilitation can neglect their treatment courses. (Marcos Cordeiro d’Ornellas et al, 2015). This is corroborated by almost all literatures exploring motivation in home stroke rehabilitation. (Alankus et al, 2010: 1) found that “only 31% of patients perform the exercises recommended by their therapists”.

The implementation of social interaction in gamified solutions has seen promising results. From the ability to share game related info and stats with a community of other patients and therapists (Borghese et al, 2012), to multiplayer, usually two player, games designed to be played competitively and / or collaboratively. (Alankus et al, 2010), (Pan, W, 2018), (Cordeiro d'Ornellas et al, 2015), (Triandafilou et al, 2018).

Optimal recovery can be achieved by performing hundreds of repetitions daily using the affected limbs. (Alankus et al, 2010). This emphasises just how important user motivation is and helps to give insight into the high noncompliance rates observed. (Alankus et al, 2010) rationalizes that multiplayer games, be that competitive or collaborative, give more motivations. During the study multiple stroke rehabilitation games were created some single player and some multiplayer. It was observed that participants in groups ranging from 1, (playing with a virtual companion), to 4 players were able to play the games for 15 – 25 minutes (Alankus et al, 2010).

An interesting observation made by (Alankus et al, 2010) is the opportunity for a patient and carer, who usually have a relationship where the patient is dependent on the carer, where they can collaborate as equals, facilitated through the context of the multiplayer game.

Another literature which was able to compare and contrast the effects if multiplayer and single player rehabilitation therapies in groups of patients, found that the group of patients assigned to a competitive game exhibited sustained player enjoyment. As opposed to the single player and traditional therapy group which had significantly decreased player enjoyment over a 12-week period. (Pan, W, 2018). It was also found that, a slightly higher exercise duration of the dominant hand was recorded in both game groups when compared with the control group. It was therefore concluded “that competitive gameplay has significant effects on long-term motivation” (Pan, W., 2018: 4).

During the literature review (Pan, W. 2018) cites the findings of (Staiano et al, 2012), (Lin et al, 2006) and (Chin A Paw et al, 2006) referencing the application of competition and cooperation applied to interventions designed to improve exercise engagement and participation. Of these authors (Staiano et al, 2012) found that social interaction results in higher motivation levels and energy expenditure and (Chin A Paw et al, 2008) found that participants are stimulated to exercise longer, and higher adherence rates are also reported when compared to single player games.

Like the other studies (Triandafilou et al, 2018) created multiuser environment which allowed patients to interact with therapists and /or other patients. Unlike the other studies however it was explicitly stated that this interaction is networked and so these interactions can occur regardless of physical distance. (Wang Pan, 2018) interpreted the work of (Nap et al, 2009) reporting that playing games with a virtual partner over the internet decreased satisfaction. However, the findings of (Triandafilou et al, 2018) contrast this, reporting that 13 out of their 15 participants either very much or extremely enjoyed training with another virtual partner, and 14 participants, of the same group, either agreed or strongly agreed that training with a virtual partner increased motivation. One reason for the disparity in the findings between these studies could be the changes in social norms between 2009 and 2018. As communicating virtually was still relatively new especially for people belonging to older demographics. However currently people of all demographics are much more familiar with communicating virtually. Modern increased familiarity with technology and communicating virtually may have broken down the barriers to the potential benefits of virtual peer play explaining why (Triandafilou et al, 2018) found such positive satisfaction in their user base. It is likely that 6 – 7 years later in 2024 /2025 that multiplayer rehabilitation will see the same unencumbered success.

Systematic reviews have been made of multiplayer game-based therapies. (Baur et al 2018) reviewed thirteen articles finding that most studies observed multiplayer modes having a positive impact on game experience and game performance. 2 studies found that single player games had better impacts on game performance, and this may be due to balancing issues in the game. The game should be able to adapt to individualize the difficulty of the game according to a players skill level in competitive modes. (Baur et al 2018). It is possible that the difficulty of the balancing played a role in the single player games having better effects than the multiplayer games in those 2 instances.

# Summary

## Scope of the games

There is a trend in making small scoped games which focus on solving a specific problem and so have a small scope. Sometimes this small game is a standalone game such as [5, 21], in increasingly complex projects the complexity comes from including multiple small scope games in the main game rather than increasing the complexity of a single game, observed in [3, 1, 4, 19, 20]. Creating a low scoped game means the goal of the game can be clear and focused, it also reduces development time and allows the developers to focus on creating effective rehabilitation software especially within their time restrictions.

Based on observations of other projects a single, low to medium scoped game, set in a visually appealing environment seems to be the most appropriate design for the project.

## Prototype design

A key difference between many of the projects reviewed and this project is the input device the user will use. Most literatures reviewed use visual systems like the Kinect which can sense arm movement well but is not effective at sensing hand and wrist movements. This project, however, will make use of etee controllers which can sense wrist and hand rotation as well as each fingers grip strength. This will be beneficial as it means arm movements and wrist and hand movements can be designed to be inputs in the game.

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