

12-12

A Physiotherapeutic Rehabilitation Game
for Older Adults Recovering from Stroke

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Abstract

Stroke is one of the most common diseases affecting older adults in Western societies. Suffering a stroke can result in a loss or weakness of mental and motor functions, severely impacting the individual's quality of life. With effective rehabilitation it is possible to recover from stroke and regain some lost capabilities. However, rehabilitation can be very taxing on the individual, both physically and mentally, and many struggle with maintaining the motivation to continue.

Those who are unable to stay motivated tend to struggle with recovery. Without regular rehabilitation of an appropriate level of intensity, the individual's progress will wane. They may lose interest or faith in their ability to recover, maximizing the negative impact of the stroke.

To combat this, we explored the incorporation of a digital game system into the rehabilitation process. Such a system introduced a more engaging alternative to existing mundane physiotherapy exercises. The system converted prescribed exercises into gameplay using a special shoe controller designed to target lower-limb rehabilitation. Health professionals were involved in its development,

ensuring the validity of the gameplay as a substitute for traditional rehabilitation methods. Tests were conducted with older adults to explore the target audience's needs and refine the system accordingly.

The final output was a digitized dominoes game (called *12-12*) that required players to perform lower-limb physiotherapy exercises to progress gameplay. *12-12* incorporates Dr. Signal's *Strength for Task Training* (2014), a novel and contemporary rehabilitation scheme, supported by the custom shoe controller developed by co-researcher William Duncan. *12-12* explored engagement through the themes of *adaptability*, *connectivity* and *meaningful interactions*.



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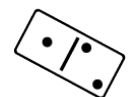
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Chapter 1

“Defining ‘patient engagement’ is not an easy or clear exercise”

- Gallivan, Kovacs Burns, Bellows, & Eigenseher, 2012

Press Start



1.1 Setting the Scene

“Quality of life is defined as psychological well-being, which is dependent on the realization of both social and physical needs.”

(Jung, Li, Janissa, Gladys, & Lee, 2009)

Stroke, or a cerebrovascular accident, is one of the most common causes for long term disability among older adults in industrialised nations (Alankus, Lazar, May, & Kelleher, 2010, p. 2113). It is the equivalent of a heart attack for the brain. A clot forms and blocks blood flow to a portion of the brain, causing the cells deprived of oxygen to start dying. Depending on the part of the brain that is deprived, the victim may suffer cognitive, visual and motor losses (ibid., p. 2113). The effects can be devastating and achieving a full recovery is not always possible.

Hemiparesis (the weakening or loss of control of one side of the body) is the main post-stroke impairment (Shirzad et al., 2015, p. 361). This can result in the non-use of the affected limb(s), which reduces chances of recovery. Such impairment greatly restricts a person’s ability to lead an

independent life. It not only affects their motor capabilities, but their sense of individualism and self-esteem.

Older adults’ sense of identity is very important, thus ‘elderly’ is a problematic term for researchers to use. Many people find the label stigmatizing and it may not reflect their physical or mental capabilities correctly (Blythe, Monk, & Doughty, 2005, p. 673). Any product or service developed to suit an older demographic should account for their desire for independence and identity. Additionally, it should enable friends, family and caregivers to support them in a meaningful way (ibid., p. 687).

Rehabilitation is the process of adaptive response to an unexpected change in lifestyle imposed by disease or trauma (Moreira, Rego, & Reis, 2010). It can only be effective if repeated regularly. More often than not, this can be incredibly tedious for patients and a lack of interest or motivation can result in incomplete treatment and lower recovery rate (Barzilay & Wolf, 2013, p. 182, Gerling Schild, & Masuch, 2010, p. 67, Lee, Tien, Chen, & Chen, 2012, p. 435, Moreira et al., 2010, Schonauer et al., 2011). Consequently, the exploration of patient engagement with physiotherapy has been acknowledged as a priority for



researchers (Jack, McLean, Moffett, & Gardiner, 2010, p. 227, Lee et al., 2012, p. 435).

The physiotherapeutic focus of this thesis is on lower-limb rehabilitation. The loss of lower-limb functionality in particular can produce a feeling of social isolation through a loss of independence, affecting one's sense of identity (Binstock and George, 2001, p. 232). Lower-limb functionality impacts a person's basic needs (e.g. walking, going to the lavatory, getting out of bed), yet we found lower-limb rehabilitation research to be less prominent than upper-limb.

1.2 The Task Ahead

“Success in rehabilitation requires three key concepts: feedback, repetition, and motivation.”

(Barzilay & Wolf, 2013, p. 182)

Games are an excellent means of generating engaging experiences. They generally involve the repetition of specific behaviours, yet elements of their design keep these behaviours from becoming monotonous. These elements can be utilized to motivate patients undergoing physiotherapeutic rehabilitation. Motivation-based cognitions have a large impact on patients' choices during training, as well as subsequent performance (Orvis, Horn, & Belanich, 2008, p. 2428). A player who enjoys the content of rehabilitation expressed through gameplay will likely play more often and for longer, exposing them frequently to beneficial content (Flores et al., 2008, p. 381, Liu, Ip, Shum, & Wagner, 2014, p.4).

The development of computer technology over recent decades has improved accessibility to digital gaming. Research into the benefits of digital games is relatively new, but results include increased attention span, hand-

eye coordination, mental functions, motor skills, problem solving, reaction time, short-term memory, and vision (Jung et al., 2009, Lee et al., 2012, p. 436). In this thesis, we explored the incorporation of digital games into the rehabilitation process, asking the question:

How can digital games facilitate engagement for lower-limb physiotherapeutic rehabilitation for older adults recovering from stroke?

The concept of engagement has been broadly discussed with “little critical exploration of the underpinning concepts the term may represent” (Bright, Kayes, Worrall, & McPherson, 2015, p. 643). In this paper the word ‘engagement’ will be defined as ‘the active participation and investment in one’s own health care, involving energy, enthusiasm, and commitment.’ This definition is derived from the works of Bright et al. (2015), Gallivan, Kovacs Burns, Bellows, & Eigenseher (2012), and Menichetti, Libreri, Lozza, & Graffigna (2014).

1.3 Research Aims

In order to investigate the research question, the main aims were as follows:

1: Define criteria for designing a digital lower-limb rehabilitation game that engages older adults recovering from stroke.

- Systematically analyse existing digital game theory and systems to situate the research in a body of knowledge.
- Acquire professional insight on how digital games can facilitate lower-limb rehabilitation for stroke.

2: Create and test a prototype digital game that facilitates lower-limb recovery from stroke.

- Explore game mechanics and genres that incorporate rehabilitation into gameplay and evaluate with clinician reviews.
- Iterate chosen concept to develop a final design.
- Critically evaluate the game through clinician reviews and user testing, iterating the design process based on the findings.



Chapter 2

The Tools at Hand

“Our most important tools are the ones that involve and empower players to make their own decisions”

- Church, 2006, p. 379



This research is grounded in a constructivist epistemology. This chapter discusses the postmodern theoretical perspective of the researchers and elaborates on the user centered design methodology that framed the research process. It covers each chosen method and why they were selected.

Therefore, we consolidated the contributing perspectives to minimize personal bias and improve the integrity of the research.

2.1 A Theoretical Perspective

Games deal in providing fun experiences, but what is defined as “fun” differs greatly from person to person. Fun has not been operationalised (Baranowski, 2014) and arguably *cannot* be. Too much is dependent on what the audience wants or expects from a game. This research was conducted under a constructivist epistemology, where meaning was drawn from the views of all parties (Crotty, 1998, p. 58); the clinicians, the participants and the researchers’ own interpretation of acquired knowledge. A postmodern theoretical perspective was adopted in acknowledgment of the multiplicity, ambiguity and ambivalence of the subject matter (Gray, 2014, p. 28). Many researchers of digital games have acknowledged the subjectivity of their findings (Alankus et al., 2010, p. 2121, Chen et al., 2014, p. 8, Flores et al., 2008, p. 383, Holden & Dyar, 2002, p. 70, Nap, Kort, & Ijsselsteijn, 2009, p. 260).



2.2 Methodology

This research was informed by a user centred design (UCD) methodology (Gregor, Newell, & Zajicek, 2002, Shirzad et al., 2015). Several studies recommend such an approach as the involvement of users and stakeholders in the design process allows for usability issues to be uncovered and resolved (Gerling et al., 2011). A user centred designer is constantly aware of the contextual needs of their users and the functional needs of the product (Shirzad et al., 2015, p. 363), combining these elements to improve the final design's accessibility. Gregor et al.'s "user sensitive inclusive design (USID)" methodology (2002, p. 152) was found to be particularly relevant for a target audience of older adults and influenced the design process as a result.

To develop a digital game system for rehabilitation, the involvement of professional clinicians and medical researchers became integral. We consulted regularly with specialists from the Auckland University of Technology (AUT). The research was developed in collaboration with fellow Master's researcher William Duncan. The goal of our collaboration was to generate a game system that enabled play through physiotherapy exercises. This system required a custom physical controller, designed by Dun-

can, that interfaced the user's exercises with digital media. The process was conducted under approval from the Health and Disabilities Ethics Committee (*for the letter of approval, see Appendix document A, p. 176*).

The methods chosen were literature reviews, case study reviews, design precedent analysis, questionnaires, interviews, matrix evaluation, observation and iterative design.

2.3 Methods by Aim

2.3.1 First Aim

The first research aim, to *define criteria for designing a digital lower-limb rehabilitation game that engages older adults recovering from stroke*, allowed for the findings of our background research to be embedded in the design process.

The first objective of this aim prompted research into literature to gain a scope of existing knowledge. This was followed by the revision of case-studies and design precedents to systematically analyse how digital games have been applied in a physiotherapeutic context, where these projects had failed and what elements fellow researchers deemed worthy of further investigation.

The second objective targeted the acquisition of a professional perspective. Interviews with specialists from AUT (Dr. Nada Signal, Dr. Nicola Kayes and Prof. Denise Taylor) were conducted in the form of research workshops. These workshops provided specialised information (Kuniavsky, Goodman, & Moed, 2012, p. 135) on the treatment of stroke, lower-limb rehabilitation and the expected difficulties patients might experience. These contacts

also allowed us to conduct a clinical observation session, which granted insight into the nuances typical for patients undertaking rehabilitation (Zeisel, 1993, p. 113).

The knowledge obtained from this background research was embedded into criteria that became the driving force behind design decisions. These criteria functioned as context-specific heuristics (Nielsen & Molich, 1990) and were used to assess the effectiveness of the game for supporting engagement. Several studies have effectively used criteria-based development processes as a means of prioritising important factors when the context of the project is complex and time is limited (Flores et al., 2008, Martin, Götz, Müller, & Bauer, 2014, Moreira et al., 2010). The criteria were refined as developments were made to ensure the most authentic and applicable version possible (Hartson, Andre, & Williges, 2001, p. 153).

2.3.2 Second Aim

The second research aim, to *create and test a prototype game that facilitates lower-limb recovery from stroke*, focused on the application of our learnings within the context of a game for stroke rehabilitation.



The first objective of this aim was to explore game mechanics and genres that incorporated rehabilitation into gameplay. Clinicians were key stakeholders, who evaluated the concepts produced in this phase. We employed matrix evaluation (also known as *Pugh's Method*) to rapidly process several concepts simultaneously. The variant we acquired from Milton & Rodgers (2013, p. 146) suggests using the strongest concept as a “datum” and comparing other concepts in a matrix using plus (+), minus (-) or equals (=). This process generates a value for each concept that ranks its effectiveness at fulfilling the needs of the stakeholders (Ulrich & Eppinger, 2004, p. 131).

The second objective addresses the iteration of the final output based on the prior evaluation. The rapid turnaround for matrix evaluation allows it to be integrated seamlessly into an iterative design process. Such an approach has been seen in several similar papers (Alankus et al., 2010, Gerling, Schulte, & Masuch, 2011, Shirzad et al., 2015, Trefry, 2010) and has been claimed by Vijay & William as particularly effective when the theory surrounding the designed system is minimal (2015, p. 224). Game design research is too new to have any definitive best practices, meaning such an experimental approach seemed appropriate.

Each iteration was subject to formative evaluation from multiple sources (Barnum, 2011, p. 12, Hartson et al., 2001, p. 149). Designs were critically assessed by the established criteria, as well as by the specialists from AUT. Critique and advice from these doctors supported the integrity of the system as a physiotherapeutic aid. Prior to formal user testing, preliminary user tests were conducted on an audience unaffected by stroke to gain an alternative view of the game's playability and aesthetics. These tests involved a brief playthrough and questionnaire (*for more information on the questions, see Appendix document C1, p. 210*) and helped establish whether or not the game was usable by such an audience i.e. caregivers, friends and family. The physiotherapeutic functionality and the generic usability of the system needed to be balanced because without usability the physiotherapeutic aspects would be inaccessible.

The final objective involved formal user tests with the complete system, i.e. the digital game plus custom game controller (smart shoe) designed by William Duncan. Recruiting for user testing began with presenting our research project, as a combined system of hardware and software, to local stroke clubs. Those who expressed interest were contacted over the phone for an interview to test

whether or not they met our inclusion criteria (*for more information on the inclusion criteria, see Appendix document C2, p. 212*). Three of those who met the criteria were asked to participate in user test sessions. For the comfort of our users, the option to conduct the test in their home environment was provided (and taken by all three). Tests involved users putting on Duncan's device, completing the tutorial phase of the application and playing a standard version of the game. During this process users were encouraged to use "think aloud protocol" (Martin & Hanington, 2012, p. 180). The test sessions concluded with an interview to discuss any points the participants missed with think aloud protocol and to explore their thoughts on the system and how it might be changed (*for more information on the interview questions, see Appendix document C3, p. 213*). The results of these tests informed subsequent iterations for both aspects of the system. The iterations were tested again with the same users, with a shortened interview afterwards. The findings from these sessions contributed to the final evaluation of the game system, helping articulate strengths and limitations of its design and inform future investigations.

Information obtained from these tests provided a small qualitative sample and cannot be expected to represent

a holistic view on the opinions of older adults. It does, however, provide usability engineering measures that may benefit future research (Hartson et al., 2001, p. 150). Given adequate time and resources, it may be possible to measure if engagement with the game system promotes greater adherence to physiotherapy, therefore better recovery. Measurement systems such as the Berg Balance Scale (Chen et al., 2014, p. 3), Fugl-Meyer Test and Wolf Motor Test (Holden & Dyar, 2002, p. 68) could be utilized to generate quantitative data.

“Games offer us a socially acceptable form of play at any age, and an enjoyable stimulus to the imagination.”
- Miller, 2004, p. 219

Chapter 3

You're Never Too Old to Have Fun



▶ Play ◀

▶ Rules ◀

▶ Options ◀

12

This chapter discusses the findings from background research that was conducted before the development of the digital game (which later came to be known as *12-12*). It covers the selection of digital games, design recommendations for older audiences, case studies of digital games for older adults and rehabilitation, design precedents for motion-based gaming and consultation with clinicians. The knowledge obtained in this chapter formed the foundation for decision-making and critique during the subsequent design phase.

3.1 Literature Review

For physiotherapeutic rehabilitation to be effective, it must be practiced repeatedly and regularly (Chen et al., 2014, p. 2, Jack et al., 2009, p. 220, McLean, Burton, Bradley, Littlewood, 2010, p. 514). Despite this, poor levels of adherence to prescribed medical treatment are extremely common in patients both young and old (Myers & Midence, 1997, p. 161). This can be attributed to a number of individual factors such as pain, monotony, low self-esteem or poor social support. For physiotherapy to be effective, participants are required to attend appointments, follow clinical advice and performing prescribed exercises correctly and frequently (Jack, et al., 2009, p. 220).

Many papers discussing the effectiveness of physiotherapy practice use the term “adherence” when referring to the consistency of individuals performing their prescribed physiotherapy. While being integral to rehabilitation, “adherence” can have somewhat insensitive connotations that imply the patient to be a passive recipient of care rather than an active participant (McPherson et al., 2014, p. 108, N. Kayes, *personal communication*, 10 August 2015). In contrast, our use of the term engagement grants the user more agency in their relationship with their rehabilitation. They choose to use the rehabilitation system because they find it entertaining or compelling, not because they were told to do so.

3.1.1 Why digital games?

“By understanding what parts of the game contribute to its enjoyability we can design games that enhance player’s desirability to continue play, therefore prolonging their exposure to elements of change.”

(Baranowski, 2014)

It is generally agreed upon that games are an intrinsically motivating platform for engagement. The more motivated a person is to perform a task, the more time and effort they will invest into its completion and the more satisfied they will feel as a result (Malone, 1981, p. 335).

Serious games, or “games that have a main purpose other than entertainment” (Moreira et al., 2010), are becoming more and more common as the industry develops. Typical applications of these games tend to be educational or medical. Due to their nature, the entertainment value of serious games is often seen as less effective than their primary industry counterparts. This is most likely the result of the medium still being in a state of development and having not fully explored the characteristics that make games so captivating (Alankus et al., 2010, p. 2115, Flores, et al., 2008, p. 381, Gerling et al., 2010, p. 66, Martin et al., 2014, p. 101, McLean et al., 2010, p. 520, Moreira et al., 2010, Orvis et al., 2008, p. 2416).

Serious games for an aging community are slowly being recognised for their ability to improve mental and physical well-being, social connectivity, as well as simply offering an enjoyable pastime (Chen et al., 2015, p. 7, Barzilay & Wolf, 2013, p. 183. Ijsselsteijn, Nap, de Kort, & Poels, 2007,

p. 17). However, the 65+ demographic is largely underrepresented by commercial games (Gerling et al. 2011, Gregor et al., 2002, p. 151, Ijsselsteijn et al., 2007, p. 17, Jung et al., 2009). This will become more relevant as those who have grown up with digital games get older.

Some scholars suggest that serious games are simply tools to encourage a specific interaction (Bogost, 2007, p. 57, Moreira et al., 2010, Lee et al., 2012, p. 436). In some cases the use of the term “tool” may be chosen arbitrarily, but Malone illustrates the point that there is a significant, fundamental difference between tools and toys (1981, p.359), or in this case games. Tools should be invisible; simply a means to an end, yet a good game deliberately provides opposition against the user. This focus on the “gamification” of serious topics may be what is limiting the success of serious games. Gamification, or “the use of game design elements in non-game contexts” (Deterding, Dixon, Khaled, & Nacke, 2011, p. 10), is a versatile concept. One limitation of gamification is that it functions as an addition to the context that hosts it. The host needs to have some intrinsic motivation already present (Deterding, 2012, p. 17). Perhaps a greater focus is necessary on generating experiences that are engaging at their core, yet

accessible to an audience with (and despite of) specific impairments.

3.1.2 Games for older adults

“Research results suggest that the [Nintendo Wii] is widely accepted among senior citizens and that playing Wii games has a positive impact on the overall well-being of institutionalized elderly.”

(Gerling et al., 2010, p. 66)

Gregor et al. notes that developers of serious games have a tendency to separate their target audience into either “disabled people” or “normal people,” overlooking the diverse range of capabilities that exist within the user-base (2002, p. 152). An older audience is rich with diversity, yet their broad range of capabilities means there are numerous barriers for engagement that can present themselves. The following section addresses these barriers and potential means of accounting for them.

3.1.3 Level of Confidence

Older adults have repeatedly shown open-mindedness towards the use of new technology (Gerling et al., 2010, p. 69, Gerling et al., 2011, Ijsselsteijn et al., 2007, p.18, Jung et al., 2009). Scholars such as Ijsselsteijn et al. (2007, p.18) and Nap et al. (2009, p. 248) claim technology is more likely to be positively received if interaction with it is simple and the benefits of its use are clear. Despite this, the user’s level of confidence can limit their ability to engage with computer systems i.e. cell phones, laptops or tablets (Nap. et al., 2009, p. 260).

Confidence with computer technology can be drawn from personal experience. Some studies suggest that existing digital games deviate too much from the physical games older adults are familiar with such as card or board games (Mahmud, Mubin, Shahid, & Martens, 2008, p. 403, Nap et al., 2009, p. 247, Orvis et al., 2008, p. 2418). The lack of a conceptual model of computer functions can limit what older users are willing to attempt. This is not necessarily due to the complexity of computer systems, given the complexity of traditional games older adults may play. Ma et al. highlight the importance of users being familiar with a system before it requires them to perform complex actions (2007, p. 688). Therefore, if the game is built



around concepts familiar to older adults, they can prioritise learning how to navigate the unfamiliar interface.

Ijsselsteijn et al. state that another way to combat ‘computer anxiety’ is to provide encouraging feedback (2007, p. 19). Self-efficacy relates directly to motivation: a user who feels capable of accomplishing tasks is more likely to engage with them (Sampayo-Vargas, Cope, He, & Byrne, 2013, p. 458). In-game feedback functions as a motivator to complete the task at hand. Post-session feedback enables players to track their progress and view information about their functional ability (Shirzad et al., 2015, p. 366). Granting players a clear sense of progression will help maintain motivation levels as the more perceived control one has over a system, the more positively they react towards it (Lee et al., 2012, p. 445, Mathwick & Rigdon, 2004, p. 325).

The subjective nature of self-efficacy and motivation renders them difficult to measure. In fact, there is little concrete evidence that one method for improving self-efficacy is more or less effective than another. This is not necessarily a problem, as an objective perspective may not be appropriate. Although inconclusive, these papers

provide a variety of avenues with which further research can be pursued.

3.1.4 Ergonomics

The second main barrier for engagement is the ergonomics of interaction with a computer system. The system’s usability is one of the most important factors that contributes to a user’s sense of control (Shirzad et al., 2015, p. 364). The natural physical decline that occurs with age includes visual and auditory decline and reduced fine motor skills.

Visual decline greatly affects how users interpret digital interfaces. Gerling et al. (2011), Gregor et al. (2002, p. 151), Ijsselsteijn et al. (2007, p. 18) and Kopacz (2004, p. 212) break down the changes as follows:

- A loss in static and dynamic visual acuity (keenness).
- Reduction of visual accommodation range (ability to track an object as its distance to the eye changes).
- Loss of contrast sensitivity.

- Decrease in dark adaptation (ability of the eye to adjust to low-light conditions).
- Declines in colour sensitivity.
- Heightened susceptibility to problems with glare.
- Fine text becomes difficult to focus on and loses readability.

Digital interfaces allow for high flexibility in this area, where it is possible to include features such as resizable font or colour filters.

Older adults also experience auditory decline meaning pure tones and notes of higher frequencies become difficult to hear. According to Ijsselsteijn et al., 500-1000 Hz is the preferable range for audio elements (2007, p. 18). It is also recommended to use multiple modes of output to generate layered information, such as haptic vibration and synchronized visual and aural cues. This enables users who are less receptive to still receive information through their strongest sensory channel (Gerling et al., 2010, p. 67, Gregor et al., 2002, p. 154, McLean et al., 2010, p. 516). Sampayo-Vargas et al. warn against confusing this with oversaturation, as redundancy should be avoided (2013, p. 453).

The decline of motor skills also impedes the user experience for older adults. This affects balance, posture and the person's ability to interact fully with their environment (Gerling et al., 2010, p.67, Gerling et al., 2011). Consequently, default input methods for computer systems, such as a computer mouse and keyboard, may not be appropriate for an older user. Instead, a specialised device that caters to their personal capabilities would be beneficial, especially if the device enables intensive repetitive training for gameplay (Alankus et al., 2010, p. 2113, Dickerson & Brown, 2007, p. 564, Shirzad, 2015, p. 361). Such a device needs to be easy to set up in a home environment as not all survivors of stroke will have access to adequate facilities for training.

Additionally, one must consider how cognitive processes decline with age. This includes “attention processes, working memory, discourse comprehension, problem solving and reasoning and memory encoding and retrieval” (Ijsselsteijn et al., 2007, p. 18). Studies have found that older adults tend to favour tabletop games, i.e. games that utilize a deck of cards or a game board (Gerling et al., 2010, p. 66, Mahmud et al., 2008, p. 404). Gerling et al. refer to these games as “simple” (2010, p. 66), however the strategic complexity of games such as poker or bridge can



be very deep. The interfaces of these games are simple; cards in hand or pieces on a board, yet the potential for rich, intelligent play is abundant (see *chess*). A similar approach can be applied to digital games. The user interface (UI) needs to be simple for accessibility, yet the gameplay can have deep mechanics that give players room to learn and develop strategy. The game needs to respect the cognitive capabilities of its audience.

Separate to user confidence and ergonomics, another means of engaging users is setting goals. Goals are an essential component of a person's experience of life as meaningful and worthwhile (Emmons, 2003, p. 107) and are therefore integral for evoking the long-term commitment to exercise needed for effective rehabilitation (Dickerson & Brown, 2007, p. 569). Accordingly, goal setting is common practice for clinicians in stroke therapy (McPherson et al., 2014, p. 105). The close connection between goal attainment, motivation, affect and sense of self (ibid., p. 109) indicates that goal setting should be a core component of any digital game designed with a rehabilitative function.

3.2 Case Studies

Several studies of serious games for older adults have been conducted with varying degrees of success. This section discusses the work of Alankus et al. (2010), Gregor et al. (2002) with *BrookesTalk*, Gerling et al. (2010) with *SilverBalance*, Gerling et al. (2011) with *SilverPromenade* and Holden and Dyar (2002) with *Virtual Teacher*.

3.2.1 Towards Customizable Games for Stroke Rehabilitation

The goal of the work by Alankus et al. (2010) was to acquire knowledge on how to generate digital games that were effective at promoting home-based rehabilitation from stroke. The “lessons” they learned came from rapidly prototyping a range of games and testing them on people affected by stroke. The lessons were compiled in a detailed report (ibid., p. 2119).

One of the challenges faced by Alankus et al. was the hardware (2010, p. 2115). For accessibility and affordability they chose to use *Nintendo Wii* remotes to detect the player's motion. Singular remotes found it difficult to

accurately map the larger motions common to physiotherapy. To combat this, researchers added more remotes to different parts of the body. Even with the inclusion of a webcam for improved accuracy, the system's affordability was compromised by the additional remotes and a more robust design would be necessary.

Alankus et al. claim the main ways games can contribute to stroke rehabilitation are social context, motion types and cognitive challenge (2010, p. 2117). They developed a large quantity of games to explore these spaces and tested them on four participants with varying degrees of affect from stroke. Although the researchers were able to extract a detailed and comprehensive list of qualities from their user testing sessions, the small sample size limits the usability of their results. The lessons learned through their research can be summarized as such (ibid., p.2119):

- Assume no use of hands.
- Simple games should support multiple methods of user input.
- Calibrate through example motions.
- Direct and natural mappings are necessary.
- Ensure that users' motions cover their full range.

- Detect compensatory motion.
- Allow coordinated motions.
- Let therapists determine difficulty.
- Audio and visuals are important.
- Automatic difficulty adjustments provide adequate challenge.
- Non-Player Characters (NPCs) and Storylines are intriguing.

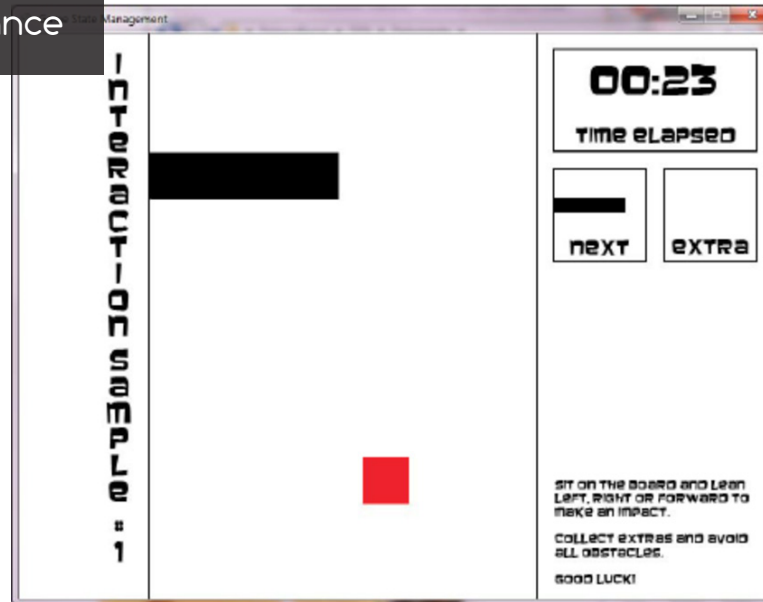
Alankus et al. acknowledge their findings are “suggestive rather than conclusive” (2010, p. 2121), as is to be expected when the field of research is so fresh. What separates Alankus et al.'s work from the other studies in this section is the breadth of their approach. Despite the lack of precise findings, the sheer variety of options they explored helped inform basic concept development, as they gave samples of how certain features might succeed or fail.

3.2.2 SilverBalance & SilverPromenade

The studies conducted by Gerling et al. (2010) and Gerling et al. (2011) specifically targeted the usability of digital game systems for older adults. Both studies generated a



figure 3.1 - SilverBalance



Gerling et al., 2010, p. 68

prototype game that was designed around the age-related changes older adults typically experience with cognition and motor capabilities. *SilverBalance* (Gerling et al., 2010) was developed following a set of criteria that served to maximize the usability of the product. The criteria were as follows (ibid., p. 67):

- Interaction mechanisms should allow for navigation while sitting or standing.
- Extensive or sudden movements should be avoided.

- Older players should be able to adjust the difficulty, game speed and sensitivity of the input device.
- The game should focus on simple interactions and provide constructive criticism.

SilverBalance's gameplay and aesthetic was incredibly minimalistic. This simplicity was positively received by a focus group of nine participants (ibid., p. 68). Gerling et al's second game, *SilverPromenade* (2011), was clearly built on the findings from *SilverBalance*.

SilverPromenade expanded where *SilverBalance* was lacking by explored research questions regarding Inter-

figure 3.2 - SilverPromenade



Gerling et al., 2011

face Design, Player Experience and Game Design. Twice as many participants were involved in the testing sessions and the focus group was replaced with a questionnaire to account for the increase in numbers. The use of likert scales in the questionnaire were translated into graphs, however the limited sample size renders these results inconclusive in a quantitative sense. Likert scales are efficient at producing quick results but the effectiveness is lessened when the data is small. For this reason, questionnaires were expanded into full interviews during the user testing phase of this research.

Additionally, both studies by Gerling et al. (2010) and Gerling et al. (2011) only involved their participants once during their research process. This leaves the sustainability of the systems' novelty untested. If a digital game is to function as a means of home-based rehabilitation, playing needs to be desirable for patients on a regular basis.

3.2.3 BrooksTalk & Virtual Teacher

Both the studies conducted by Gregor et al. (2002) and Holden and Dyar (2002) explore the significance of adapt-



figure 3.3 - BrooksTalk



Gregor et al., 2002

ability with digital systems. Gregor et al. claim adaptability within the system is a necessity due to the immense level of diversity within an older demographic (2002, p. 152). Their sheer range of physical and cognitive capabilities makes developing systems for older adults very complex. It is understandable then that many of the studies in this field reach inconclusive results. Even Holden and Dyar, whose detailed process involved subjects to perform thirty test sessions over several weeks and mapped their clinical progress using the Fugl-Meyer Test and Wolf Motor Test, used only nine participants and warned readers to interpret their results with caution (2002, p. 70).

Gregor et al.'s "user sensitive inclusive design (USID)" (2002, p. 153) methodology provides a largely applicable alternative to the traditional user centred design (UCD) approach. USID has enough differences to address a complex audience but not be so bold as to claim universal application. Ultimately USID is a formal way of acknowledging that any user groups involved in tests will not be truly representative of the whole demographic, nor would it be possible to achieve such a thing. Instead, Gregor et al. discuss the many of the ways diversity can manifest; vision, confidence, memory and how one might account for these (2002, p. 153). In most cases it comes down to

having a flexible interface, which Holden and Dyar agree improves learning and performance (2002, p. 66). It is clear that any design ‘solution’ developed alongside an older user base will only ever be representative of that particular group of users. This does not lower the value of any solutions of this type, as all contribute to a rapidly growing field of research.

A recurrent theme throughout the studies presented is the lack of conclusive findings. Many targeted a specific aspect of the user experience such as game mechanics, visual design, hardware, etc. The complexity of an older user-base means focusing too heavily on one element will lead to inevitable errors. In this paper we attempted to develop a digital game for rehabilitation from a holistic viewpoint, where aspects of human-computer interactions, game design, visual and sound design and rehabilitation were considered in equal portions.

3.3 Design Precedents

Many commercial games require rapid or complex responses from players as part of their interaction. This makes them unsuitable for older adults with motor impairments. However, there are digital game systems that enable engagement from an older audience.

3.3.1 Nintendo Wii & Wii Fit

A reoccurring system in studies is the *Nintendo Wii*. The *Wii*’s games, particularly *Wii Fit*, are very popular in older communities and are heavily referenced in relevant literature (Bainbridge, Bevans, Keeley, & Oriel, 2011, Chen et al., 2014, Gerling et al., 2010, Ijsselsteijn et al. 2007, Jung et al., 2009). *Wii Fit*’s popularity can be derived from its beneficial nature; providing a means to stay both fit and socially connected with peers (Gerling et al., 2010, p. 66, Jung et al., 2009). *Wii Fit* strikes a balance between functioning as a serious game for personal health and a commercial game for entertainment. The serious aspects of the game are packaged in yoga classes, training regimes and personal statistics, but players are given the freedom to meet their exercise targets within playful contexts such



figure 3.4 - Nintendo Wii Console and Wii Fit Board



as ski-jumping or tightrope walking. The use of vibrant colour and humour enhances the joyful nature of the interaction.

Engaging with *Wii Fit* provides the extrinsic motivation of improving one's physical health. Physical development is a slow process with very little gratification during the early

phases. *Wii Fit* counters this by rewarding regular interaction and gradual development through badges, high scores and personal goals. It even includes a “fitness age” which can serve another means of extrinsically motivating players to either maintain an age similar to their own, or achieve a lower age to feel fitter than average.

figure 3.5 - Lokomat in use 1



Hocoma, 2016

The *Nintendo Wii* also expands the opportunities for player engagement through “real-time visual representation of the player (i.e., avatars)” (Jung et al., 2009). These customizable avatars enable players to invest in their gameplay experience. They also foster social interaction between players through online leaderboards and social hubs (ibid., 2009).

Many commercial games that use motion-based input are unsuitable as rehabilitation aids due to the expectation that their audience has a full range of motion (Alankus et al., 2010, p. 2114). The *Wii* is no different. However, the *Wii* has clear personal benefits in its use, such as focusing on

hand-eye coordination and balance to help reduce the risk of falls. The *Wii* encourages goal setting, which is integral in a physiotherapeutic context (McPherson et al., 2014, p. 105). The popularity of the *Wii* debunks the notion that digital games are explicitly for younger audiences (Jung et al., 2009) and greatly contributes to the acceptance of modern technology by the older community.

3.3.2 Garbarello

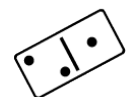


figure 3.5 - Lokomat in use 2



Hocoma, n.d.

A less versatile but highly applicable game developed for lower-limb rehabilitation is *Garbarello*. Although primarily designed for children, there are many elements of *Garbarello* that are relevant to this study. *Garbarello* was designed with the purpose of making physiotherapy motivational, optimized and purposeful (Martin et al., 2014, p. 101). To play, patients strap into a *Lokomat*: a driven gait orthosis that guides patients walking on a treadmill, which can be connected to an interactive virtual environment. The combination of the *Lokomat*'s physical support and *Garbarello*'s virtual guidance provides patients with a sense of individualism and frees the practitioner from the

need to intervene. In addition to the *Lokomat*, “Pediatric Interactive Therapy System” (PITS) gloves are used to perform tasks with the patient’s upper limbs. By diverting the focus of the patient to upper limb functions, *Garbarello* trains the user to automate the gait process (Martin et al., 2014, p. 102).

The main restriction of this system is the size of the *Lokomat*. Interacting with the device is strictly limited to time spent in the clinic as its price and size restrict accessibility. Despite this limitation, there are several things to be learned from *Garbarello*'s development. The game is aimed at helping people physically recover from a

traumatic incident, balancing the physical and cognitive demands on the player and offering positive incentives only, even at minimal exertion (Martin et al., 2014, p. 103). The creators of *Garbarello* used analysis of gait-orthosis therapy training and consultation with target audience experts to generate criteria for the development of the game. These criteria were as follows:

- It must be self-explanatory for the benefit of both the target audience (children) as well as for therapists in order to avoid introducing additional stress to the therapy setting.

This is highly applicable beyond *Garbarello*. Not only does it cater to a broad user-base, it is essential for the game to be set up and played in a home environment by patients.

- It had to be naturally, subtly and constantly motivating, even after several training sessions.

The game cannot rely solely on novelty to keep its audience engaged.

- It had to have no gender or age bias.

Keeping the game gender-neutral and age-neutral is a secure way of keeping it accessible to a wide audience. This

is important as there is no guarantee of survivors of stroke sharing any personal traits.

- It had to be easily integrated into therapy and could not distract the therapist from monitoring the patient.

If the game requires too much effort to set up, is difficult to interpret, or detracts from the therapy process in any way, then it limits its application in a physiotherapeutic setting. The game's primary purpose is rehabilitation, therefore any elements that may hinder the process should be removed.



3.4 A Clinical Point of View

To expand and challenge our understanding of developing a system for stroke rehabilitation, we consulted with three doctors from Auckland's University of Technology. These specialists were Prof. Denise Taylor, Dr. Nada Signal and Dr. Nicola Kayes. Throughout the development process several subsequent meetings were conducted to ensure the medical integrity of the system was maintained. This section explores the ideas the doctors presented and applies them to the criteria established in Chapter 2.

3.4.1 A Research Session with Dr. Nicola Kayes

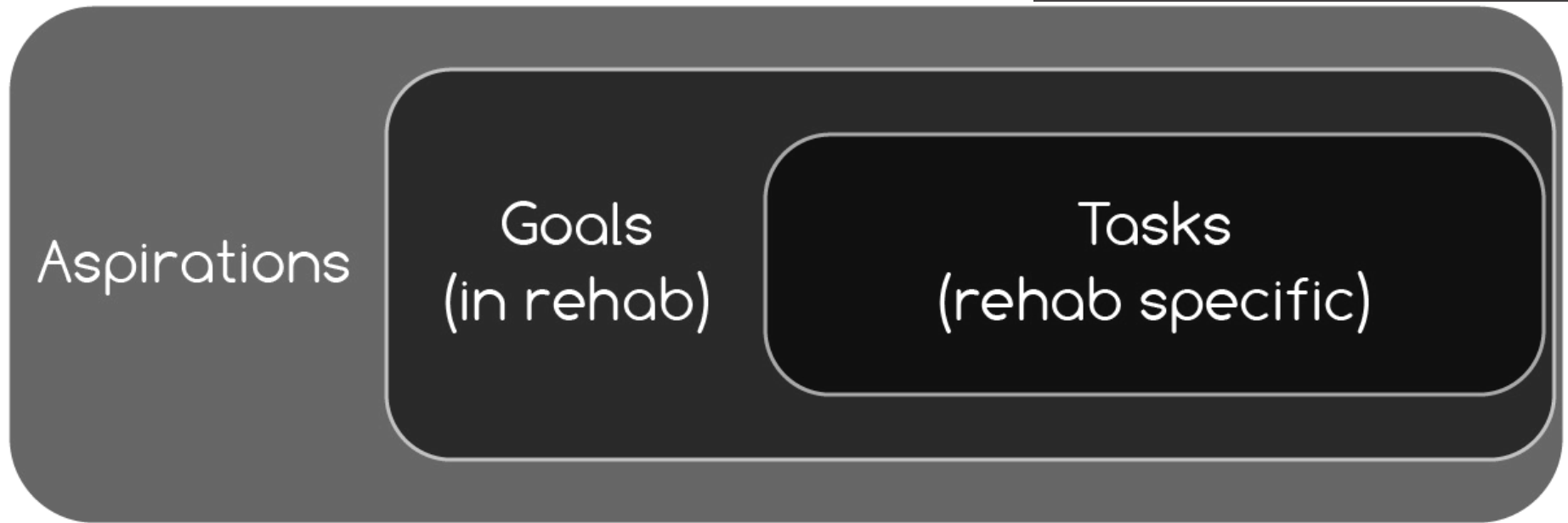
Dr. Kayes, a specialist in the field of neuro-rehabilitation, has conducted studies into understanding the perspective of people suffering from stroke.

Kayes stressed the importance of differentiating between “adherence” and “engagement.” Adherence, like compliance, implies the patient is the recipient of care; that they are following recommendations and doing what they are told. Engagement implies active commitment to the recovery process; that they are a driving factor in their own

recovery. This active participation and dedication is what allows the patient to receive the optimal benefits of their rehabilitation.

Kayes' research into rehabilitation from the perspective of the patient highlighted the significance of connectivity. This can be separated into two components. The first connection is between the patient and the practitioner. The patient must be able to trust the practitioner in their judgement and advice and trust them with their physical safety. The second connection is between the patient and their personal aspirations, hopes and goals. Each person has their own desires of what they want to accomplish outside of their rehabilitation. This might be playing with their grandkids, go fishing with their friends, or simply be able to move independently without supervision. Rehabilitation is the path they must travel that connects them to these goals.

Kayes emphasised that rehabilitation is an extensive journey, therefore it is important that those taking it have a clear sense of progression. Without it, patients run the risk of losing faith in their ability to recover. Therefore, it is important to bridge the gap between the patient's broader aspirations and smaller, manageable goals.



Each patient's therapy tasks should be linked to their broader aspirations, allowing for a more personal and relevant experience. Examples of such are depicted in figures 3.7 and 3.8.

The system must also be noticeably connected to the clinic to function as an extension of it. To support this,

Dr. Kayes illustrated the ideal qualities of a practitioner. These qualities should be apparent in any system that is substituting the role of the practitioner.

(For additional notes on this session, see Appendix A, p. 193)

figure 3.8 - Progression of Tasks



3.4.2 Application of Kayes' Ideas

In light of Kayes' comments, each quality could be represented in a different way; be it in the UI, the use of language, the nature of interactions with the system, or the information that is shared between the clinician and patient. Some are more easily accomplished than others. For example; a digital system can be highly adaptive and

reciprocating but lacks the human qualities that allow it to be "entrusting."

There are plenty of successful games that utilize endowed progression to provide addictive and satisfying gameplay. Endowed progression entails granting artificial momentum towards a task by giving the person free points (e.g.

The Ideal Practitioner

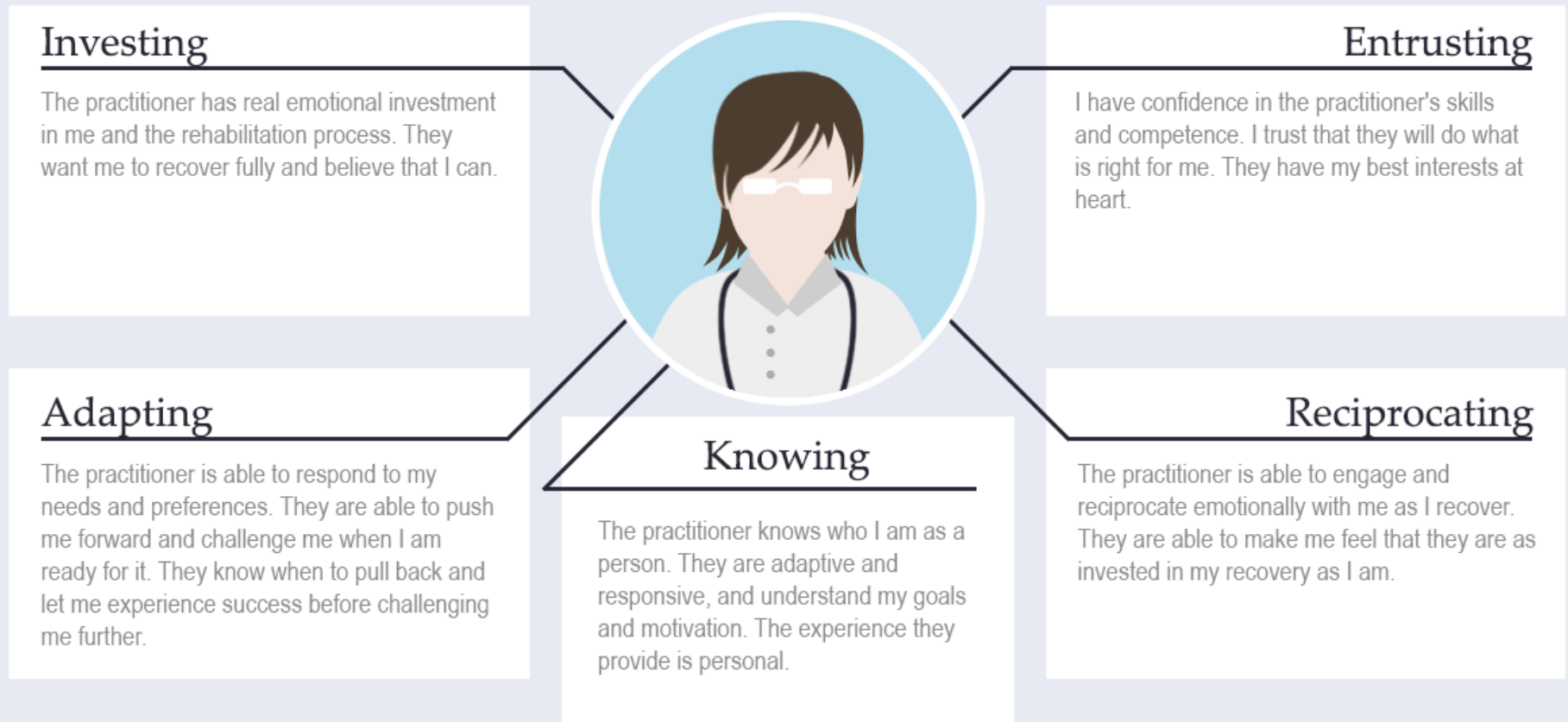
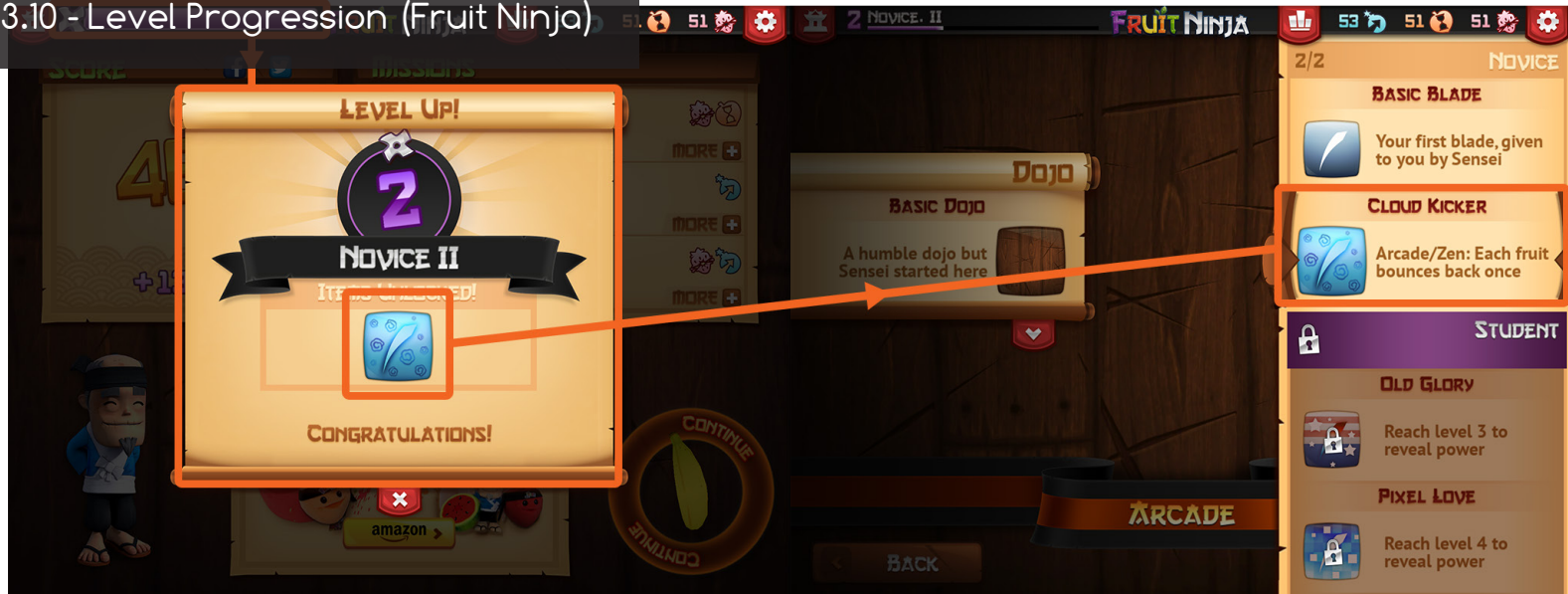


figure 3.10 - Level Progression (Fruit Ninja)



Halfbrick Studios, 2010

stamps, badges, or stars) while extending the goal to account for the free points. Although both versions of the goal require the same amount of work to accomplish, the one with free points elicits stronger motivation for its completion (Nunes & Dreze, 2006, p. 504).

Jetpack Joyride and *Fruit Ninja* utilize multiple layers of progress tracking to encourage repeated attempts. The layering of simple ‘missions,’ gaining experience for levels and earning points for buying upgrades combines to give players a staggered series of goals that are never too far away. Nunes and Dreze’s experiment suggest “people are increasingly motivated to complete a task as the get closer

to completion” (2006, p. 507), meaning these staggered goals can generate consistent, high levels of motivation.

Many of the elements Kayes discussed relate to extrinsic motivation and are evident in game systems like *Wii Fit*. The popularity of the *Wii* (Bainbridge et al., 2011, p. 127, Jung et al., 2009) improves the credibility of these elements. The effectiveness of personalized goals and progress tracking shows a lot of promise for embedding extrinsic motivation into the game. Players can see their goals reflected in the game’s design and are rewarded for reaching them. This combines with the intrinsic motivation of



figure 3.11 - Rewards (Jetpack Joyride)

Halfbrick Studios, 2011

playing the game for entertainment to make a compelling and engaging experience.

3.4.3 A Research Session with Dr. Nada Signal

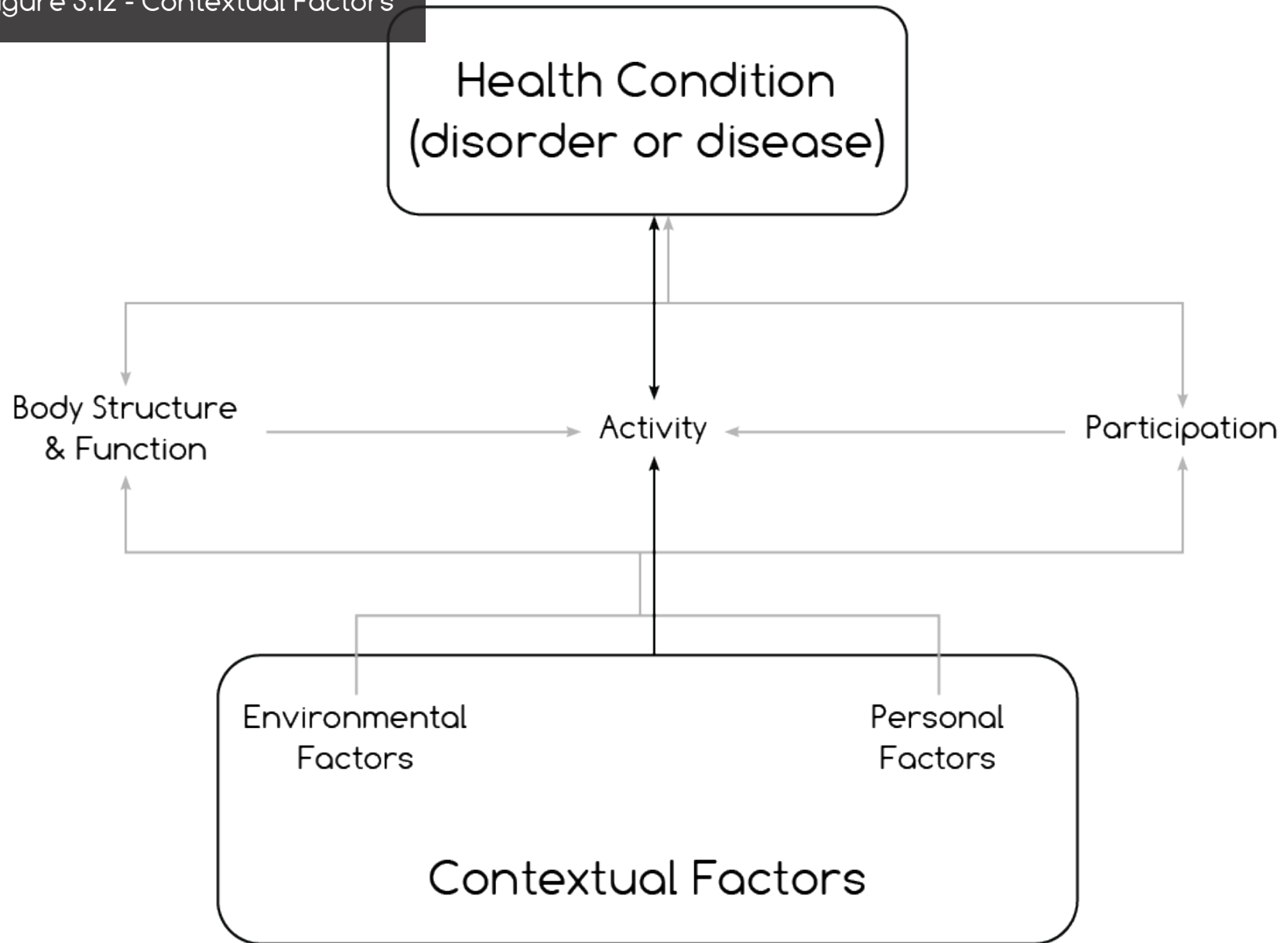
Dr. Signal is a physiotherapy expert and researcher. She has conducted research into developing physiotherapy practice and has explored the benefits of “Strength for Task Training” (STT) (2014).

Signal explained how the clinical reasoning that determines each patient’s type of rehabilitation comes from a

mixture of circumstances. These contextual factors are both subjective (what is important to the patient, what is their social context, who looks after them, or what their goals are) and objective (patient difficulties and limitations determined through tests). These do not determine *why* the patient has their problems or restrictions but do indicate the level to which they are affected.

Personal factors include the individual’s view on their rehabilitation scheme, their relationships with others and their perspective on personal health. Signal spoke of how a patient’s mindset can have a heavy influence on their

figure 3.12 - Contextual Factors



ability to recover, therefore it is important for them to feel empowered by their recovery process.

These factors interact with each other; a person's ability to perform an activity is dependent on both their contextual factors and the symptoms of their health condition. The combination of these factors illustrates the sheer complexity of each individual's journey towards recovery. While patients' symptoms may be similar, the nature of their impairment(s) can vary greatly, thereby requiring different treatment. The types of impairments commonly experienced by survivors of stroke include the following:

Motor impairments:

- Passive range (amount of motion at a given joint when the joint is moved by an external force)
- Muscle length (the distance the muscle tissue stretches)
- Muscle tone (the tension in the muscle; its resistance to passive stretch)
- Muscle strength (how much force the muscle is capable of exerting)

- Neuromuscular control (the amount of influence the individual has over the nerves that control their voluntary muscles)

Sensory impairments:

- Pain
- Somatosensory (touch, pain, temperature, proprioception - static and dynamic)
- Visual
- Vestibular (balance, eye movement)

Perceptual and cognitive impairments:

- Memory
- Attention


3.4.4 Application of Signal's Ideas

Signal made it clear that developing a solution that could be deemed 'universal' would be impossible. Achieving such complexity and detail is not within the scope of this research. Rather, focusing on a more refined set of qualities will allow our solution to be more usable. As it is not within our capabilities to embed clinical reasoning into

figure 3.13 - Strength for Task Training

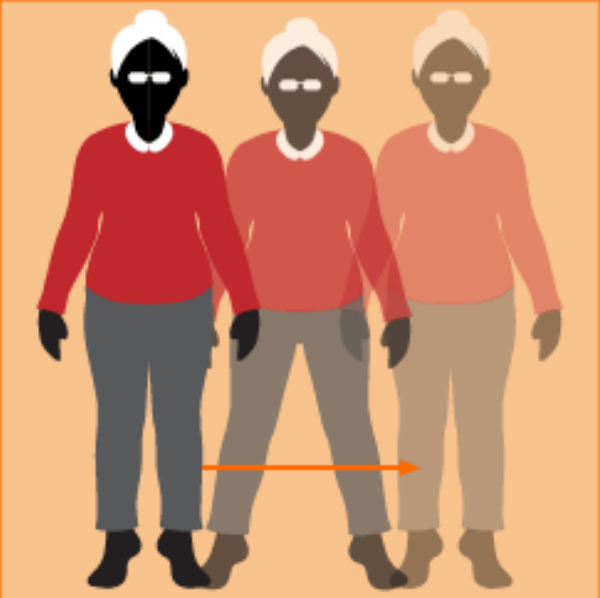
Strength Training: Hip Abduction

- Standard exercise uses theraband for resistance.
- 15 repetitions using weighted sole.
- Weight varies depending on user's strength.



Task Training: Sideways Stepping

- Weighted sole is removed.
- Variants include sideways walking, stepping onto elevation and grapevine.



Hip abduction is a component of sideways stepping. By performing these exercises at a high intensity, it excites the nervous system and enhances neural plasticity for subsequent exercises. The transition between the two exercises needs to be prompt.

(Signal, 2014, p. 47)

our system, we will not implement any functionality that performs diagnosis. Instead, the system would be prescribed to patients by clinicians who think it beneficial. Signal stated that some exercise is better than none, so despite the system not catering to all people within the survivor of stroke community, it can still be an asset for it.

Our interview ended with Signal explaining the clinical reality that patients spend a lot of time during clinical sessions inactive, recovering from exercises, etc. Patient contact time with their clinic is limited. A mode of rehabilitation that can be addressed several times throughout the day will allow for more exercise overall.

Ex. An individual performs their exercises in the morning, breaks for breakfast/lunch, performs more in the afternoon between stationary activities and performs another set before going to sleep.

To enable this type of interaction the system needs to be portable as not to restrict users to a specific location in their homes. Ideally the device that hosts the media would be something like a tablet (e.g. *Samsung Galaxy* or *Apple iPad*), allowing for high mobility with ample screen-space for in-game graphics.

Signal's STT model (2014) is a developmental rehabilitation technique whose novelty resonates with using a digital game for stroke rehabilitation. STT utilizes strength training to "systematically prime the central nervous system prior to task specific training" to maximize gains in locomotor ability (ibid., p. 46). STT is broken into two distinct phases; priming and task-training. Because of this, any game that incorporates STT into play needs to have phases that are proportionally similar to their therapy counterpart.

(For additional notes on this interview, see Appendix A, p. 194)

3.5 Clinical Observation

Early in the process we visited a physiotherapy clinic with Prof. Denise Taylor and Dr. Nada Signal. This provided the opportunity to observe a physiotherapy session conducted by professional clinicians. We were able to experience the type of exercises we would promote within our system.

(For more detail on this observations of this session, see Appendix A, p. 195)

The patient performed simple mobility tasks to test strength and balance. During these tasks, the clinician engaged the patient in conversation.

The purpose of distracting the patient with conversation was explained to promote an unconscious response. For the patient to regain their original mobility, their movements need to be functioning on an unconscious level. Distracting the patient can also help them manage or even forget pain (Lee et al., 2012, p. 436, Moreira et al., 2010). And, of course, an action that is perceived to be less painful is more likely to be repeated than one that is.

This is where the digital game could excel. While interaction with the game facilitates the mobility task, the in-



game goal combined with the visual and aural feedback draws the patient's focus.

The clinician used a technique described as “cueing” where they explained the actions the patient was to perform. This was different to feedback as it occurred prior to the action's execution. The purpose of cueing is to aid the patient in visualising their goal, giving the action meaning. This can double as instruction for patients have difficulty remembering their therapy motions.

Imagine the movement > Apply the movement

Cueing was not limited to verbal instruction. Sometimes it was as simple as rhythmic clapping to encourage momentum. Something as subtle and a vibration could cue a patient's movements and would provide them with haptic feedback. Such a function on the device could be tied to key moments of gameplay, for example: a player is about to perform a significant task and receives an auditory prompt combined with a gentle vibration that increases to a brief purr on the task's completion.

Sometimes an individual with a brain injury cannot filter out additional information, both visual and aural, so any form of feedback should be able to be toned up or down

as appropriate. It is also possible for such individuals to experience “central neuro-muscular fatigue,” which affects the drive from the cortex to the muscle. We were told, however, that rarely do patients experience genuine muscle fatigue. If the rehabilitation system is engaging enough and can successfully distract a patient from this type of fatigue, they will be able to maximise the time they spend exercising their limb before becoming too tired to continue.

This observation session prompted consideration of how supportive messages could be included in the software. A basic tutorial is necessary, but it would also be worthwhile to include feedback specific to rehabilitation. Prof. Taylor and Dr. Signal discussed how if a person is not familiar with physical exercise and then suffers a stroke, they may confuse the two sensations and categorise both as negative. It is part of the physiotherapist's job to normalise these sensations with their patients. The software could support this with reminders such as “not all pain is bad. Sometimes it just means you're working hard. If the pain persists, however, please contact your doctor.” Ijsselstein et al. emphasize the importance of encouraging feedback during the early phases of the game where the player's confidence would be at its lowest (2007, p. 19). The game

should encourage players to keep trying in spite of failed attempts, rather than risking them concluding that the system is too difficult to use.

The last observation we discussed was how task-specific training is constructed differently for different patients. Task-specific training (a core component of Dr. Signal's *Strength for Task Training*, 2014) is an effective means of generating salience for those partaking in it. Giving context to the patient's actions can make the task's relevance (and benefit) more apparent. Patients and clinicians alike tend to prioritise tasks that the patient deems important to complete. This varies greatly depending on the individual. Luckily independent mobility is a universal priority, increasing the importance of focussing on lower-limb rehabilitation.

The information gathered from this observation session combined with an interview with rehabilitation researcher Samantha Ogilvie helped establish a set of user profiles. These profiles helped maintain the UCD methodology by emulating potential users until formal user tests were conducted.

(For additional notes on this interview, see Appendix A, p. 196)



figure 3.14 - Bruce



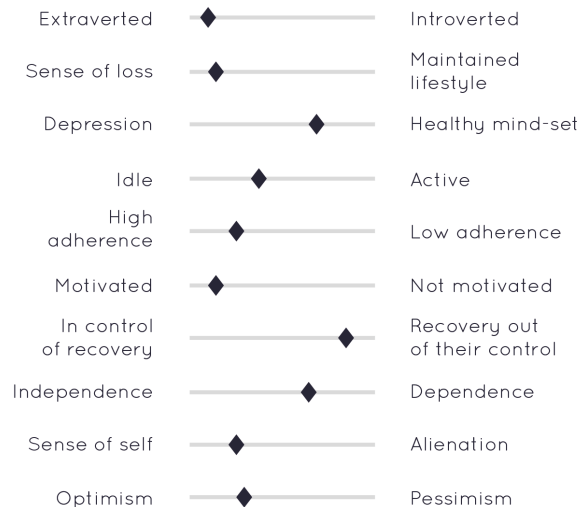
Age: 60

City: Hastings

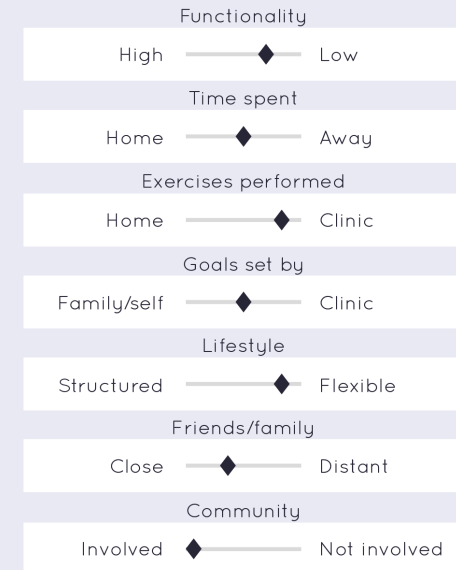
Condition: Right leg is stiff and lacks strength. Walking is possible for short intervals. Can maintain performance for longer with the use of an aid.

Bruce

Emotional Condition



Situation



Bio

Bruce's stroke impaired his ability to enjoy some of his favourite leisure activities and as a result his ability to express himself was reduced. His involvement with the community meant he had a few friends he could use for support which has made the difference between him sinking into a negative state of mind. He views his therapy to be very separate from his daily life and is embarrassed by his need for it. Bruce views his independence to be an important part of his character and resents his impaired movement. He desires greater understanding and control over his rehabilitation process to overcome his stroke and return to his normal life.



Camping



Fishing



Drinking

Needs:

- Confidence boost in rehabilitation and ability to recover.
- Independence with rehabilitation.
- Leisure activities better suited to his physical condition.

figure 3.15 - Janet

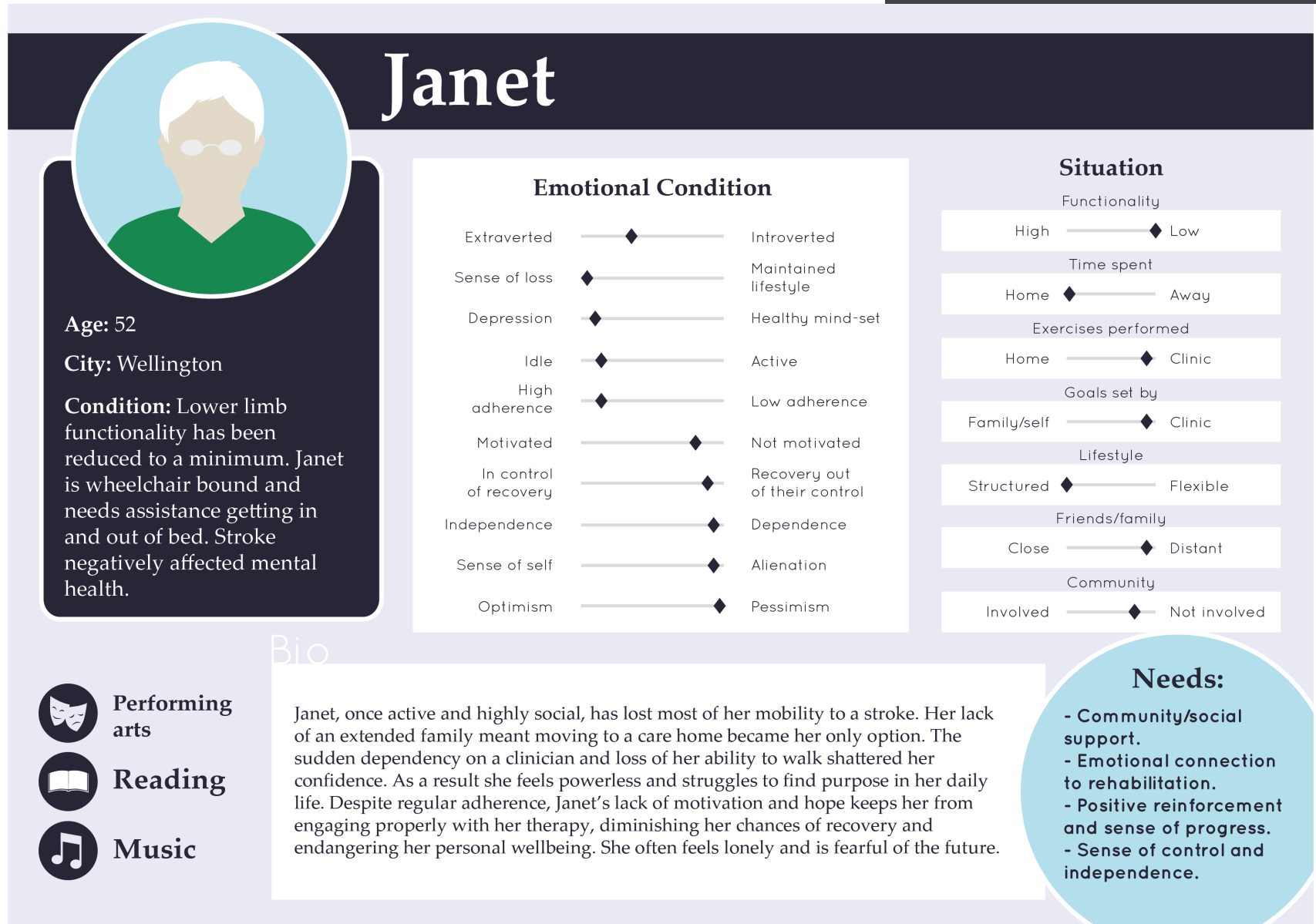


figure 3.16 - Paxton



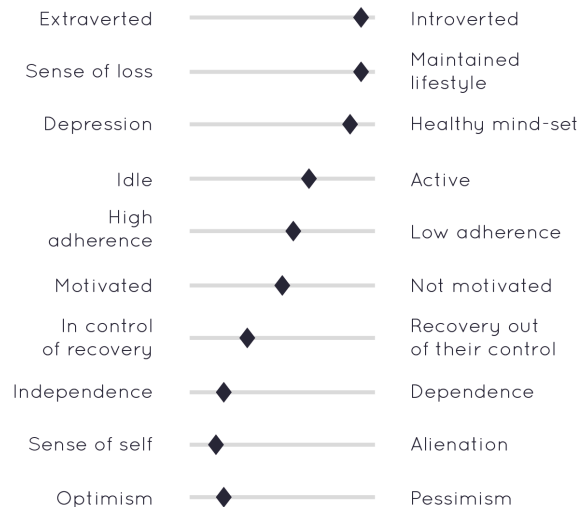
Paxton

Age: 68

City: Auckland

Condition: Left leg has very restricted mobility. Walking requires a lot of effort and often needs help climbing stairs. Can move horizontally with a walking stick over short distances. Cognitively unaffected.

Emotional Condition



Situation



Bio



Film



Cooking

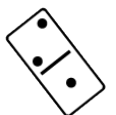


Family

The support of Paxton's wife and children has helped maintain his confidence after suffering a stroke. He prefers to stay in the comfort of his home, only going to the clinician for organised check-ups. He finds therapy mundane and prefers to do things his own way. Paxton was not very physically active before the stroke so his motivation to recover mainly stems from Camille's insistence. These have resulted in a lower adherence rate to his treatment and puts him at risk of not achieving a full recovery. The support of his family has kept Paxton's stroke from affecting his mental health too severely but from time to time his lack of mobility leads him to give in to apathy.

Needs:

- Effective therapy that can be performed at home.
- A reason to stay active.
- A stronger relationship with the clinician.



Chapter 4

Win Conditions

“Making the right choice for criteria and performance measures depends on understanding the alternatives available and the limitations of each.”

- Hartson et al., 2003, p. 153

```
IEnumerator GameRound()
```

```
{
```

```
    while (!EndGame()) {
```

```
        if (firstTurn)
```

```
            yield return StartCoroutine (PlayerTurn (player));
```

```
        else
```

```
            yield return StartCoroutine (PlayerTurn (otherPlayer));
```

```
    }
```

```
    for (int i = 0; i < gm.players.Length; i++)
```

```
        if (gm.players[i] != null) {
```

```
            score = 0;
```

```
            print ("Score just got scored. Current score: " + score);
```

```
            player p = gm.players[i];
```

This chapter explores the resolution of our first research aim. It covers the establishment and refinement of criteria for developing a digital game for post-stroke rehabilitation. The three criteria that were assessed to be the most relevant were *adaptability*, *connectivity* and *meaningful interactions*. The final output game was specifically aimed at lower-limb rehabilitation, however these criteria act as generic principles and could be applied beyond this research.

4.1 Criteria for Success

Exploring existing knowledge in this field has made a number of things clear. Firstly, it is impossible to create a universally applicable game experience for everyone (Malone, 1981, p. 343). Secondly, for a game to function successfully as a physiotherapy aid it must prompt accurate therapeutic exercise and report relevant data (Lee et al., 2012, p. 435). Thirdly, in the amount of time available for this research it was not possible to explore all avenues of game design in detail and selected elements needed prioritisation. The game was still developed holistically (capable of existing as a standalone experience rather than just an experiment with mechanics) with elements that were deemed significant given greater attention.

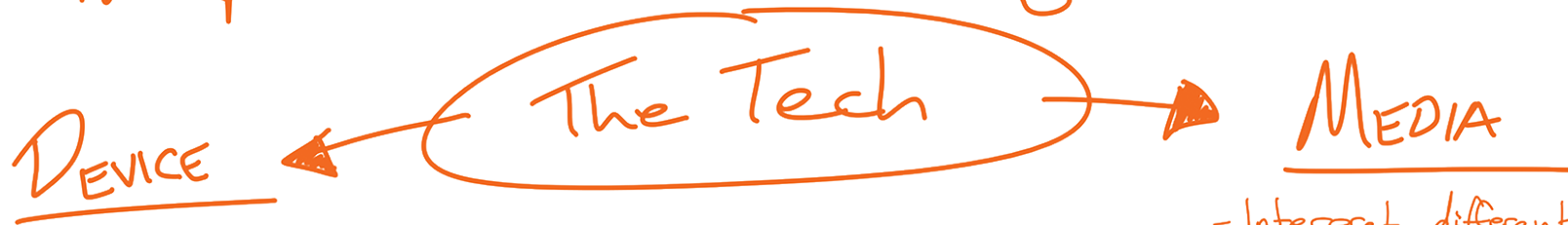
4.1.1 Establishment of Criteria

Consultation with the clinicians generated a list of properties the system should exhibit to be effective as a physiotherapeutic aid.

Three criteria were chosen from this selection to be prioritised by the game.

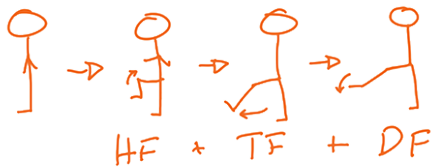


Therapist uses Clinical Reasoning recommends:



- Sequencing input data so therapist can customize movements e.g.

Kicking = hip flexion + thigh flexion + dorsal flexion



- Variance

ADAPTABILITY

Haptic Feedback

- Vibration
- Temperature
- Audio
- LEDs

- Interpret different inputs to in-game actions e.g. one player moves through flexion, another moves through rotation
- In-game rules can be customized
- Calibration
- Difficulty curves (cognitive difficulty vs. motor difficulty)
- Single player + multiplayer
- Custom UI
- Toggle audio cues
- Manual interface fail-safe

DEVICE

- Personal points of conversation
(Device is celebrated)
- How can we represent the individuality of each user's therapy/recovery?
- Sync to devices nearby
- Haptics could sync splints up to beat of music

CONNECTIVITY

MEDIA

- Multiplayer!
- Varying input to same play experience
- Game statistics
- Player accounts
- Clinic messages
- Player chat
- progress reports
- Clinic challenges
- Player challenges
- Forum
- Custom Avatar



figure 4.3 - Entrusting

DEVICE

- Comfort
- Reliable/accurate
- Clear when low on battery

- Minimize room for technical error

Make sure the patient knows when an error occurs so they don't blame themselves.

ENTRUSTING Salience

Build trust in the tech

Intensity Engagement

↓
in
Balance

MEDIA

- Acknowledging the clinicians connection to the tech
- Daily goals

too much compromises engagement

Room for users to challenge themselves knowing the harder they work, the more they are getting out of it.

DEVICE

Intrinsic value in device through materials

- tactility
- ease of use
- customized to user
- celebrated or discrete?
- Put your shoes or slippers over it?

To consider:
modular bracing

INVESTING Salience

MEDIA

- Data tracking
- Personalized messages
"Good morning Paxter"
- Goals*
- Notifications from specialist
(don't have to be online simultaneously)
- Positive reinforcement

* Patient can set personal goals
Clinic can set goals remotely
Game has inbuilt benchmarks:
Player stats, hours played,
developments in therapy



DEVICE

Material/colour
choice

Movement
Compensation

- how does hardware encourage correct form?
- how does the device cater to involuntary movement?

KNOWING Salience



- do we not allow incorrect movements?
- reward correct form?
- positive reinforcement
vs.
constructive criticism

MEDIA

- User profiles
- Progress reports
- Customizable UI
- Avatars
- How does the media encourage correct form?
- Timed responses for input to counter jitter

DEVICE

- Haptics *
- Modular bracing
you remove as you progress
- When I'm using the device
 - 1) What actions do I receive haptic feedback from?
 - 2) When during the action do I receive the feedback?
 - 3) What does it mean to me?

* Calibrated haptic response
Turns on = purring
Threshold for movement reached

RECIPROCATING

MEDIA

- Clinic Feedback
- Positive reinforcement
- Reward system
- Unlockable content
- Player survey
- Motion capture visualisation of correct movement



4.1.2 Adaptability

The first criterion is *adaptability*. Dr. Signal emphasised the importance of “specificity to the individual” (*personal communication*, 10 August 2015). The three main points of adaptability that are covered by literature are: mode of input, difficulty and interface (Alankus et al., 2010, Gerling et al., 2010, Gerling et al., 2011, Gregor et al., 2002, Holden & Dyar, 2002, Ma et al., 2007, Mahmud et al., 2008, Moreira et al., 2010, Orvis et al., 2008, Sampayo-Vargas et al., 2013, Schönauer, Pintaric, & Kaufmann, 2011, Shirzad et al., 2015). Adaptable input methods are particularly important with rehabilitative games, as the system needs to be able to adjust as the user grows stronger. Ma et al. claim that this allows for the improvement of the patient’s residual capabilities “without causing fatigue and frustration” (2007, p. 683). It is also integral for the long-term usability of the system in both a clinical environment and in home-based rehabilitation (Alankus et al., 2010, p. 2121).

The significance of adaptive difficulty in games is the connection between challenge and engagement. If a game is too hard the audience will become frustrated with their inability to progress. If the game is too easy they will become bored. This concept is referred to as ‘flow theory’ (Mathwick and Rigdon, 2004, Sampayo-Vargas et al.,

2013). If the game’s flow is engaging enough, it can even help players cope with pain (Lee et al., 2012, p. 436, Moreira et al., 2010). The problem remains that the flow’s balance resides in a different place for each user. Matters are further complicated by the target audience experiencing difficulty from physical limitations as well. Gregor et al.’s (2002) discussion on the variation of decline of physical and mental faculties in older adults makes it clear that any system being designed for this demographic must be able to adapt to a broad range of user needs.

4.1.3 Connectivity

Connectivity was found to be of recurring importance (Alankus et al., 2010, Binstock & George, 2001, Blythe et al., 2005, Costikyan, 2006, Flores et al., 2008, Gerling et al., 2011, Ijsselstein et al., 2007, Jack et al., 2010, Mahmud et al., 2008, Trefry, 2010) and therefore became the second criterion. Social isolation is one of the biggest issues faced by older adults, many of whom “feel a crippling sense of loneliness” (Blythe et al., 2005, p. 683). Whether users are dependent on others for health care, or simply desire social contact and support, the game system needed to enable social interaction. It was beneficial that digital

games are widely perceived as an enjoyable means of maintaining social connections through common interest (Mahmud et al., 2008, p. 403).

To fully utilise the positive effects of *connectivity* in gaming, several things needed to be considered. Most importantly, as Blythe et al. write, “there is no substitute for human contact” (2005, p. 681). Solitary rehabilitation can be incredibly mundane but this can be remedied by local (offline) support. Face to face contact is a crucial part of traditional games that many digital games lack (Mahmud et al., 2008, p. 404) and many patients believe “they would more readily exercise if accompanied by someone else doing the activity” (Jack et al., 2010, p. 227). Sharing an experience with another person can generate interpersonal motivations, which is particularly important when the individual has reduced self-efficacy (Moreira et al., 2010).

The option to play with people who are either impaired or unimpaired would be beneficial as users may prefer one to the other. For example; one player may feel discriminated if they are the only one using a device, in contrast to someone who simply wishes to play with their grandchildren. Therefore the game needs to be functional without exercise-based interactions.

4.1.4 Meaningful Interactions

The third and final criterion was *meaningful interaction* with the system. This concept represents the system’s ability to communicate its purpose through gameplay. This can manifest as the game supporting the player’s extrinsic motivations. *Interaction* with the system generates *meaning* through its salience to the player. Ijsselstein et al. reinforce the significance of this criterion, claiming many older adults disregard new experiences due to a lack of perceived benefits (2007, p. 19). Such perspectives generate a problem in physiotherapy where the lower-order tasks required for rehabilitation seem too mundane to bother with. They lack context and positive reinforcement (McPherson et al., 2014, p. 110).

Task-oriented exercises are a common means of improving the salience of motor learning (Shirzad, 2015, p. 361), as they situate the exercise within a context relevant to the user. For example; a survivor of stroke is an enthusiastic drinker of tea, yet the shelf that holds their mugs is level with their shoulder. The task their clinician sets may involve lifting a ceramic mug up to shoulder height with an extended arm. The patient is more likely to attribute this task to a positive experience and may be more motivated to complete it.



Tasks within a physiotherapy game can be functionally similar. Nunes & Dreze claim that people often exhibit persistence in achieving goals that have discrete, extrinsic rewards (2006, p. 504), therefore in-game features such as achievements (e.g. badge or trophy systems for accomplishments like “won five matches in one day”), progress tracking (such as levels, rankings or personal analytics), or in-game objectives (such as quests, tasks or daily goals) have the potential to increase extrinsic motivation by rewarding players for interacting with the system. Such interactions could be interpreted as salient through their ability to realise the goals of the player.

Gregor et al. recommend game designers use “meaningful metaphors and relate real world actions” (2011) to improve accessibility to an older audience. What can be deemed “meaningful” will differ from person to person, however mapping in-game actions to logical real-world motions is less subjective. Players of rehabilitation games are likely to have the extrinsic motivation of improving their health, thereby rewarding players who complete exercises could help them maintain motivation to play the game. Logical connections between a player’s exercises and the in-game response could reinforce the game’s purpose as a rehabilitation aid.

4.1.5 A Criteria-based Thesis Model

These criteria were core components of the following design phase. Much like the designs, the criteria were subject to an iterative process, being refined as the research developed to best represent the ideal outcome. As developments were made the weighting of the criteria became more defined.



Chapter 5

“Computer games are especially clear illustrations of how the unique capabilities of computers can be used to create motivating environments.”

- Malone, 1981, p. 340

Variety is the Spice



The knowledge explored in the earlier chapters was used to generate the concepts that follow. Each concept was subject to critique from clinicians and assessed using matrix evaluation. Clinician responses prompted an atypical approach to development whereby the initial concepts were expanded before narrowed down to the most applicable idea. These expanded concepts were also evaluated via matrix, albeit with more precise criteria. The criteria for both matrix evaluations represented specific aspects of *adaptability, connectivity and meaningful interactions*.

5.1 Beginning hypotheses

The information compiled from literature reviews formed the basis of the game's content thematically, mechanically, and aesthetically. We hypothesised that a digitized version of a familiar game, such as cards (*Poker, Euchre, Bridge* etc.) or board games (*Chess, Mahjong, Backgammon* etc.) would likely be the most effective concept. The concept was not required to be a digitized version of such games, as the recycling of familiar mechanics could prove equally as effective.

As discussed in Chapter 3, older adults who recognise thematic elements of the game may feel more confident in its

use. This is critical if they rarely interact with digital technology (Mahmud et al. 2008, p. 403, Orvis et al., 2008, p. 2418) and could make the difference between them trying the system or not.



5.2 First Iteration Concepts

The rapid turnaround of these concepts and their second iterations meant there was not enough time to develop digital prototypes. Subsequently, each concept manifested as a miniature game design document. An expanded description of each concept can be found in Appendix B, beginning at page 198.

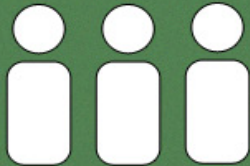
This concept was the most developed in this phase because it appeared to be the most promising. This assessment came from *Four Seasons*' heavy grounding in literature. It was chosen to be the datum for matrix evaluation as a result.

5.2.1 - Four Seasons

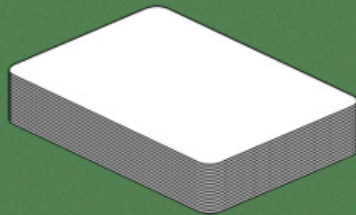
This concept stemmed from the idea of familiarity. It was a simple tile game built from the combination of a number of card game mechanics. The primary strength of *Four Seasons* was how the game had enough recognisable elements to be encouraging to new players, yet enough new elements to be exciting. It also promoted *connectivity* through the potential of local multiplayer. This concept's greatest weakness was the arbitrary way the exercises would be integrated into gameplay. However, the abstract connection between these aspects allowed for flexibility in what players needed to perform.

figure 5.1 - Four Seasons

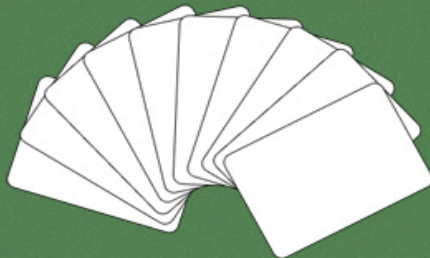
Four Seasons



2-6 players



120 card deck
(3 standard decks
without face cards)



Each player starts the
round with a hand of
10 cards

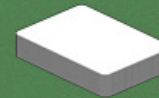


= 4 points

At the end of each round,
players gain a point for
every remaining card in
their hand



Cards needed for
hand of 10 = 6



Cards left = 5

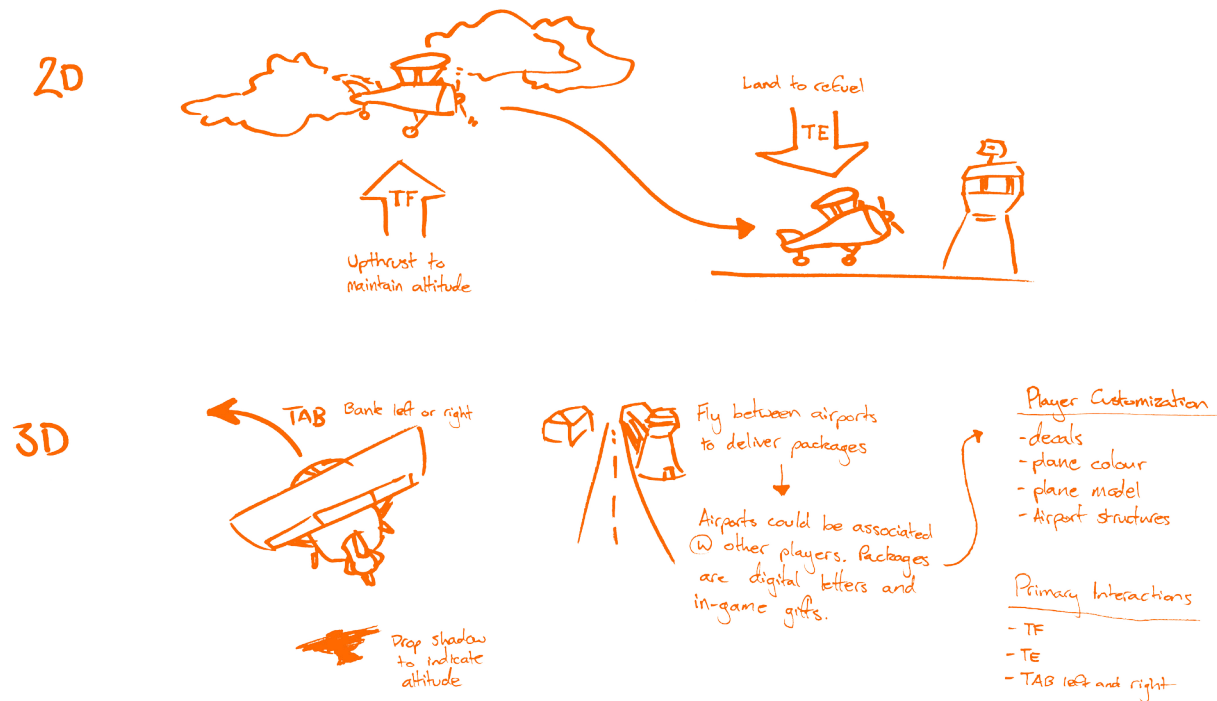


The game ends when there aren't
enough cards left in the deck to
top up every players hand to ten.
The player with the lowest score
wins (like golf).

Paxton	Janet	Bruce	Sophie
3	2	5	4
6	5	9	9
11	10	14	16
16	14	19	22
	👑		



figure 5.2 - Plane

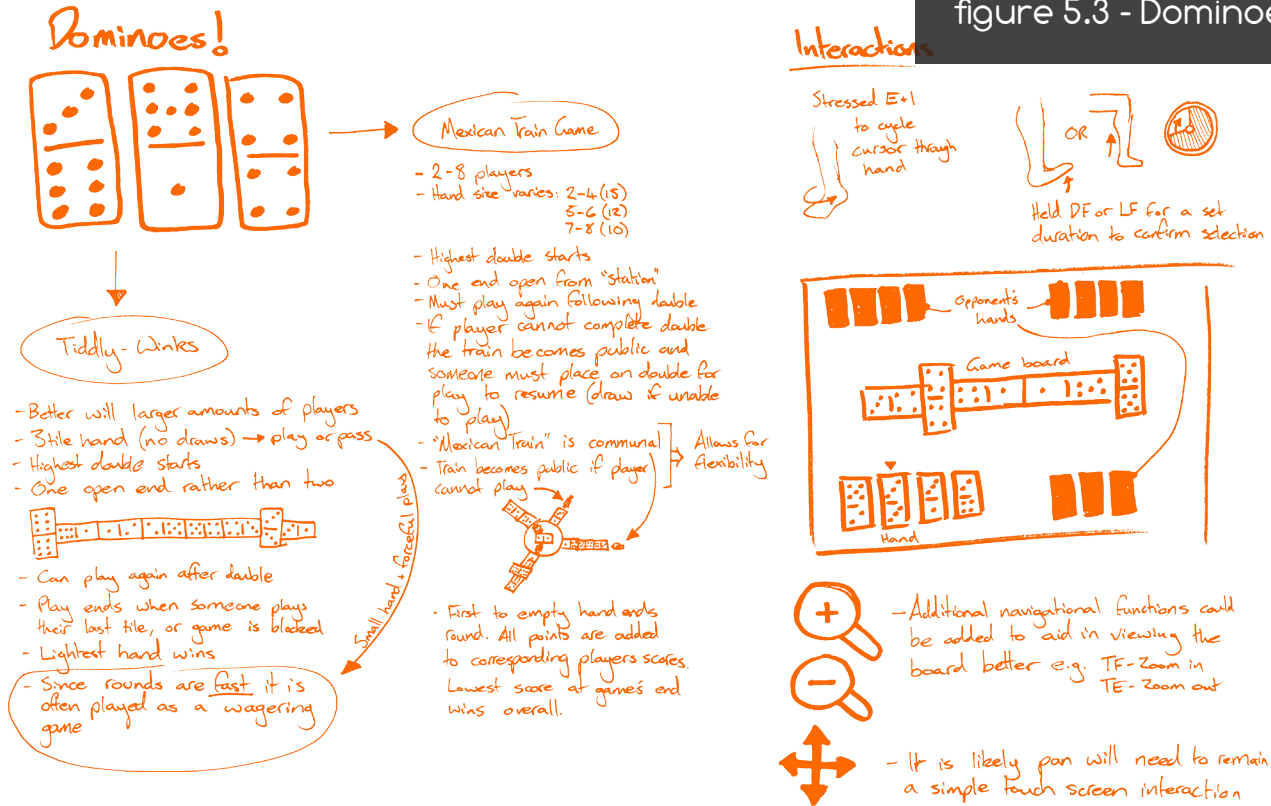


5.2.2 - Plane Concept

This concept worked as both a 2D and 3D game. The player performed regular exercises to keep the plane aloft as they delivered packages to different airports. This concept's strength came from the logical connection it provided between players raising their affected limb and keeping the plane aloft. Its greatest weakness was the

repetitive gameplay that lessened replayability. The concept felt more appropriate as a game for a clinical session rather than something players took home to practice with.

figure 5.3 - Dominoes



5.2.3 - Dominoes Concept

This concept was similar to *Four Seasons*, being a digital recreation of classic tabletop dominoes. As a result it held all the same strengths as *Four Seasons* but with greater simplicity and accessibility. The portability of the tablet and turn-based play allowed it to be passed from player to player, minimizing the amount of devices needed for local

multiplayer. The similarity dominoes had to *Four Seasons* meant it also shared its weaknesses. Using exercises to interact with the game was reliant on novelty, which wanes over time.



5.2.4 - Perpetual Motion Concept

This concept revolved around removing forward motion from the player's control, making gameplay more reactive. Players guided their avatar as they perpetually moved forward, avoiding obstacles and collecting points. The advantage of this concept was the simplicity of interaction, making it easier to learn. Its most prominent weakness was the reliance on reaction time. Reducing the pacing to something more manageable risked the forward motion losing meaning. Additionally, the core play loop revolved around playing until a point of failure (hitting an obstacle), rather than playing until a point of success (reaching the summit of a mountain).

5.2.5 - Painting Concept

This concept functioned as a colouring book for adults whose mobility is very limited. Players completed detailed vector illustrations by tapping on the area they wished to paint and completing repetitions to fill it with colour. One of the strongest aspects of this concept came from granting players complete control over the pace of their experience. This was a double-edged sword however, which ran the risk of less motivated patients leaving exercises incomplete. The main weakness was the same as *Four Seasons* and *Dominoes*, whereby the inclusion of exercises was more of a novelty than a core component of the game.

figure 5.4 - Perpetual Motion & Painting

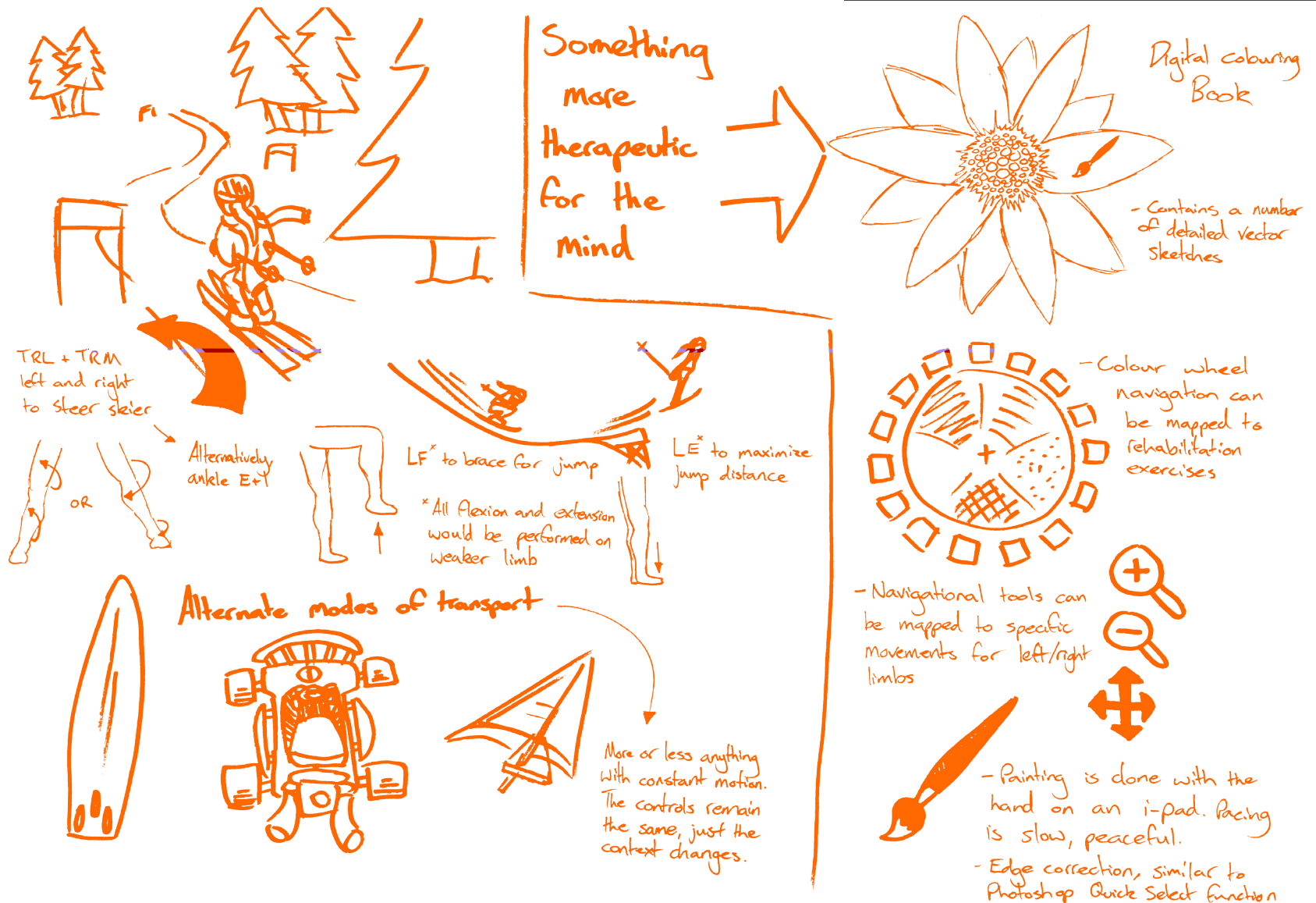
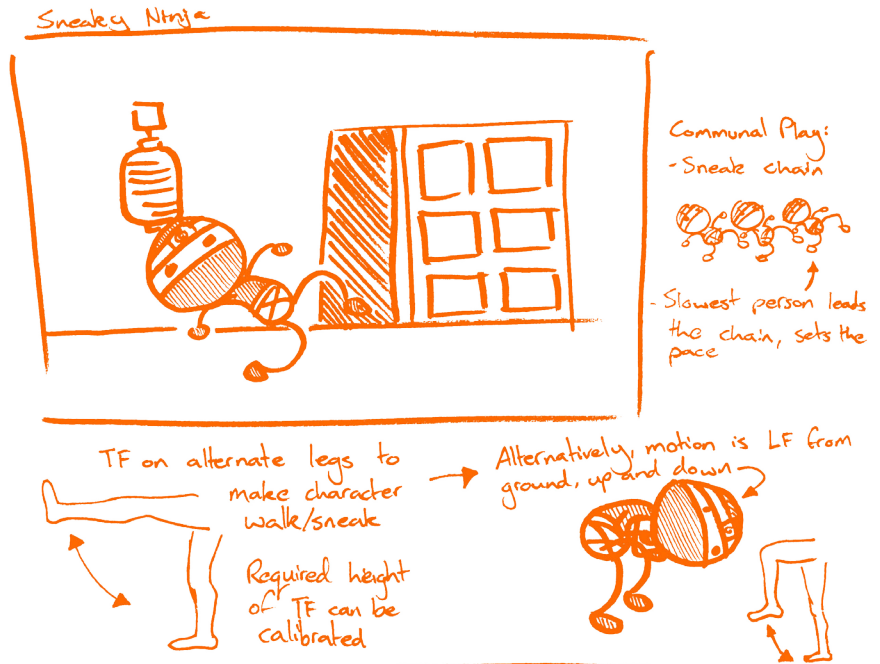
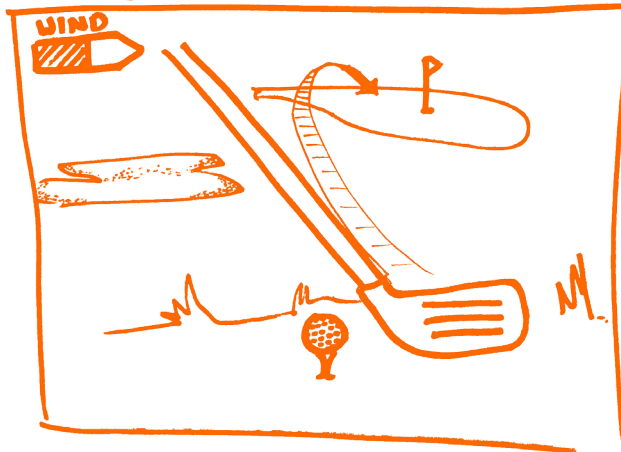
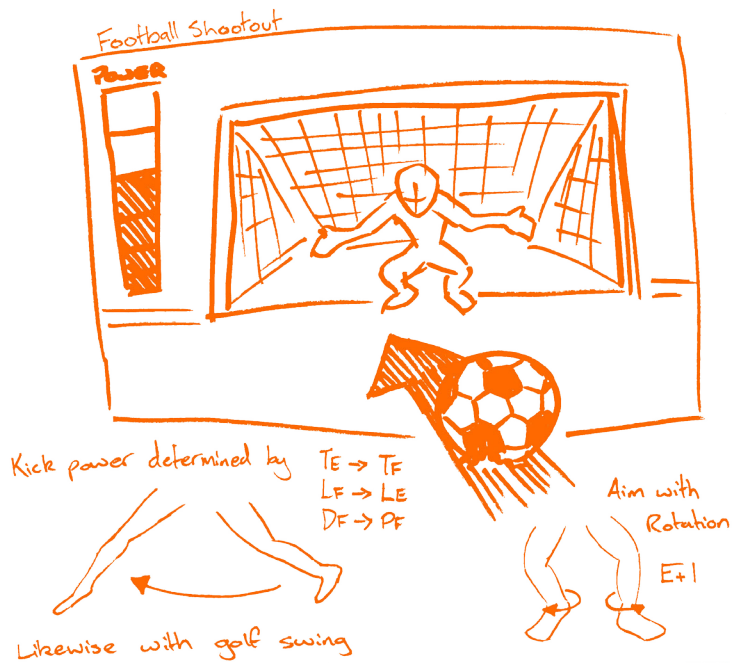


figure 5.5 - Sports & Sneaking



5.2.6 - Sports Concept

This concept presented two visualisations of the same idea. Players completed exercises to shoot hoops or kick goals etc. Preference would be given to the golf theme due to its popularity and pacing. The strongest aspect of this concept was how it hosted *meaningful interactions*. The theme of sports helped establish a clear connection between the player's motions and the in-game response. It also promoted salience by representing the desire players may have to be active outside, or a sport they used to play. The largest weakness of this concept was that it required a fair bit of mobility from its users to be effective and may have been difficult to learn as a result.

5.2.7 - Sneaking Concept

This concept explored the use of fantasy elements in gameplay whilst maintaining clear translation of player motions. The game's appeal came through its playful representation of the player. The incorporation of exercises into gameplay was the strongest aspect of this game, where player actions were given clear responses. This tied into the game's primary weakness, which was the limitation of exercises that could be applied yet maintain a strong connection. Without this connection the fantasy context lost meaning and the novelty wore thin.



figure 5.6 - Mountain Climbing

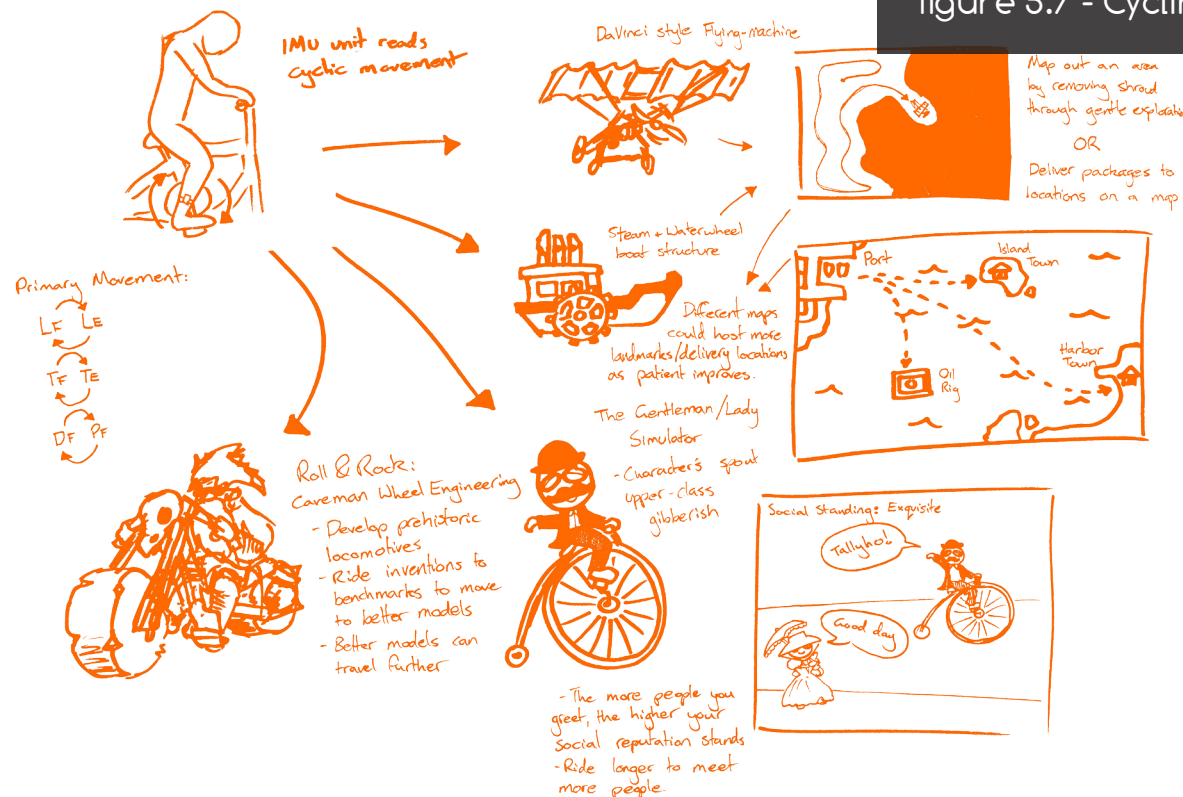


5.2.8 - Mountain Climbing Concept

This concept held the strongest metaphors for the player's recovery. Play consisted of exploring mountains, temples, caverns etc., all of which involved ascension in some way. The strongest aspect of this game was its connection to the therapy process, both figuratively and through logical motion mappings. The primary weakness of this concept

was the lack of multiplayer capabilities. Goals in the game were completely self-focused and adding additional players did not contribute to the experience in any meaningful way.

figure 5.7 - Cycling



5.2.9 - Cycling Concepts

These concepts were a brief deviation from our attempts to integrate William Duncan's device. Instead, they used a cycling machine to play. The primary focus of these concepts was to establish a strong mental connection between the motions the player conducts in real life and those in-game. Due to the lack of *connectivity* and the

adaptability of input motion, they were not developed beyond their inception.

figure 5.8 - First Iteration Matrix Evaluation

Criteria	Concepts								
	<i>Four Seasons</i>	<i>Planes</i>	<i>Dominoes</i>	<i>Mountain Climbing</i>	<i>Perpetual Motion</i>	<i>Painting</i>	<i>Cycling</i>	<i>Sports</i>	<i>Sneaking</i>
Multiplayer	D	-	=	-	-	-	-	-	-
User profiles	A	+	=	+	=	+	=	=	=
Logical motion mapping	T	+	=	+	+	=	+	+	+
Ease of learning	U	-	+	-	-	=	=	=	-
Adaptable difficulty	M	=	=	-	+	-	=	+	=
Variation of task		=	=	+	+	=	-	+	+
Totals		2+ 2= 2-	1+ 5= 5-	3+ 3= 3-	3+ 1= 2-	1+ 3= 2-	1+ 3= 2-	3+ 2= 1-	2+ 2= 2-

5.3 First Concepts Review

Each concept was presented to clinicians as part of their review. Through their critique we were able to calculate the value for each point in the matrix. The totals for positives, negatives and equivalents were deliberately left separate as the weighting of some positives and negatives were not equal to their counterparts. For example, the painting and cycling concepts yielded the same amount of positive and negative values, yet the painting score was deemed to be strong by the clinicians.

Appropriately, other considerations were involved for selecting how each idea would be developed. Such considerations included the simplicity of setting up the system, whether or not a clinician would be required to learn it, how the system enables goal setting and realisation and whether or not it requires online functionality.



5.4 Expansion of Ideas

Critique from Dr. Signal and Prof. Taylor prompted an expansion of concepts to explore potential genres and mechanics more broadly. The doctors wished to examine the accessibility of each concept and the viability of incorporating physiotherapeutic exercises into gameplay without the influence of thematics. This meant the second iteration of concepts was more about styles of gameplay than specific applications. The results were less focused, albeit more diverse.

5.4.1 - Tabletop Games

The hypothesis that a familiar game such as dominoes or cards would be widely accepted by an older audience was supported by the doctors, reinforcing the claims of Mahmud et al. (2008) and Orvis et al. (2008, p. 2418). It was possible for this familiarity to greatly improve the game's initial accessibility. The other strength this concept had was its firm grounding in *connectivity*. Tabletop games are primarily social experiences (Costikyan, 2006, p. 208). Such a game allowed the patient's loved ones to support them in a fun and meaningful way.

Much like the painting concept, the connection between player input and in-game action was abstract. Players could struggle with making the connection that their leg movements control a game that is generally played by hand. These interactions stemmed towards novelty rather than being *meaningful*. In paying this cost, the game's input was not limited to being entirely logical and allowed the required exercise to be adapted to the player's needs.

figure 5.9 - Tabletop

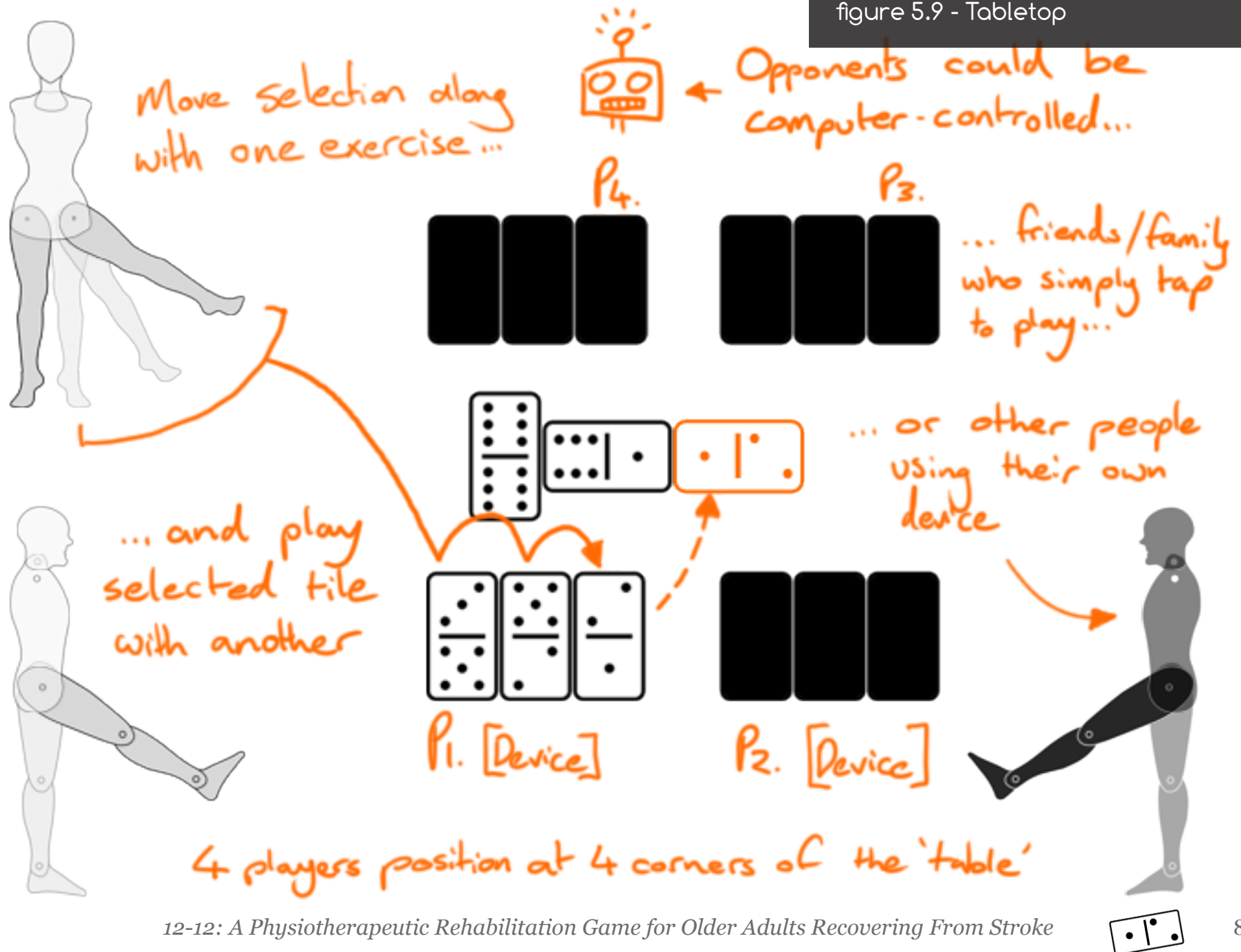
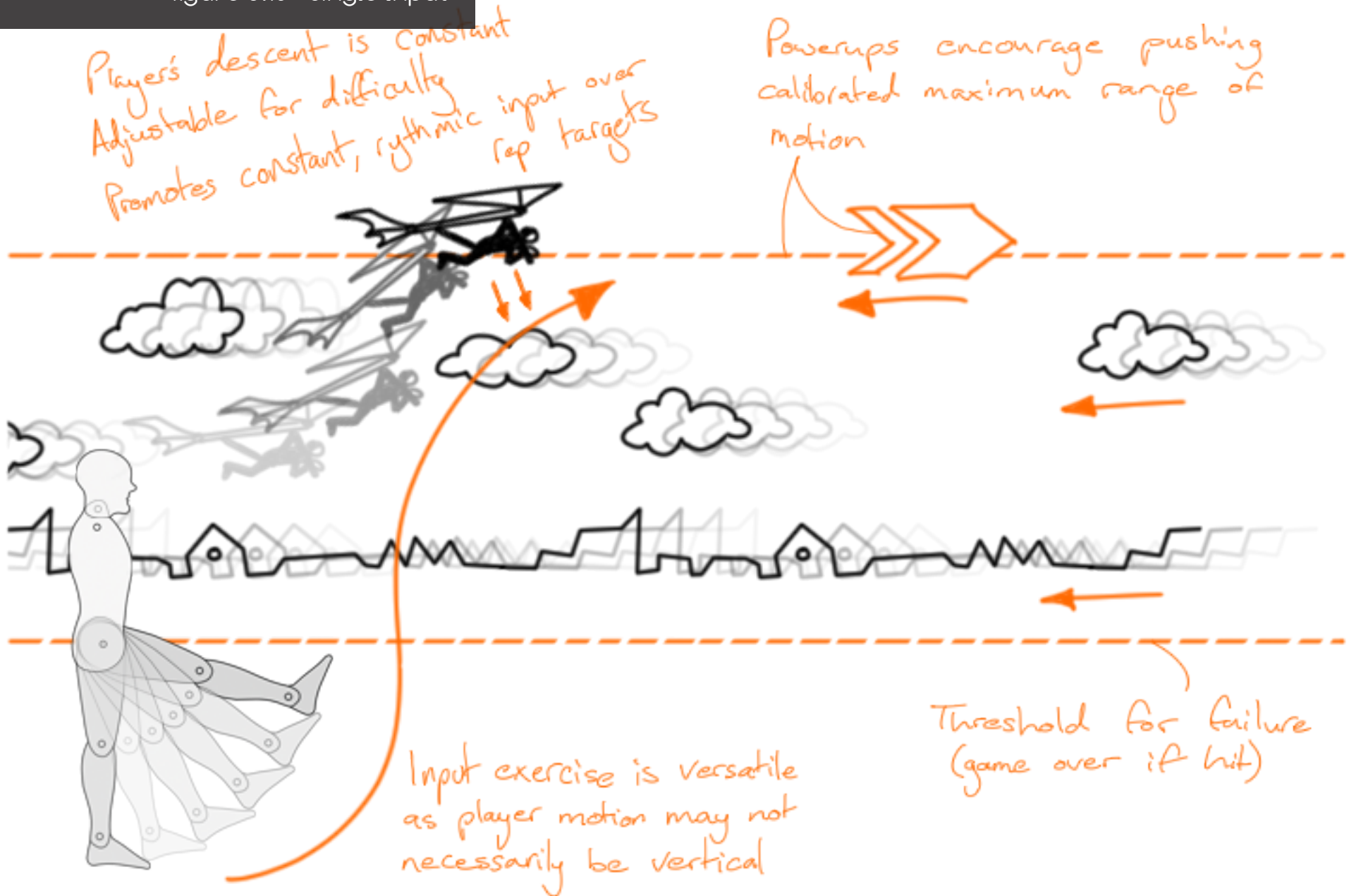


figure 5.10 - Single Input



5.4.2 - Single Input Games

Interaction with these games could be isolated to one button/exercise. The input could prioritise whatever exercise the player needed to be practicing. Ideally the motion would be mapped to in-game action logically (e.g. raising a limb for vertical translation), but this was dependent on the context the game set. These games primarily embody the simplicity Gerling et al. found to be so popular (2010, p. 68). The minimal input would be easy to remember and apply, benefiting those whose cognition has been affected.

To encourage expanding players' range of motion, powerups could be placed near and above each individual's calibrated maximum. The potential for these games to be *meaningful* and *adaptable* was high, however the sheer simplicity of the game risked users becoming bored with them over a long period of time. Moreira et al. emphasise the importance of extended adherence to physiotherapy (2010), making these games less effective in the long run.

5.4.3 - Literal Motion Games

These games prioritised *meaningful interactions* at the cost of *connectivity* and, to a lesser degree, *adaptability*. Flexibility in the types of motions that could be implemented was largely dependent on the quality of calibration. Discussion with Prof. Taylor revealed the positive influence that variety can have during task training (*personal communication*, 10 August 2015), highlighting the benefits of having distinctive motions for separate in-game actions. The context of the game contributed greatly to making the interactions meaningful (such as the mental connection between climbing stairs to climbing a rock face), but this resulted in grounding the theme, thereby reducing the potential target audience.

figure 5.11 - Literal Motion

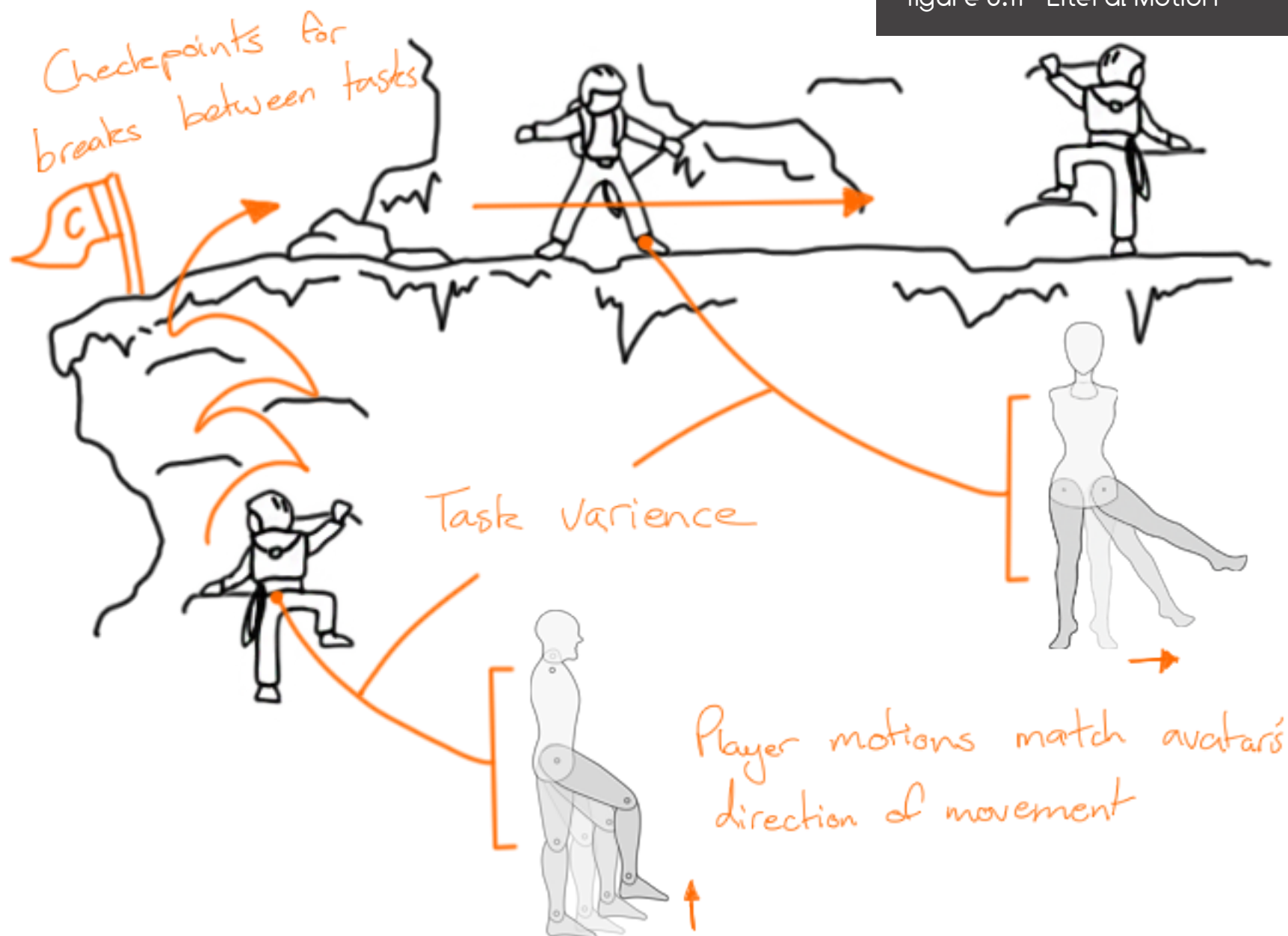
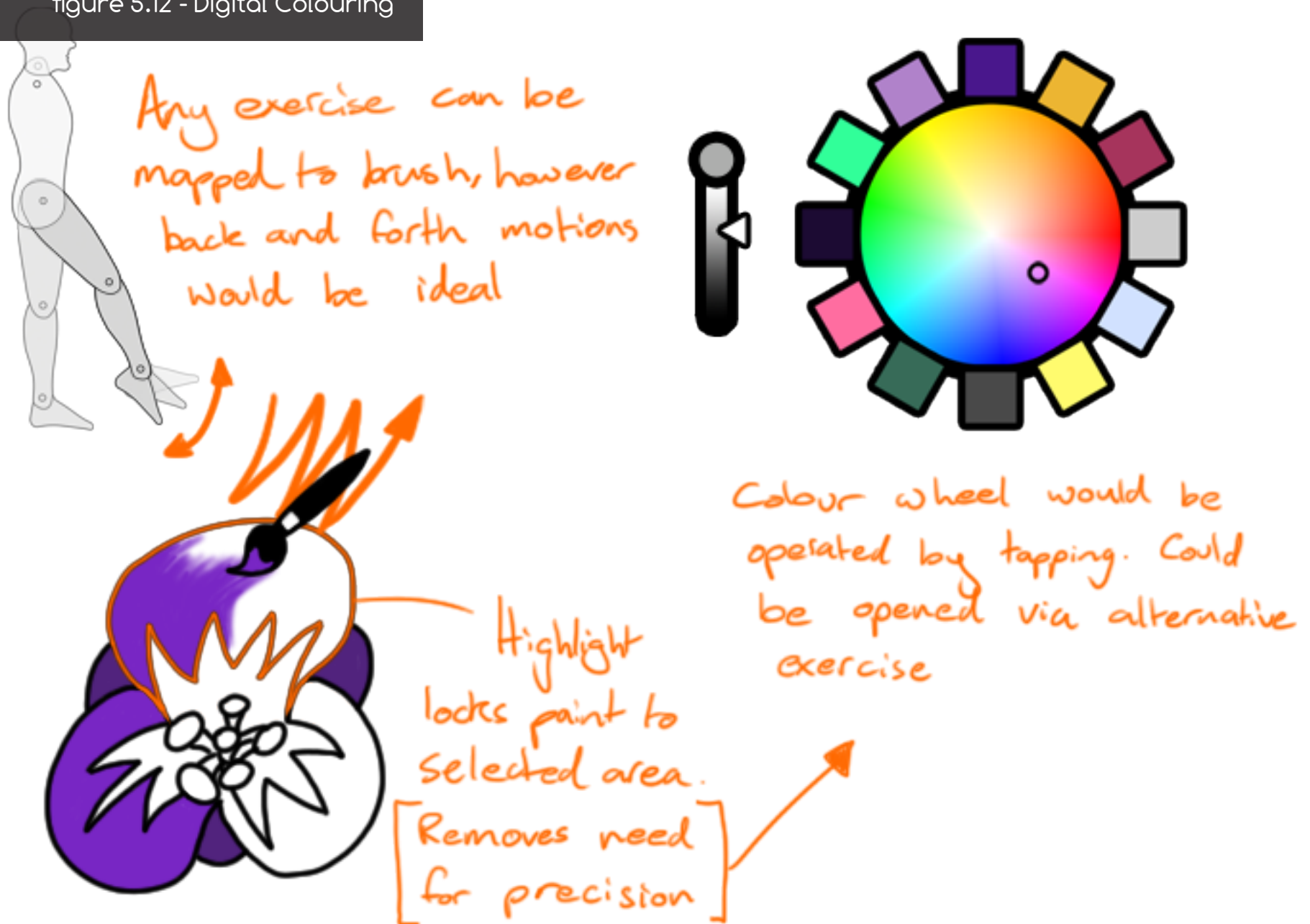


figure 5.12 - Digital Colouring



5.4.4 - Digital Colouring

This concept was possibly the most adaptable of those presented. Like the first iteration, the level of separation between the player's motions and the resulting in-game action was drastic enough to reach a point of novelty. This allowed for the painting motion to be substituted by any exercise the player needed to be practicing. The UI of the system would be minimal and unobtrusive, acting purely as a host for whatever vector packs the user downloads. Enabling users the choice of which drawing to download allowed them to make a personal investment in their recovery. This investment could result in greater motivation to complete the associated task, as explained by Dr. Kayes (*personal communication*, 10 August 2015) and yield greater satisfaction on its completion (Malone, 1981, p. 335).

The specialists from AUT suggested an alternate mode of interaction whereby painting was location-based. Users would calibrate their range of motion and the cursor on the canvas would adjust to fit the new range. The problem with this concept was that removing the masked section mechanic meant that users would be doing little more than finger painting, albeit using their feet. Considering people tend to be less dextrous with their feet, the novelty of this interaction would likely be short-lived.

5.4.5 - Cooperative Games

This style of game required two players to work together to achieve a common goal and was built on the potential Alankus et al. saw in cooperative games over competitive games (2010, p. 2121). Players were not necessarily performing identical tasks. In the example given, one player would control the flight pattern of the ship, the other the defensive turret. This enabled different task training, dependent on what each player needed to be improving. The connection (and dependency) this game fostered between its players was its main strength.

A suggested alternative for when two players are not available was to have the singular player coordinate two limbs. This would be limited to those who have advanced enough motor control and could prove difficult even for people unaffected by stroke. A more applicable alternative was to have the missing functionality automated by the computer with a range of difficulties to suit the each player's skill level.

It became apparent during this process that any game using a camera perpendicular to the action (as depicted in the example) should adjust the direction of action to match that of the player's exercises. This may help estab-

lish a visual connection between the player's input and the game's output.

figure 5.13 - Cooperative

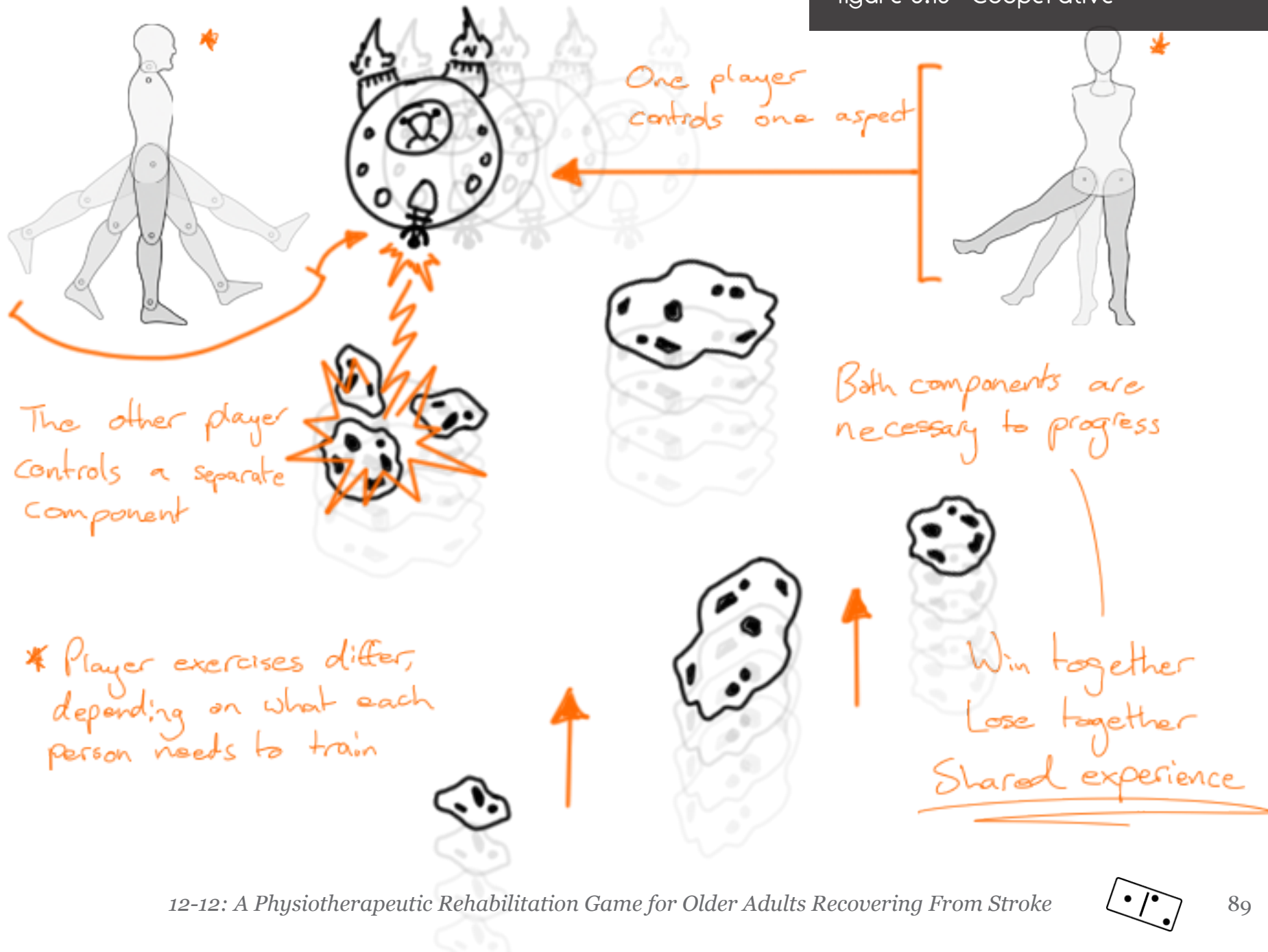
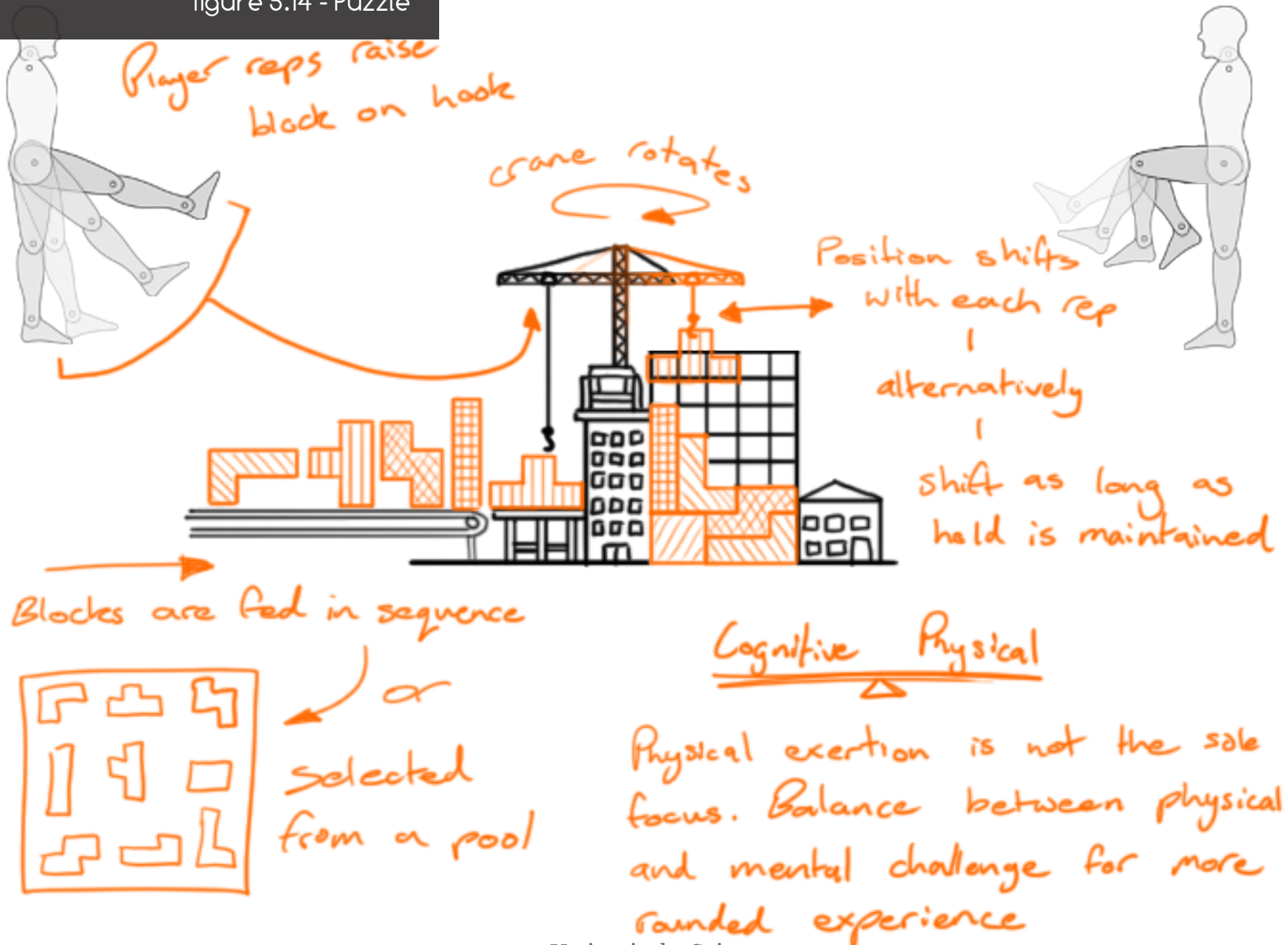


figure 5.14 - Puzzle



5.4.6 - Puzzle Games

The strength of puzzle games was the cognitive challenge they harbour. They were generally free from thematic bounds as they did not depend on particular action or narrative elements to keep players engaged. Appropriately, puzzle games tended to have broad audience appeal (Gerling et al., 2010, p. 67, Nap et al., 2009, p. 247).

The difficulty of such games was highly dependent on how the puzzles were generated. If the puzzles were pre-determined (functionally similar to a riddle with a singular answer) then the game lost any replay value unless new variants were constantly made available. In cases such as *Sudoku*, *Tetris* and *Bejewelled*, the generative nature of the puzzles grants endless replayability where the difficulty can be adapted to the player based on how much information they are given, how quickly they have to react, or how many moves they have to succeed.

Additionally, the physical input needed to play the game could increase the difficulty by requiring more accuracy from the user. Some processes could be automated in the beginning where the player is only capable of single joint - mono-directional - movement, progressing to multi-joint - multi-directional - movement once they regain mobility.

The *connectivity* of puzzle games was somewhat lacking. Generally puzzles are more satisfying if solved individually rather than having the help of another. This placed a single-player limit on these games. Social variants of classic puzzle games do exist (see *Tetris Battle*) but with significant enough differences to their core mechanics that they are quite separate to their original concept.

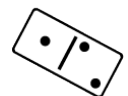


figure 5.15 - Second Iteration Matrix Evaluation

Criteria

Concepts

	<i>Single Input Games</i>	<i>Cooperative Games</i>	<i>Puzzle Games</i>	<i>Digital Colouring</i>	<i>Literal Motion Games</i>	<i>Tabletop Games</i>
Multiplayer	-	=	-	-	-	D
User profiles	+	=	+	+	+	A
Logical motion mapping	+	+	=	=	+	T
Ease of learning	+	-	=	=	-	U
Adaptable difficulty	=	-	=	=	=	M
Variable input	=	=	=	=	-	
Variation of task	-	+	=	=	+	
Replayability	-	=	-	-	-	
Single player value	+	-	+	+	=	
Totals	4+ 2= 3-	2+ 4= 3-	2+ 5= 2-	2+ 5= 2-	3+ 2= 4-	

5.5 Expansion Review

(For more detail on the criteria for this matrix evaluation see Appendix B, p. 208)

The criteria for the evaluation of this iteration were expanded to provide a more detailed exploration of the benefits of each concept. It became clear during this phase that one of the primary weaknesses of matrix evaluation is that it does not represent the comparative significance of each criterion. While some concepts netted more positive values than others, that did not necessarily mean they were the most appropriate decision. Any weighting added to specific criteria is subject to the bias of the researcher. Therefore, matrix evaluation seems more appropriate as a method of summarising the relevant properties of concepts rather than a measure for their overall quality.

Ulrich & Eppinger state that using more detailed criteria for assessment is largely meaningless due to the concepts only being general notions of what they might become (2004, p. 131). To this end, matrix evaluation had served its purpose and led on to the creation of the minimum viable product (MVP), version 1.0 of the rehabilitation game, *Tiddlywinks*. And so began the next phase of the design process.



*“[Play is] a critical activity necessary
to achieve a healthy adulthood”
- Miller, 2004, p. 163*

Chapter 6

New Game



This chapter discusses the development of the rehabilitation game from its first realisation as an MVP through to the final iterations that were used for user testing. During this process we consulted with clinicians several times, which resulted in large changes to the gameplay and features (often marked by a version increment: v1.# - v2.0). This chapter concludes with testing the *alpha* version of the game with potential users to make final assessments on the effectiveness its design.

6.1 MVP

(Minimum Viable Product)

Tiddlywinks is a digitized version of block dominoes that allows players to use rehabilitative exercises to execute specific in-game actions. Gameplay was modelled loosely after *Tiddly-Wink* (see Appendix D, p. 221) due to its rigid ruleset.



Tiddlywinks 1.0

Gameplay:

- Anywhere from two-to four players can play together in a round.
- Players have a hand of three tiles and each takes turns to play one from their hand that matches the most recent tile played to the table (beginning with the highest double).
- Players using a rehabilitative device have to perform rehabilitation exercises to play tiles.
- A round ends when a player has no tiles left or nobody can play a tile that matches the table.
- Player received points based off their remaining tiles and the game ends when a predetermined score is reached.

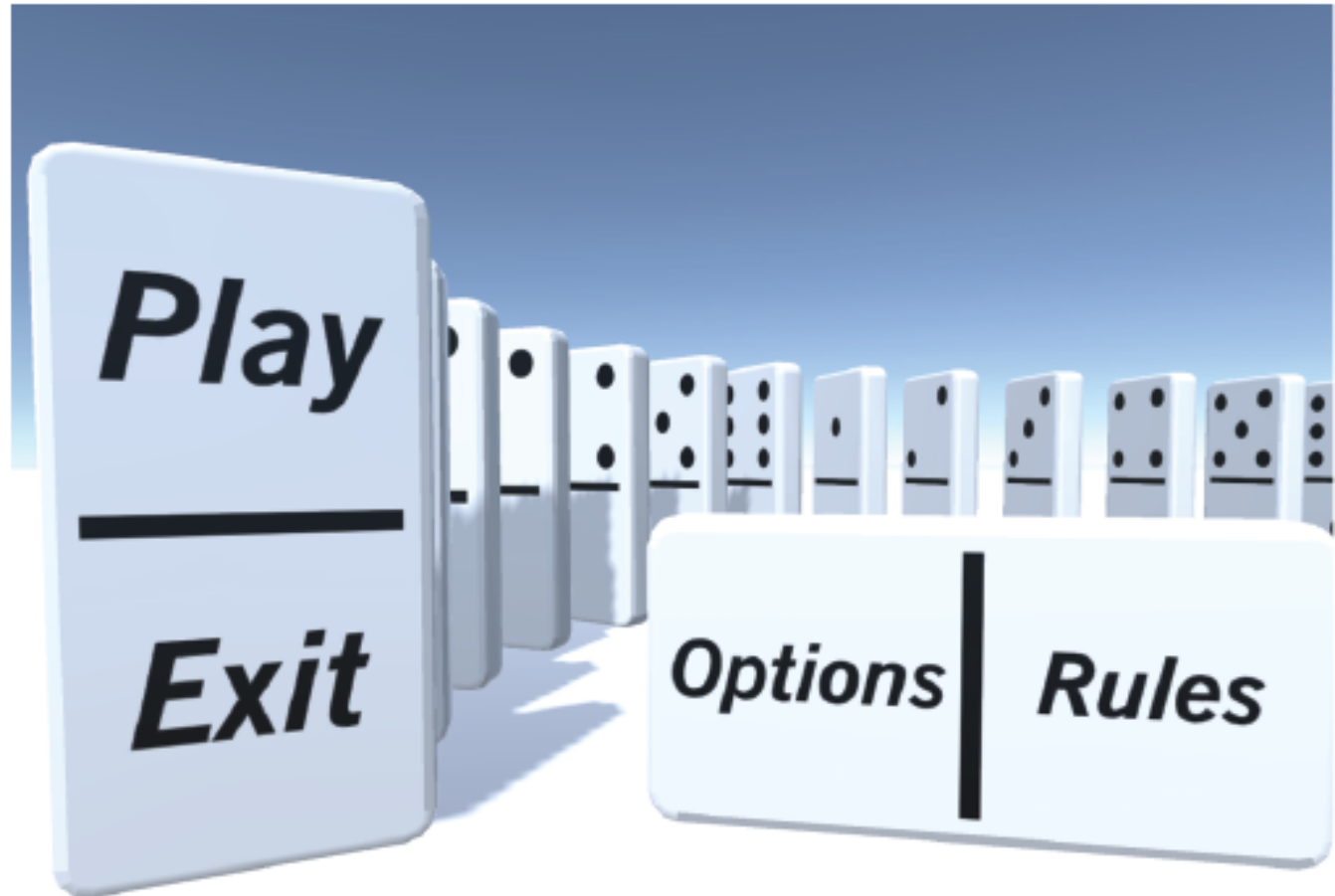
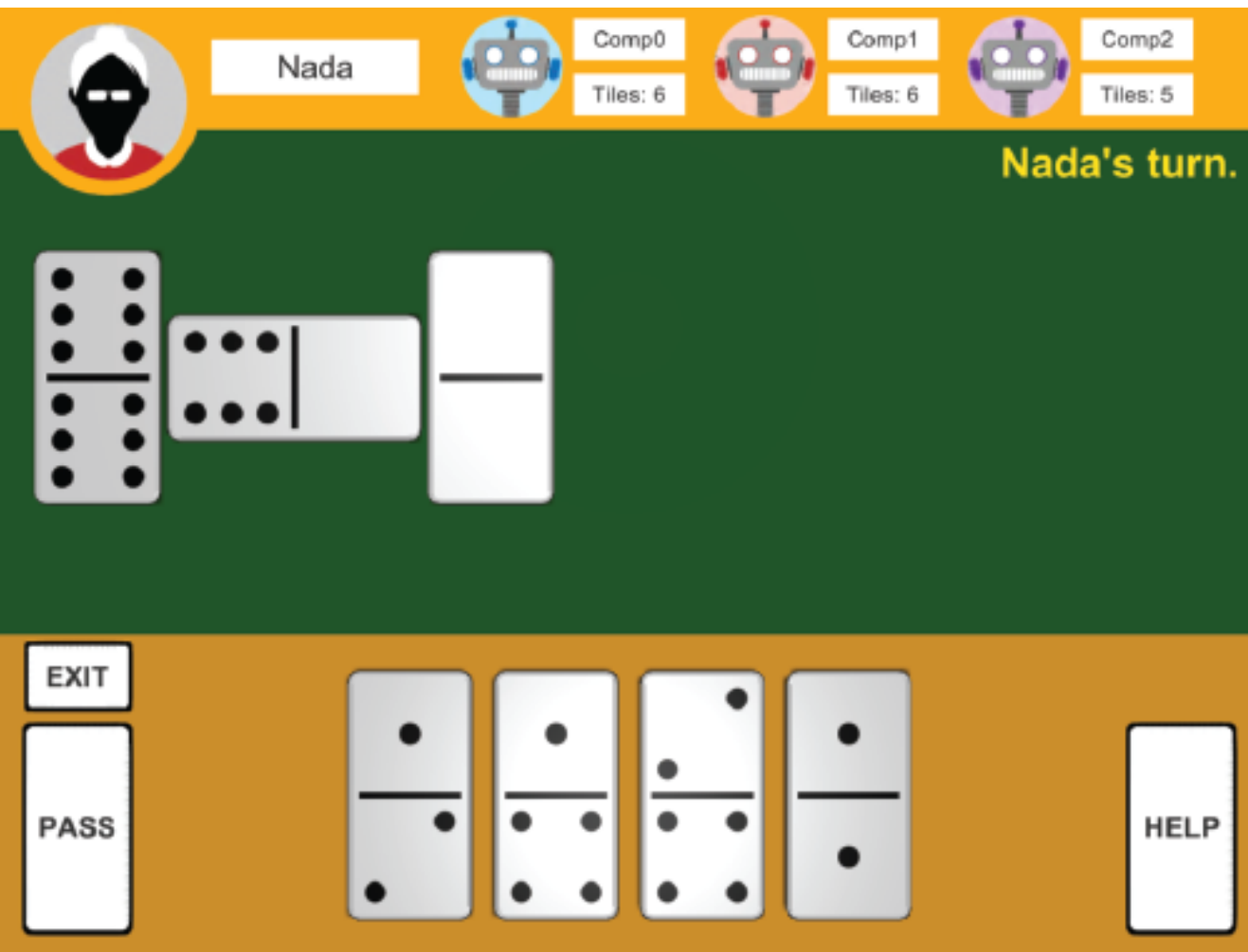


figure 6.1 - Tiddlywinks



Aesthetic:

- Minimal design to avoid superfluous visual elements.
- High contrast and use of vibrant colour to maximise the visibility of important information and account for visual deficit common to older demographic.
- Large, simple fonts to maximize readability of instructions.
- Skeuomorphic elements to promote sense of familiarity.
- Interactive object would be bold or animated to draw attention.

Systemic Requirements:

- Special game controller with bluetooth functionality.
- Digital tablet.



Computer Player Decision Tree



figure 6.2 - Decision Tree

Version 1.0 of the rehabilitation game was chosen to be a digital tabletop game for several reasons; the first of which was that it enabled high levels of *connectivity* and *adaptability* at the cost of *meaningful interactions*. No concept held all three criteria in equal portions, yet this one had the highest potential for satisfying two of the three.

The rules of *Tiddly-Wink* helped establish the MVP requirements for a playable domino game.

Another strength of this concept is its innate familiarity with the target audience. To be effective as a rehabilitation game, potential users must first be willing to give it a try. The digitization of a classic tabletop game caters to a broad audience. This is supported by the low learning threshold of dominoes.

The specific choice to use dominoes comes from the simplicity of the core interaction. Cards typically use four suits for every numeric value (and the inclusion of jokers in some games), whereas dominoes only requires the player to focus on one number at a time. Simplicity was integral for all elements of the game. Increasing the complexity of the game came down to tweaking the base rules: how many dominoes does each player start with?

How many players are there? How big is the deck? Do you draw on a pass etc.

Domino games are social by nature. A patient may not always have access to people to play with therefore computer substitutes were necessary. Complicated artificial intelligence for non-human players was out of scope for this research. A computer player's turn is broken down into a few simple steps.

6.1.1 Inclusion of Strength for Task Training (STT)

The first phase of Dr. Signal's STT (2014, p. 47) involves priming: high exertion exercises that promote neural plasticity and prepare the patient for repetitive exercises. The relationship between priming and base repetitions is a physiotherapeutic equivalent of shuffling a set of dominoes before playing a game with them. Mapping these rehabilitative processes to their in-game equivalents may help maintain immersion.

A common concept in strength training is "fifteen reps to failure" (N. Signal, *personal communication*, 16 March



2016). This involves performing fifteen repetitions of a set exercise with an attached weight, ideally one that the patient would be unable to lift a sixteenth time. This weight is indicative of roughly 50-60% of the maximum a person can lift with that muscle group. For the user to experience proper strength training, they require external components such as weights or therabands. Thus, part of the training is out of the game's control and there is an element of trust introduced that relies on user's to be truthful in their input. Additional sensors could be included to prevent this, however such an addition was beyond the scope of this research.

Signal stated that there are approximately nine parameters clinicians can use to tweak exercises to enhance certain aspects (N. Signal, *personal communication*, 16 March 2016). Of these nine, she recommended we focus on excursion (distance), speed and accuracy, as they best match our proposed system of movement to gameplay.

Although the digital game was developed to use STT as its mode of rehabilitation, it was designed in such a way to enable response from a variety of input methods. This was to maximize the game's versatility, rather than restrict its application to a singular style of physiotherapy. The

following section discusses significant changes that happened to the game and the reasoning behind them.

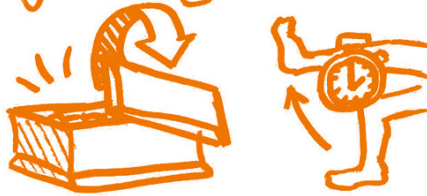
Calibration



Each priming rep jostles the bag to shuffle it pre-game

Range of motion is determined by first raise lift and hold

Calibration is prompted via text, but represented by opening box lid.

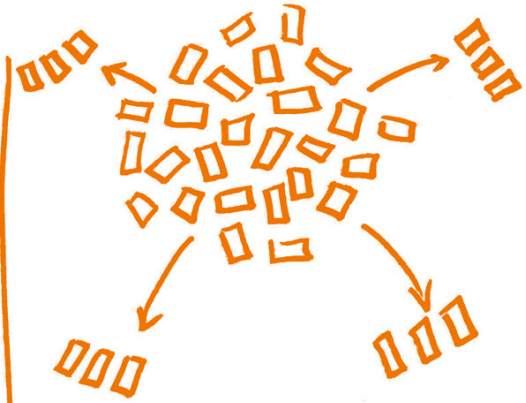


Like the bag, priming reps shuffle the tiles.



Boxes are easier to animate than bags. < Preferable

Note: These are purely aesthetic animations. They quality of the players' priming does not affect the game's random elements.



Particle based dominoes on table. Each priming rep deals one tile (or more) to each player's hand.

Remain reps are done by returning the leftover tiles to the bag

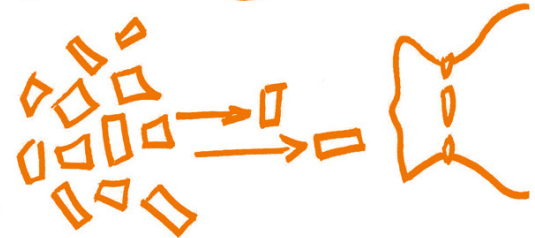
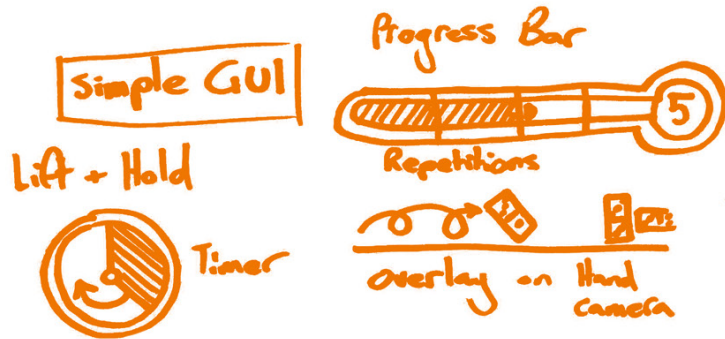
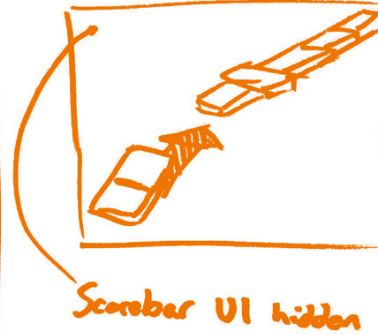


figure 6.4 - Representation of Exercise

Representation of Exercise



Perspective Change



Upon selecting a tile the camera shifts to perspective



Player input raise and drags tile to position. Distance depends on amount of reps/hold time.

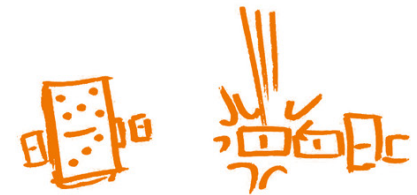
Graphical Representation



Effect Gauge



Use visual effects as cues for progress.



Tile gets closer/rises to a mark. Slams dramatically into place once target is reached

6.2 Alpha

6.2.1 Tiddlywinks to 12-12 v1.0

The gradual increase of functionality moved the game away from *Tiddlywinks* to a general platform for block dominoes. Several important additions were made to account for users who are not familiar with dominoes or simply forget how to use the interface. The first was a help button that was always visible from the in-game UI. Clicking it toggled reminder text for what the player sees on-screen.

An integral addition was a prompt system that calculated all the legal moves a player can perform on their turn and highlighted them after a predetermined time. This functioned as a failsafe for players who did not understand the generic help text or needed assistance planning their turn. The significance of the timer was to keep help text off-screen until it became necessary, aligning with Gregor et al.'s point that the oversaturation of information can make it less digestible (2002, p. 154)

Additionally, upon loading the game for the first time (or later times if the option is reset), the player was asked if they wished to receive a tutorial on how to play. Selecting

“Yes” prompted specific UI elements that told the player how to navigate the menus and start a game. Pressing “Play” loaded a tutorial level that dealt a predetermined hand to both the player and their computer opponent. During this level, the player was prompted to select tiles in a specific order which granted them the experience of beginning play, playing matching tiles, how to pass, and how to end a round. Showing the players all the typical manoeuvres of a game meant they might recognise them in future sessions. The development of this tutorial was in accordance with Ma et al.'s claim that users need to familiarise themselves with a system before it becomes too difficult (2007, p. 688).

In constructing the tutorial it became apparent that the ‘options’ menu was too dense and risked overwhelming new users with too many choices. To counter this, only the functionality required to play a basic game against computer opponents was kept. It was this version of the game that was used for preliminary user testing.



figure 6.5 - Main Menu Concepts

MAIN MENU CONCEPTS

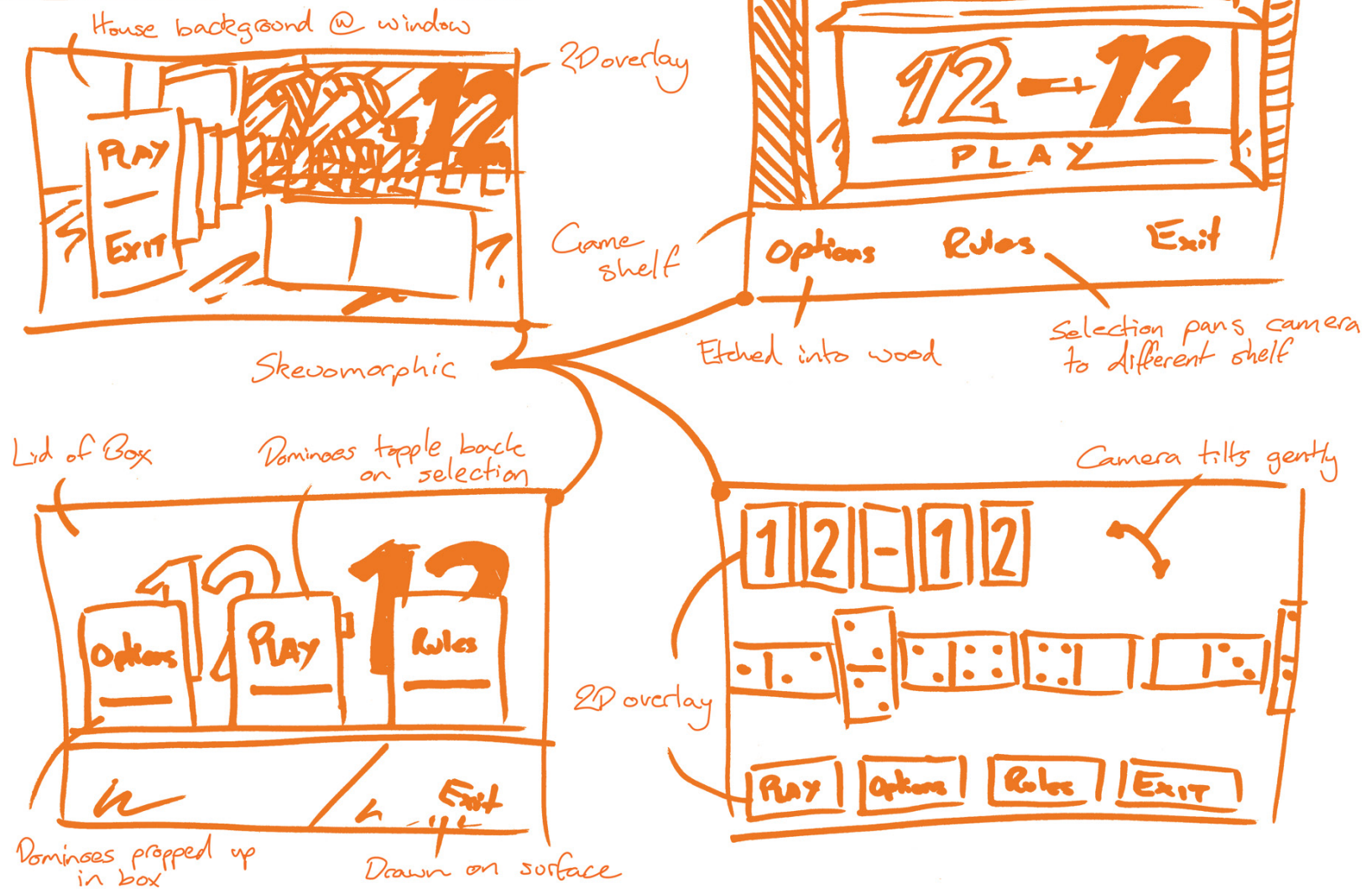
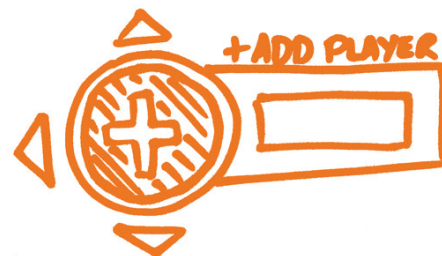
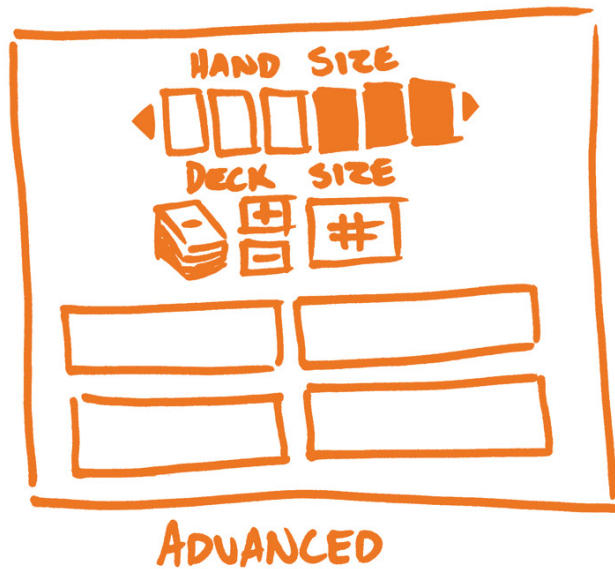
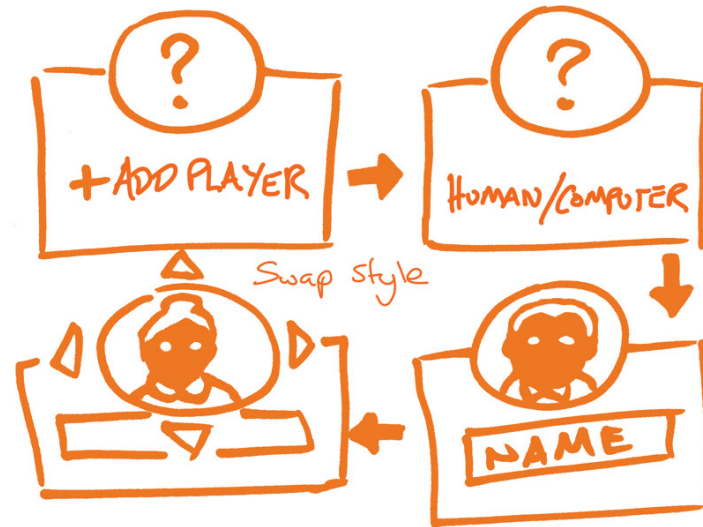
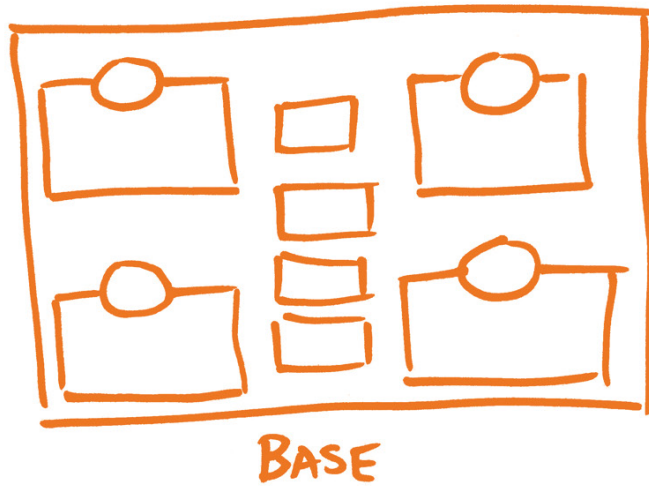


figure 6.6 - Options Concepts



In-game UI Concepts - Layout

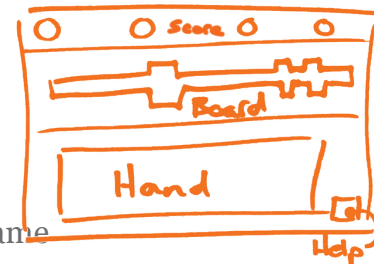
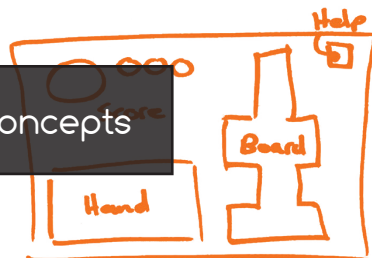
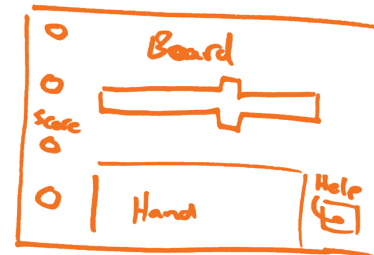
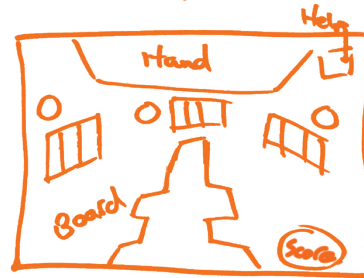
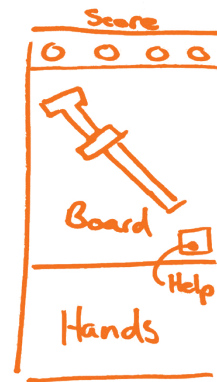
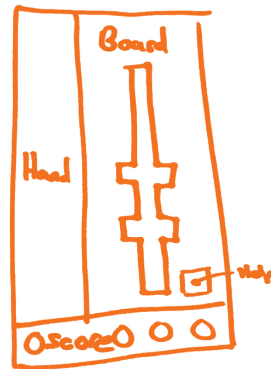
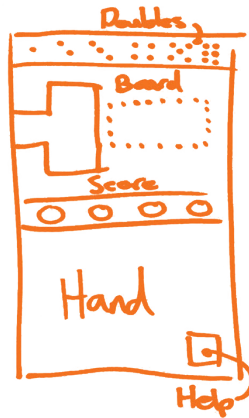
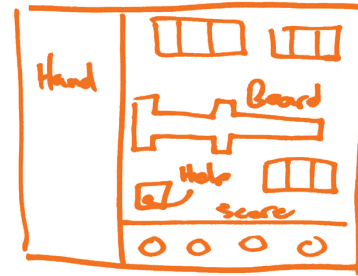
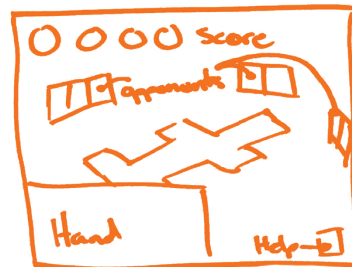
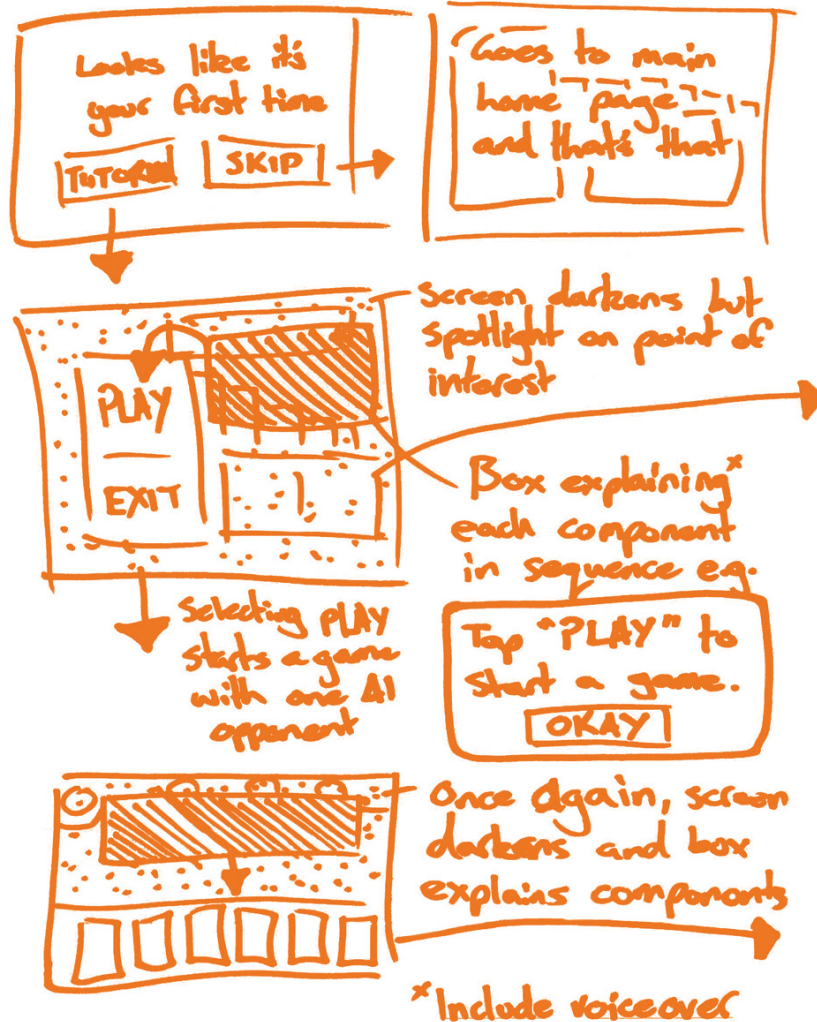


figure 6.7 - UI Layout Concepts

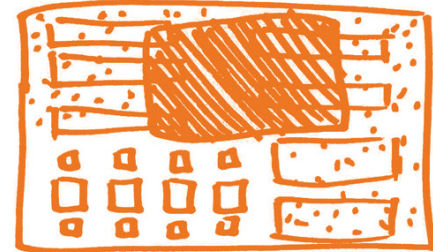
New Game

Tutorial



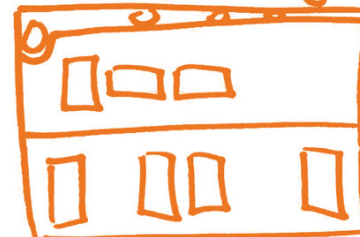
Look into Playerprefs

If the player visits "Options" or "Game Setup" for the first time after selecting tutorial, each component has a breakdown



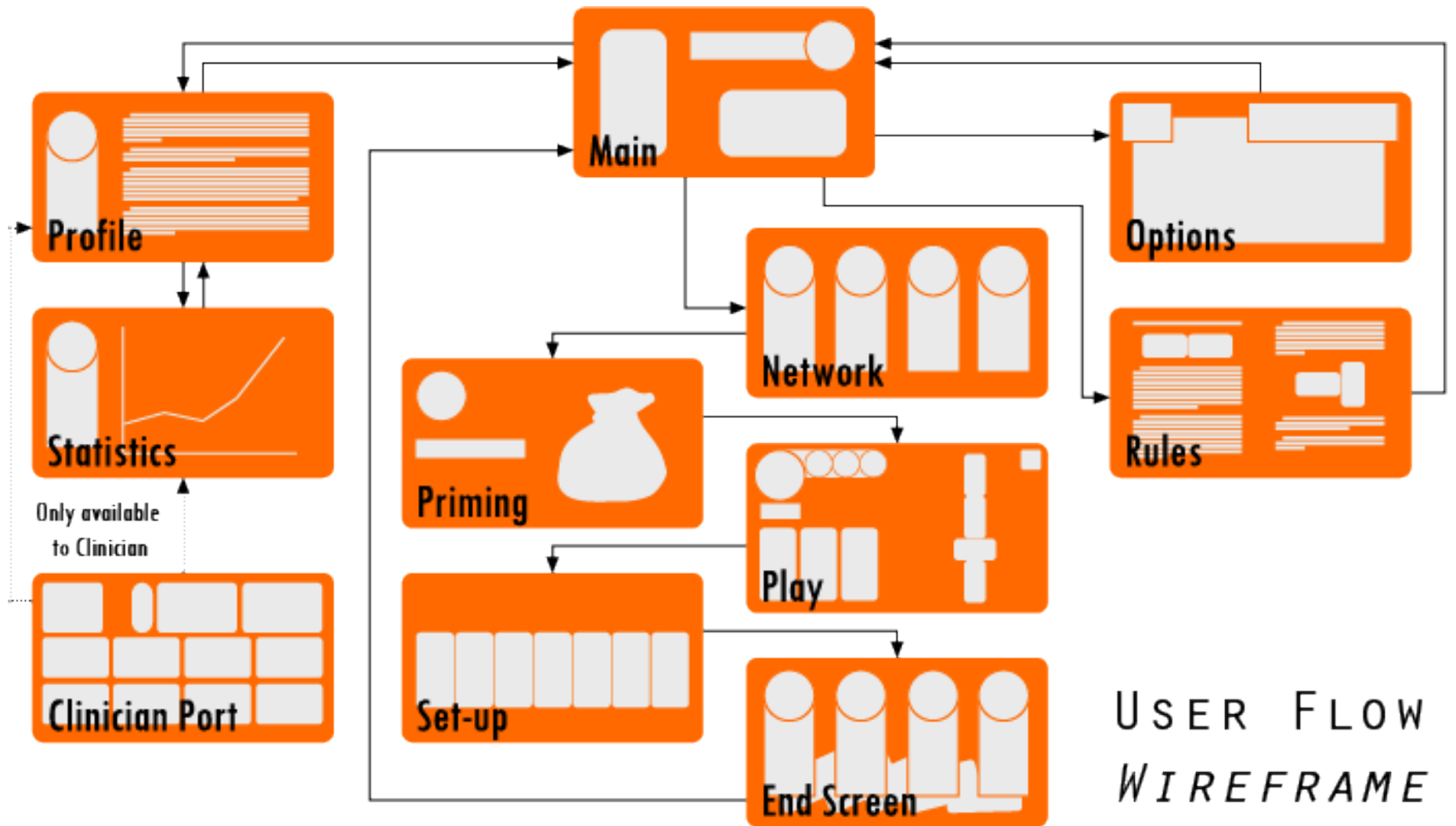
Note: The tutorial information will be accessible at any time from any screen via a help button

Game plays through normally, with short prompts explaining AI



AI decisions will be portrayed by simple unique UI

figure 6.9 - Wireframe



6.2.2 Preliminary Testing

To maximise the effectiveness of user testing with survivors of stroke, preliminary user tests were conducted with colleagues who had not experienced the game before.

Inclusion criteria was kept simple. The user testers must:

- Not have experienced a stroke before.
- Not have any significant cognitive deficit.
- Not have experienced the game before in any way.

The purpose of these tests was to ensure that the basic gameplay was functional and easy to understand, which was reflected by the inclusion criteria. Without stroke-related impairments, the testers were able to provide feedback based on the raw gameplay experience.

Six user testers were asked to load the application, play through the tutorial, and play a basic round of the game. To keep responses simple and to the point, a questionnaire using a five-point Likert scale and short written answers was provided (*for the full questionnaire and a more detailed summary of the written results, see Appendix C, p. 209*).

The strengths of the game that were made apparent were:

- The game was easy to learn.
- The interface was easy to understand.
- It was clear when players could and could not play.
- The use of language was relatable.
- Animations were smooth and enjoyable.
- Player icons were popular.

Of these strengths, the interface's ease of use and the players' ability to learn the game is highly subjective and would need to be properly tested with survivors of stroke. "Relatable" language is also subjective, however this prompted the use of less clinical terminology. More animations and icons were developed in response to their popularity.

Elements that needed work were as follows:

- The win/loss conditions were unclear.
- The scoring was unclear.
- The sense of competition was not as evident as it could be.
- Main menu scene was too sparse and the 'options' menu too cluttered.
- The tutorial information was overwhelming.



- Pacing was too slow.

The users reported that the tutorial felt overwhelming, yet some elements were still unexplained. This highlighted that the problem was not a matter of the quantity of information being presented, but *how* and *when* it was being presented. The primary purpose of the player is to play a game, therefore any instruction referring to elements of the main menu, other than the ‘play’ button, were removed. The tutorial was extended to include the score screen to explain scoring mechanics once the player had already learned how to play a round.

6.2.3 12-12 v2.0 to v3.0

A return visit from Dr. Signal prompted an overhaul of the game in both code and aesthetic. One of the core ideas behind the developments of this version was to embed the criteria for success into as many elements as possible in subtle but meaningful ways.

Adaptability: The ‘options’ menu needed robust error handling. The game needed to be playable regardless of the settings the player adjusted e.g. trying to start a game with zero opponents and defaulting to one computer op-

ponent. The amount of user icons was expanded to allow more personalisation.

Connectivity: Time constraints meant we were unable to explore the effect of including online networking or player profiles, leaving these aspects of *connectivity* unexplored. To counter this, local multiplayer was ensured to be fully functional. Adding in features like concealing player hands until the ‘ready’ button is pressed and clear variation in the profile pictures allowed the game to be played by up to four separate people, all using the same device.

Meaningful Interactions: Embedding meaning into the interactions of the menu was more difficult than the other criteria. Our inability to test on users at this point in the research meant we could not test the proposed methods of interaction.

Menu navigation via device input was removed as it preceded gameplay (therefore calibration) and would pose a significant barrier to those who are not used to the connection between the device and the game, namely first time users. Instead, focus was placed on making the behaviour of the menu as logical as possible; e.g. rather than the hand size being depicted by a number, the player can

see three to six tiles in a row that reflect how many remain in their hand.

6.2.4 Integrating the Device

The use of a special sensor had to be accounted for in the gameplay. If the sensor was not available, a ‘simulate’ button became active. Whilst not an ideal substitute, this does act as a failsafe, albeit one that relies on the player’s honesty.

Initially we tried to use Inertial Measurement Units (IMUs) to directly replicate the motion in-game but interpreting the devices’ data proved more difficult than anticipated and the results were unfavourable. The calibration scene was implemented in an attempt to counter this, which integrated naturally into the priming phase of the exercises.

An alternative solution was to use gesture recognition and teach the device which exercises to be looking for. This would allow each clinician to build a library of movements that set the standard for what their patients should be aiming to meet. Such a method removes the need for

repeated calibration, allowing players to get to the primary gameplay faster. Tying the device’s calibration to the tutorial is an organic way of getting the user to set everything up before they dive into the core experience.



1.1 Main Menu

2.3 Main Menu

4.3 Main Menu



Target sign became obscured by more important information and was removed.



REPETITIONS TO GO

2

TARGET

figure 6.10

3.1 Task Repetitions

Domino became animated, disappearing in a puff of smoke upon reaching its target.



SIMULATE

4.3 Task Repetitions

SIMULATE

Exit

Player Names

Player1 Name

Player2 Name

Player3 Name

Player4 Name

Computer Players

1

+

-

Reset
Tutorial

Exit

HAND SIZE (minimum 3, maximum 6)

Hand size input area with 6 slots and a plus sign.

HIGHEST DOMINO VALUE (increases deck size)



+

6

-

Draw on PASS

Basic Options

DEVICE USER

Exit

Player Name

Player Name

Ending Score

(Game over when reached)

30

Add
Player

Player Name

Player Name

Add
Player

Repetitions

(Reps required to play a tile)

5

Advanced Options

Reset Tutorial

1.1 Basic Options

2.3 Advanced Options

4.3 Basic Options

4.3 Advanced Options

Exit

HAND SIZE (minimum 3, maximum 6)

Hand size input area with 6 slots, 3 of which are highlighted in orange, and a plus sign.

HIGHEST DOMINO
(increases deck size)



+

-

Prompt Toggle

(Activate/disable prompting)



Prompt Time

(How long until help
text appears)

10

Basic Options

Blank Value

(Points per blank face)

10

figure 6.11

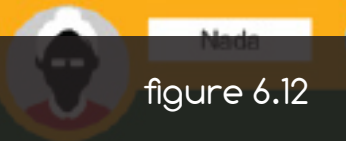


figure 6.12

Comp0	Comp1	Comp2
Score: 0	Score: 0	Score: 0
Tiles: 6	Tiles: 6	Tiles: 5

Nada's turn.



1.1 Table

EXIT

PASS

HELP

Nada	Comp1	Brian	Comp3
Score: 0	Score: 0	Score: 0	Score: 0

EVIC E Nada's turn.



4.3 Table

PASS

EXIT

HELP

Nada	Comp0	Comp1	Comp2
Score: 0	Score: 0	Score: 0	Score: 0
Tiles: 6	Tiles: 6	Tiles: 5	Tiles: 4

Nada's turn.



2.0 Table

EXIT

PASS

HELP

Nada	Comp0	Comp1	Comp2
Score: 0	Score: 0	Score: 0	Score: 0

E Nada's turn.



3.1 Table

PASS

EXIT

HELP

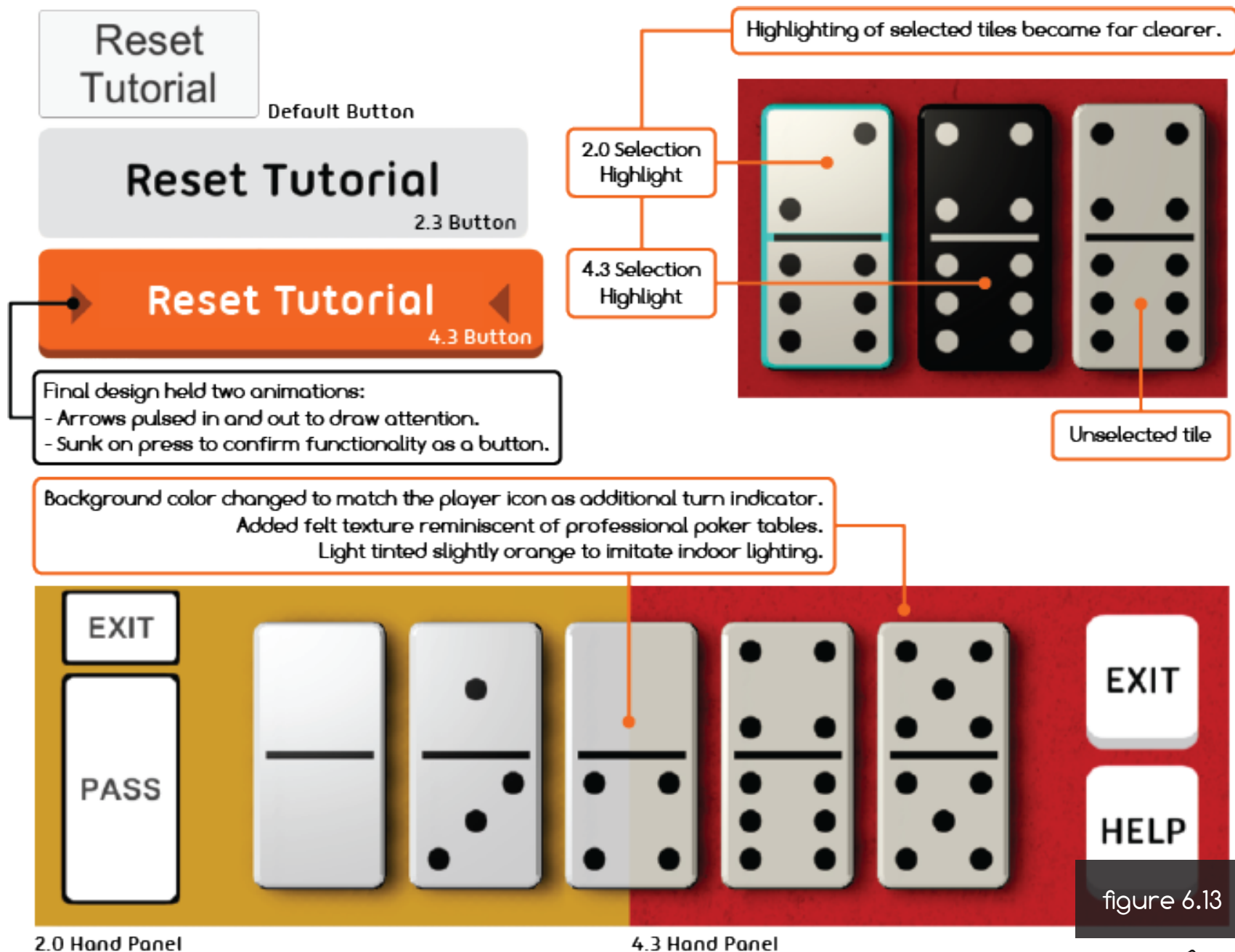
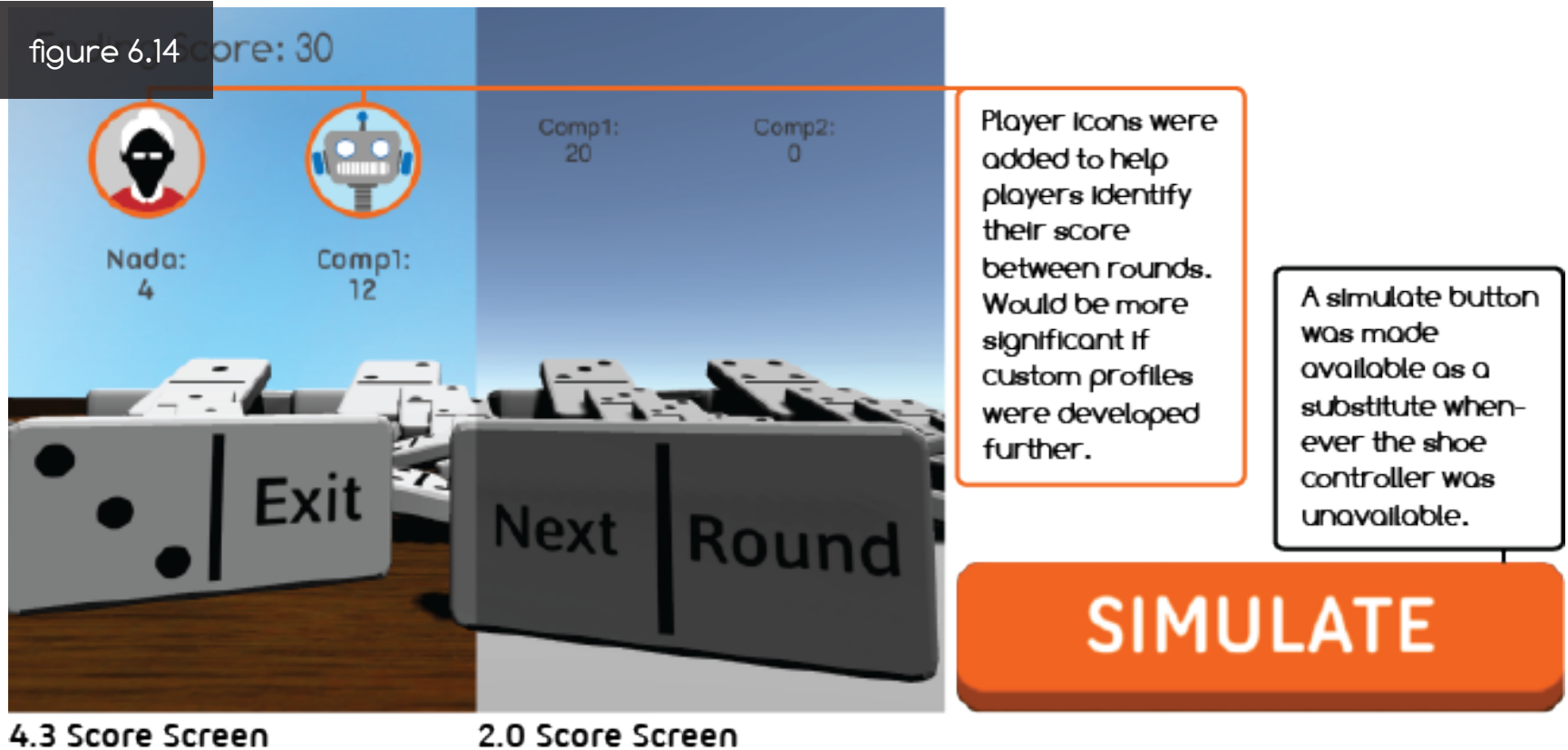


figure 6.13



figure 6.14



4.3 Score Screen

2.0 Score Screen

Are you sure you want to leave this game? If you want to play again you will have to start over from the beginning.



This sub-menu became active whenever the 'Exit' button was touched as a catch for accidental pressings.

6.3 User Testing

This section discusses the testing of the complete system (William Duncan's hardware and the digital game), the discoveries made and their subsequent iterations.

Prof. Taylor explained that within a therapeutic context it is expected to take roughly three months of training to make any noticeable difference to the patient's condition. This meant we could not prove that our solution would be able to make any effective change to a user's mobility or physical health. Instead, we focused on the usability of the system.

Recruitment began with contacting local stroke clubs and presenting our research. From these presentations we acquired the contact details of potential participants. These participants were contacted via telephone and those who met our inclusion criteria were given an over-the-phone interview. According to Dr. Signal, neural plasticity can happen months after an incident, meaning we were not restricted to survivors of recent strokes.

Inclusion Criteria:

- Aged > 18.

- Had experienced a disabling stroke.
- Has or has experienced hemiplegia or hemiparesis following stroke.
- Can walk 10m without standby assistance.

Exclusion Criteria:

- Significant cognitive deficit.
- Unable to follow a 1 step verbal command.
- Unable to give informed consent.
- Medically unsuitable in the opinion of the screening physiotherapist, G.P or medical specialist.
- Experiencing excessive joint pain.
- Suffering other conditions that could impact results (eg. substance abuse, significant mental illness such as major depression).
-

(For our phone interview questions, see Appendix document C2, p. 212)

The purpose of the inclusion and exclusion criteria, aside from establishing the participants' experiences with stroke, was to ensure they would be capable of safely



interacting with our system without the need for clinical supervision. Our system was designed for home-based rehabilitation, therefore is unable to depend on clinical aid to function. These criteria also ensured our participants would have enough communicative ability to articulate their thoughts regarding the system clearly.

Our recruitment process resulted in several participants donating their time to our study. Participants were given aliases to protect their identities.

6.3.1 The Players

‘Alex’ survived a cerebellar stroke that affected the right side of her body. She was originally wheelchair-bound but recovered her ability to walk through rehabilitation. Her balance remains affected and she occasionally requires a walking stick. Alex lives independently and is an active member in the local stroke club.

‘Bernie’s stroke afflicted him with left hemiplegia and affected cognitive capabilities. Bernie’s communicative abilities were limited and he had a caregiver who occasionally spoke on his behalf. Despite retaining his ability

to walk (with the aid of a quad cane), Bernie’s hemiplegia severely limits his gait and he experiences falls regularly. This necessitated his test to be conducted from a seated position.

(Bernie was not part of the original recruitment process. For more information regarding Bernie as a user tester, see Appendix C, p. 214)

‘Charlie’ was the most physically able of our participants. Despite experiencing two strokes in the past decade, Charlie only has minor right hemiparesis and is fully capable of living independently. She has the fastest gait of our participants with only minor balance and coordination issues. However, Charlie’s short-term memory was affected and she can be very forgetful at times. Charlie often finds technology hard to use because she forgets how it works.

‘Dannie’ had multiple sclerosis prior to his stroke, which worsened its effects. At the beginning of his recovery process he was completely bed-ridden. Dannie suffered left hemiplegia which locked up the left side of his body but over time he was able to recover some of the lost functionality. He lives with his partner who cares for him. Dannie is capable of moving about independently, albeit with a

walking aid. He has no fine motor control over his left foot and arm.

6.3.2 Testing Protocol

With permission from our participants, we visited them in their homes to conduct the tests in a safe environment. Tests began with the observation of usability heuristics. Media-specific elements included the readability and articulation of text-based information, the players' comprehension of the visuals and the players' comprehension of the game's rules. The use of think aloud protocol helped us assess these heuristics. During this process we took handwritten notes and non-identifying video of our participants for revision purposes.

The lack of functioning sensors in the device was addressed through the implementation of Kelley's 'OZ paradigm' (1984). This method gives experimental participants the impression that they are interacting with the system as it is desired to function, thus giving genuine reactions. In actuality, the researcher is surreptitiously intercepting communication between the participant and system, providing appropriate responses (ibid., p. 27). For our tests

we used an application on a cell phone to wirelessly transmit to the tablet each time the player performed a correct exercise.

The exercise requirements of our participants were fifteen leg raises (hip abduction) for the priming phase. The tutorial phase involved playing six dominoes, each requiring the player to perform five side-steps. Participants were then required to play a standard game, running through a further fifteen leg raises and twenty to thirty leg raises over the course of the following round. As this round was against a randomised computer opponent, the amount of playable dominoes fluctuated from four to six between participants. Each player completed these steps at different rates, taking between twenty-five and thirty-five minutes.

We conducted a semi-structured interview with our participants after the observation session. The purpose of these interviews was to give them the opportunity to comment on anything they had missed with think aloud protocol. Questions were kept simple to avoid leading our users' responses. The interview was recorded using a simple microphone to avoid participants becoming camera shy. Our participants were free to speak in as much detail



Participants placed the tablet on a table or bench. In the second test, books were used to elevate the tablet to an optimal height.

A chair was available nearby to make putting on the shoe controller easier and for breaks between game rounds.

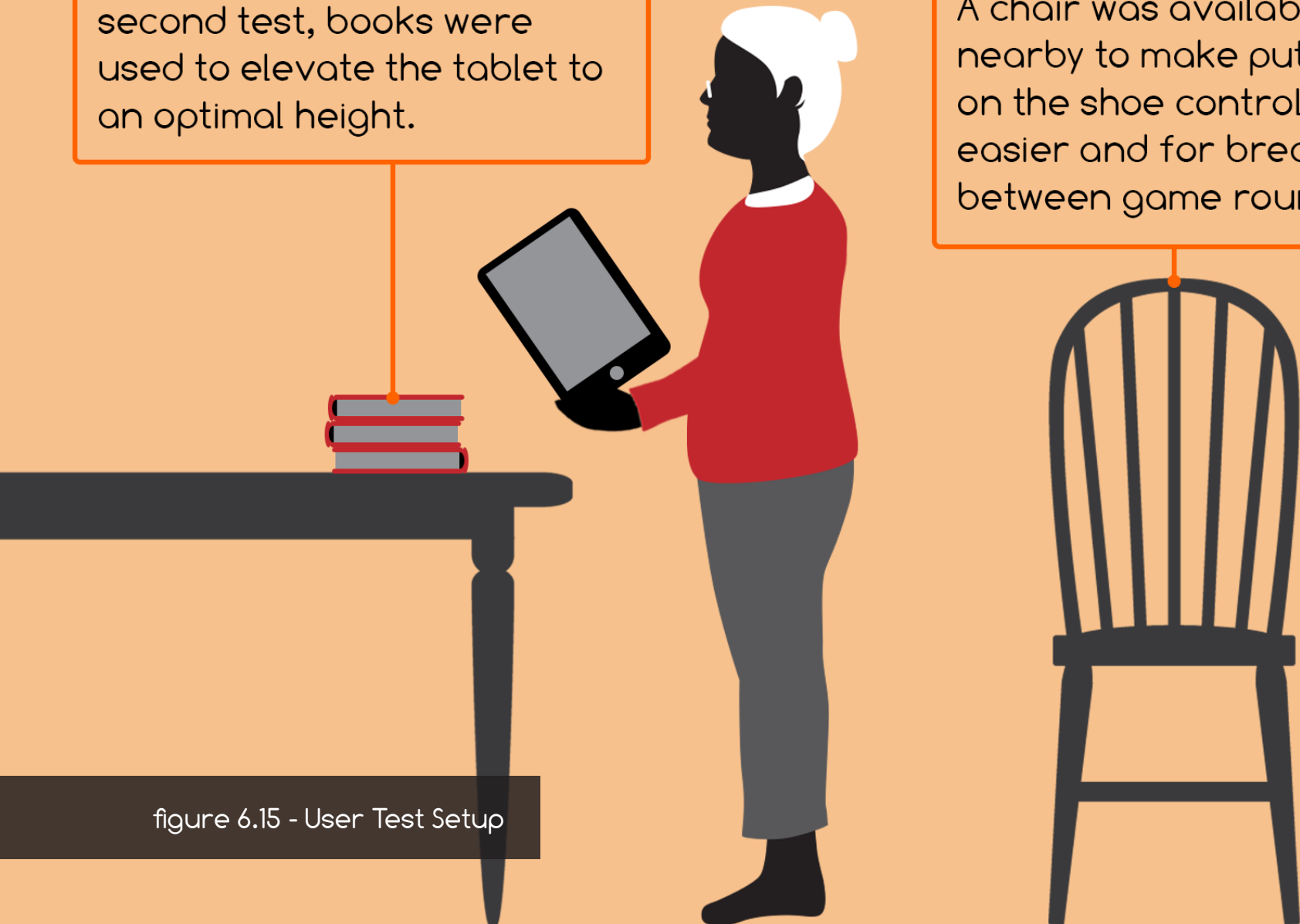


figure 6.15 - User Test Setup

as they chose. The interview was designed to take fifteen minutes to complete, but some participants spoke for as long as thirty-five minutes.

(For interview questions, see Appendix document C3, p. 213)

6.3.3 Test 1

Testing was conducted according to the protocol above. Each test involved the participant putting on William Duncan's smart shoe, completing the tutorial of 12-12 and then playing through a standard game.

6.3.4 Feedback 1

It became apparent very quickly that no participant was confident enough to play while holding the tablet. This meant the tablet had to be placed on a table and any exercise that required stepping needed to be repeated back and forth. Despite being a minor issue, this demanded very clear setup instructions for the beginning phase of the game.

Alex stressed the importance of the affordability of the system. She explained with an example from her stroke club where members were offered discounted gym memberships but had to discontinue their membership once the promotion expired because they could not afford the standard rate.

Both Alex and Charlie expressed excitement about interacting with the system. They liked the “you can do it” mentality of the game and how it encouraged them to move out of their comfort zone. A large contributor of their enthusiasm came from the attention the system granted them. “We need to be pushed to get the brain to do these things,” stated Charlie, “this makes you feel like a normal person.”

The main difficulty that was experienced by all users was what to do in each phase of play. Every participant needed to be reminded which exercise to perform and when. For the majority of play, each user displayed uncertainty on what to do next until the prompt text informed them. Despite this prompting, it was common for the participants to request clarification on how to perform the exercises correctly.



Elements of the UI were unclear as well. Most participants did not recognise the buttons to be interactive right away and had to be prompted to press them. This problem occurred several times during play, indicating the style of the buttons was too subtle. Similarly, several participants did not realise the dominoes were interactive via tapping and needed to be shown.

Both Alex and Dannie suggested a less intense version of the game for less able players. Shorter game sessions with less dialogue would make the game more accessible for people with less motor and cognitive functionality. This wouldn't need to resemble a complete block dominoes game proposed Alex, "even if [players] don't remember everything, it's the novelty of pressing a button and seeing something happen." The game's complexity could gradually be built up, mapped to each player's physical and cognitive development.

6.3.5 Test 2

Our second tests were conducted in an identical manner to the first ones with a few exceptions. Bernie was excluded from this round because the changes made to

the game's build were not significant enough to account for their cognitive deficit. Participants were encouraged to raise the tablet to a more appropriate height by using books as a makeshift stand. Lastly, the interview questions were reduced to avoid redundant information. These reduced interviews took between ten to twenty minutes to complete, depending on the participant.

(For the second test interview questions, see Appendix document C4, p. 216)

6.3.6 Feedback 2

Elevating the tablet to an appropriate height using books removed the need for participants to lean over the tablet. We received no reports of pain or discomfort after the session was completed.

All participants requested a simple breakdown of how to perform each exercise properly as part of the introductory gameplay. This would remind users who do not have access to clinicians how to correctly perform their exercises. It also coincided well with Alex and Dannie's suggestion

that a reduced version of the game be available for people whose stroke is more recent.

The more each participant played, the greater understanding they exhibited of how the game worked. During the post-tutorial game, the participants would wait until the prompt came up before they would make a move. Before the end of the game, each participant had figured out the gameplay well enough to make decisions before the prompt was activated. When asked about the difficulties of learning the game, Alex responded that it was not disheartening to make the wrong decisions initially and “once you get the hang of it, it could grip you.”

Both Alex and Charlie emphasised the significance of keeping the pacing of the game slow. It wasn’t enough just to let the player move at their own pace, it had to be acknowledged by the game that they were able to do so. This was particularly important for reading instructions; “you’ve got to take your time to read it. You can’t rush it.”

All participants became confused as to which exercise to perform at least once. It is possible an introductory panel that explains the change in exercises at the end of the priming phase would remedy this. Alternatively, the

addition of animated visual prompts when a player selects a tile could suffice.

Time constraints on testing meant we were unable to test the multiplayer capabilities of the game, however, each participant expressed interest in being able to play the game with others. Dannie made the point that for competitive play to be enjoyable, their opponents would have to be of a similar skillset to them. Being a beginner, they would need to play with other beginners or they might become frustrated. Charlie also enjoyed that she did not need people around to play, claiming “I can do it for me,” as it allowed her to test their personal capabilities.

(For raw notes on these sessions, see Appendix C, p. 214.)

6.4 Results Analysis

The findings of these testing sessions suggest that *12-12* provides a stimulating, yet demanding experience for older adults recovering from stroke. The enthusiasm our participants displayed supports the claims of Gerling et al. (2010, p. 69) (2011), Ijsselsteijn et al. (2007, p. 18) and Jung et al. (2009) that older adults can be positively receptive of new technology. Even Dannie, who was initially sceptical, became more engaged as his understanding of the system grew. He reported the game to be both cognitively and physically stimulating, commenting how he was “starting to break out a sweat” by the end of his second game.

Conducting user testing in the homes of our participants proved how minimal the requirements were to set up the system. Each participant was able to find a comfortable surface to play from and used simple objects like books to raise the tablet to the appropriate height. The portability of the tablet enabled this type of setup, reinforcing the accessibility of the system within a home environment. The only object specifically designed for rehabilitation was the shoe-based controller.

A large portion of user feedback was directed at the system’s usability. To reach the deeper qualities of a system, such as *adaptability* or *connectivity*, one must understand it at a surface level. It did not matter if *12-12* promoted local multiplayer with friends and family if players did not understand how to start a game. Ijsselsteijn et al. (2007, p.18) and Nap et al. (2009, p. 248) made it clear that the system would need to be simple in order to be usable, but even these basic tests showed our implementation of a ‘simple’ game system was in need of further development.

Participant responses also made it clear that system feedback needed to be more than just encouragement. The game had to let users know that if they required a break, they would not be disappointing anyone or “failing” at the game. Two of our participants claimed such reassurance would boost their confidence. This is reflective of the work of Lee et al. (2012, p.445) and Mathwick and Rigdon (2004, p. 325), who proposed that greater perceived control over a system (in this case, pacing) tends to make users react more positively to it.

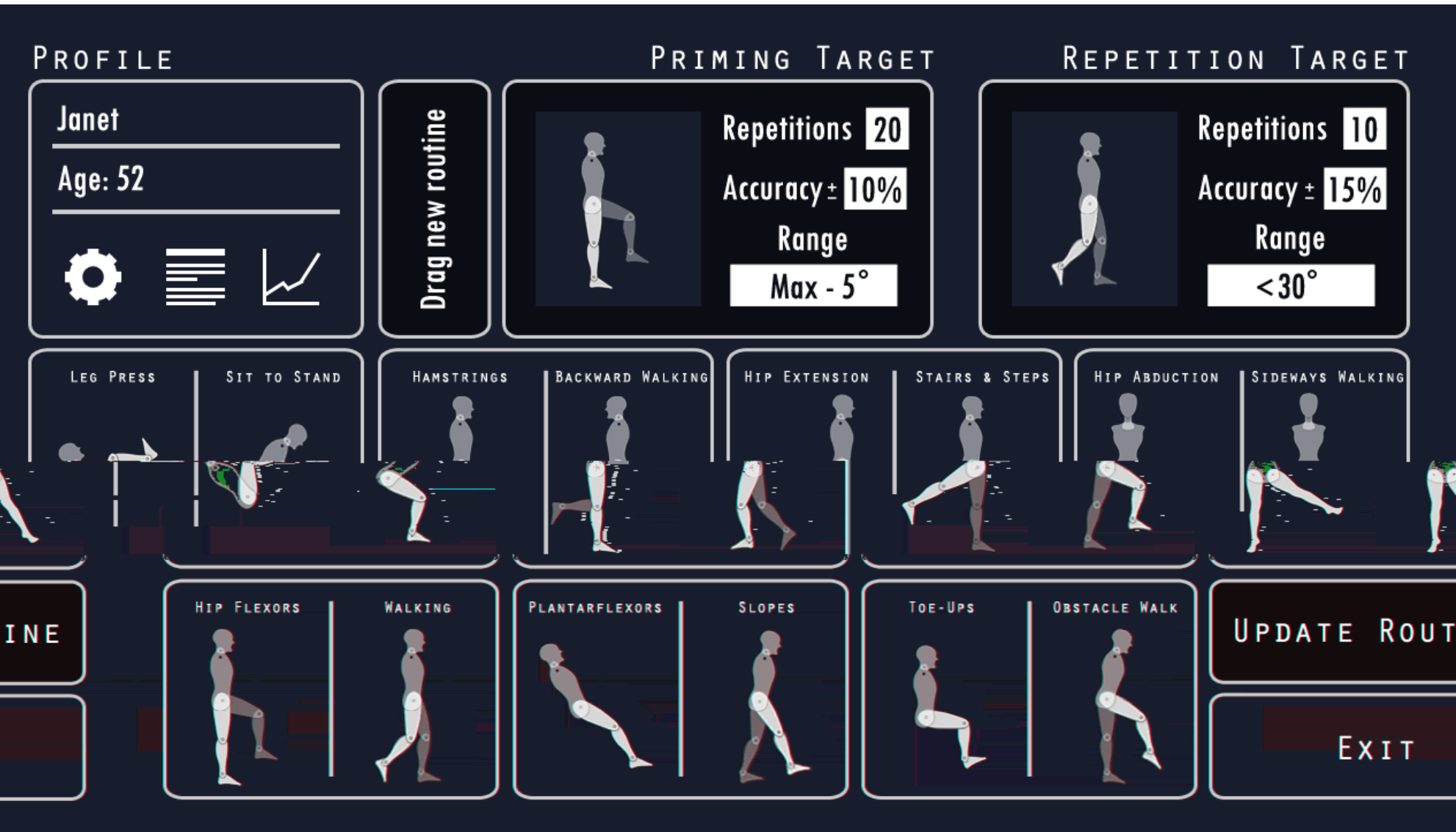
Each participant’s proposition of an adapted system for less able survivors of stroke verified *adaptability* as a criterion for success. Feedback suggested that system

adaptability would be the strongest contributor towards accessibility. Although each participant acknowledged the *connective* potential for constructive competitive play, it was comparatively less important. Similarly, *meaningful interactions* were initially less important based on participants' comments that it didn't matter how they were achieving it; there was a simple novelty in seeing the game's response to their movement.

In every test our intervention became necessary during the early phases of play, generally to explain a specific aspect of interaction. It is possible to make the UI more explicit by using multiple avenues of information (such as text, animated imagery and sound effects), yet our participants seemed more comfortable with asking us questions directly. The more they played with the game, the less help they needed. This behaviour is indicative of how the system is to be used in conjunction with clinical rehabilitation. Clinician input is still necessary for the initial setup of the system (prescription of exercises, sole weight, repetitions etc.) and its maintenance (adjustment of exercises, weight and repetitions). As the user learns the system, the clinician is needed less and less. This knowledge means a clinician-specific interface is necessary for the system's integration into a clinical environment.

Lastly, the aesthetic of the game yielded no complaints from participants. They reported it to be vibrant and the text was easy to read. This aligned with the works of Gerling et al. (2011), Gregor et al. (2002, p. 151), Ijsselsteijn et al. (2007, p. 18), Kopacz (2004, p. 212) and Martin et al. (2014, p. 104), which informed most of the design decisions regarding the game's interface.

figure 6.16 - Clinician Interface (Speculative)





Chapter 7

*“The more that we can do for
ourselves the better.”*

*- ‘Charlie,’ personal communication,
30th May 2016*

End Screen



This chapter discusses the final version of *12-12* that was used for the secondary user tests. We revisit the criteria for success established in Chapter 4 to evaluate this final version of the game. We acknowledge what the game accomplished and speculate on which aspects need further development.

7.1 Beta

The following images depict the final version of *12-12* we developed for this research.

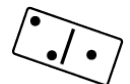


figure 7.1 - Main Menu

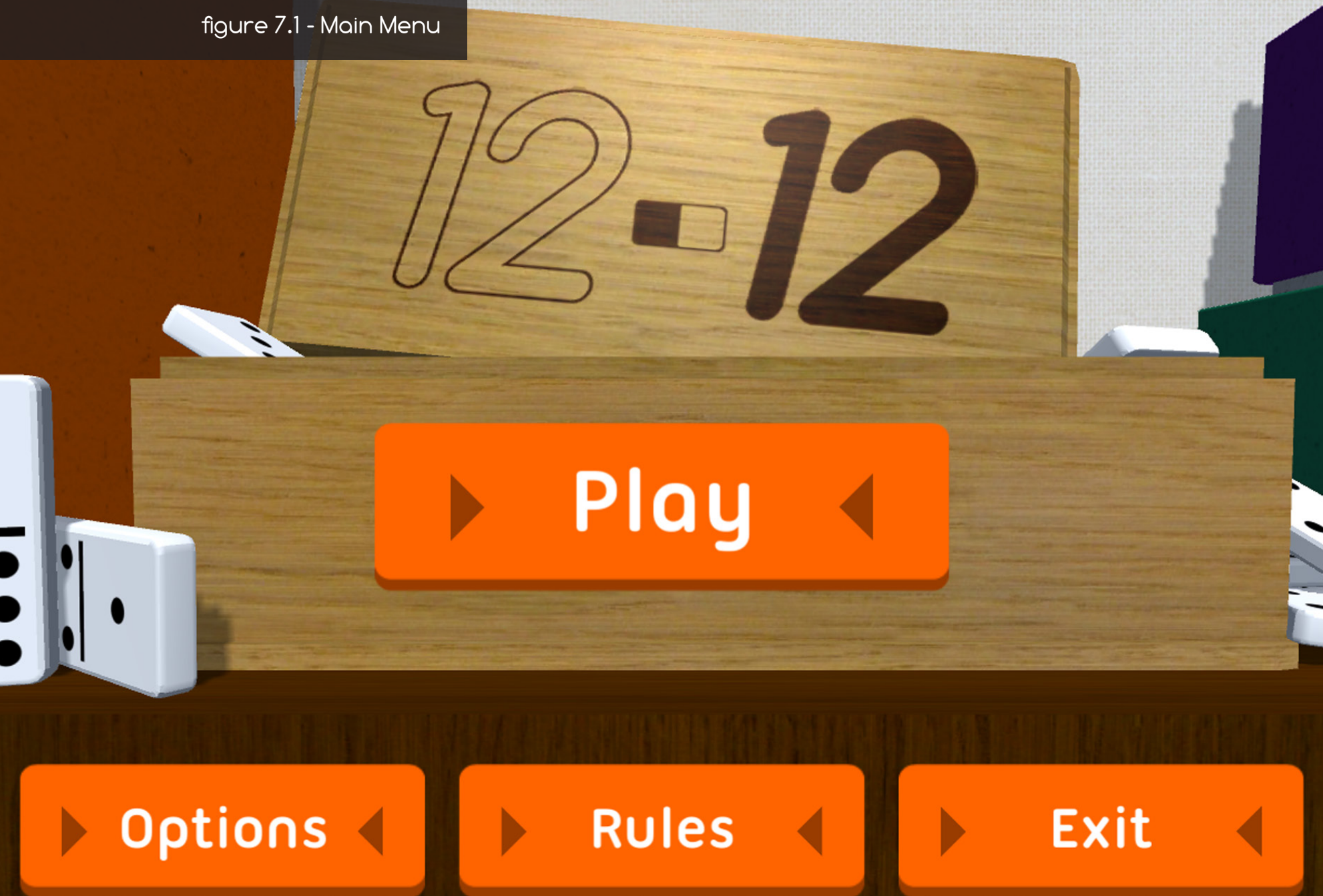


figure 7.2 - Basic Options

The screenshot shows a game settings menu with a light beige background. At the top center is an orange button with the text 'Exit' and left and right arrow icons. In the top right corner, there is a dark grey header bar with the text 'figure 7.2 - Basic Options' and a close button (an 'X' icon). On the left side, there is a circular icon of a person with glasses and a red shirt, with a grey arrow pointing up above it and a grey arrow pointing down below it. To the right of this icon is the text 'DEVICE USER'. Below this is a row of two white input fields, each containing the text 'Player Name'. To the right of these fields is a circular icon of a robot head. Below the 'Player Name' fields is a dark grey box containing the text 'Ending Score' in large white font, with '(Game over when reached)' in smaller white font below it. To the right of this box is a white input field containing the number '30'. Below the 'Ending Score' box is another row of two white input fields, each containing the text 'Player Name'. To the left of these fields is a dark grey circular button with a white crosshair and the text 'Add Player'. To the right of these fields is another dark grey circular button with a white crosshair and the text 'Add Player'. Below the 'Player Name' fields is a dark grey box containing the text 'Repetitions' in large white font, with '(Reps required to play a tile)' in smaller white font below it. To the right of this box is a white input field containing the number '5'. At the bottom of the screen are two large orange buttons. The left button contains the text 'Advanced Options' and left and right arrow icons. The right button contains the text 'Reset Tutorial' and left and right arrow icons, with a small domino icon in the bottom right corner.

Exit

figure 7.2 - Basic Options

DEVICE USER

Player Name

Player Name

Ending Score

(Game over when reached)

30

Player Name

Player Name

Add Player

Add Player

Repetitions

(Reps required to play a tile)

5

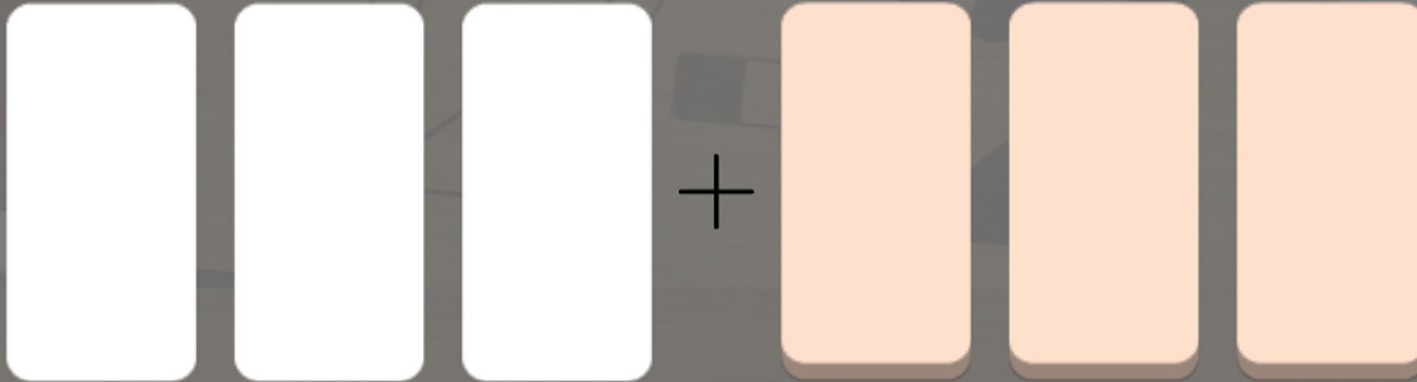
Advanced Options

Reset Tutorial

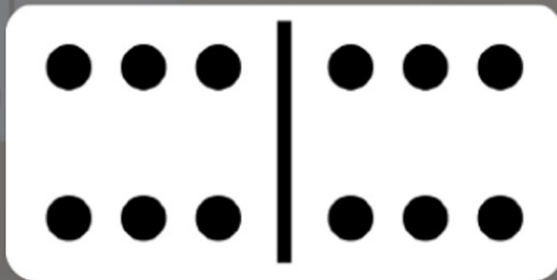
figure 7.3 - Advanced Options

▶ **Exit** ◀

HAND SIZE (minimum 3, maximum 6)



HIGHEST DOMINO
(increases deck size)



+

—

Prompt Toggle

(Activate/disable prompting)



Prompt Time

(How long until help
text appears)

10

Blank Value

(Points per blank face)

10

▶ **Basic Options** ◀

2

REPETITIONS TO GO



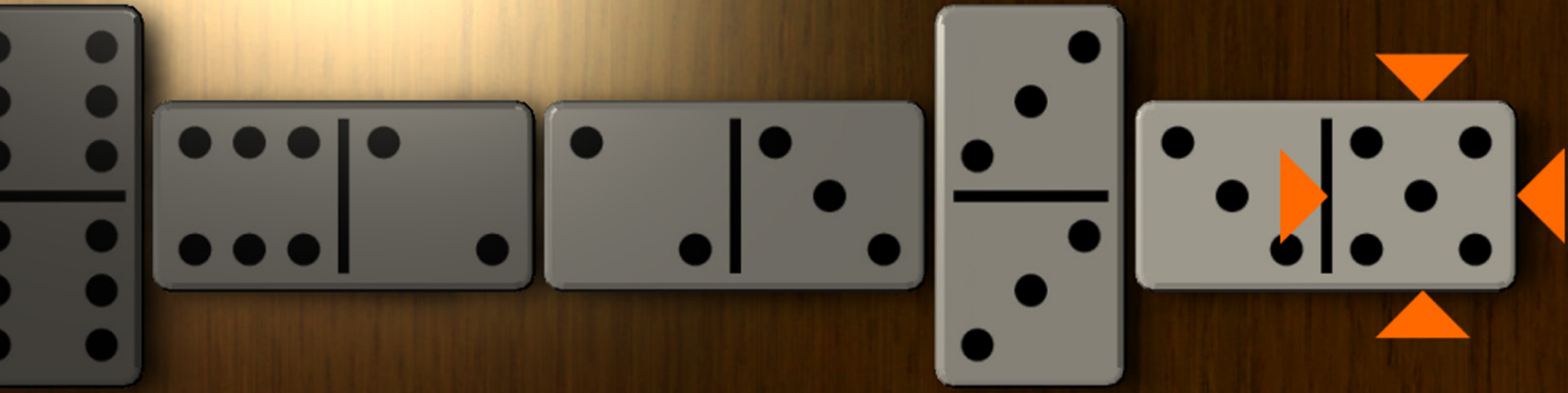
SIMULATE



 Nada Score: 0 <div><div></div><div></div><div></div><div></div><div></div><div></div><div></div></div>	 Comp1 Score: 0 <div><div></div><div></div><div></div><div></div><div></div><div></div><div></div></div>	 Brian Score: 0 <div><div></div><div></div><div></div><div></div><div></div><div></div><div></div></div>	 Comp3 Score: 0 <div><div></div><div></div><div></div><div></div><div></div><div></div><div></div></div>
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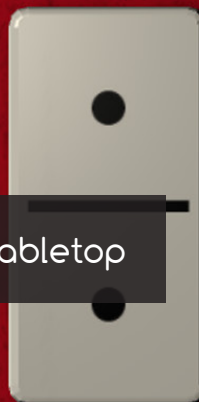
DEVICE


Nada's turn.





SIMULATE


PASS











EXIT

HELP

figure 7.5 - Tabletop



REPETITIONS TO GO

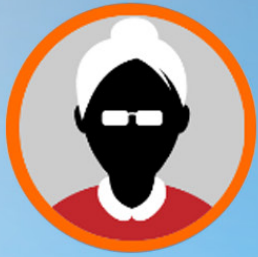
2



figure 7.6 - Task Repetitions

 SIMULATE

Ending Score: 30



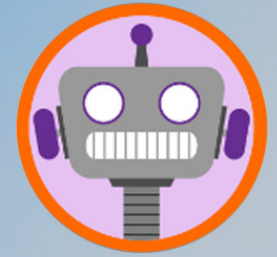
Nada:
4



Comp1:
12



Brian:
0



Comp3:
8

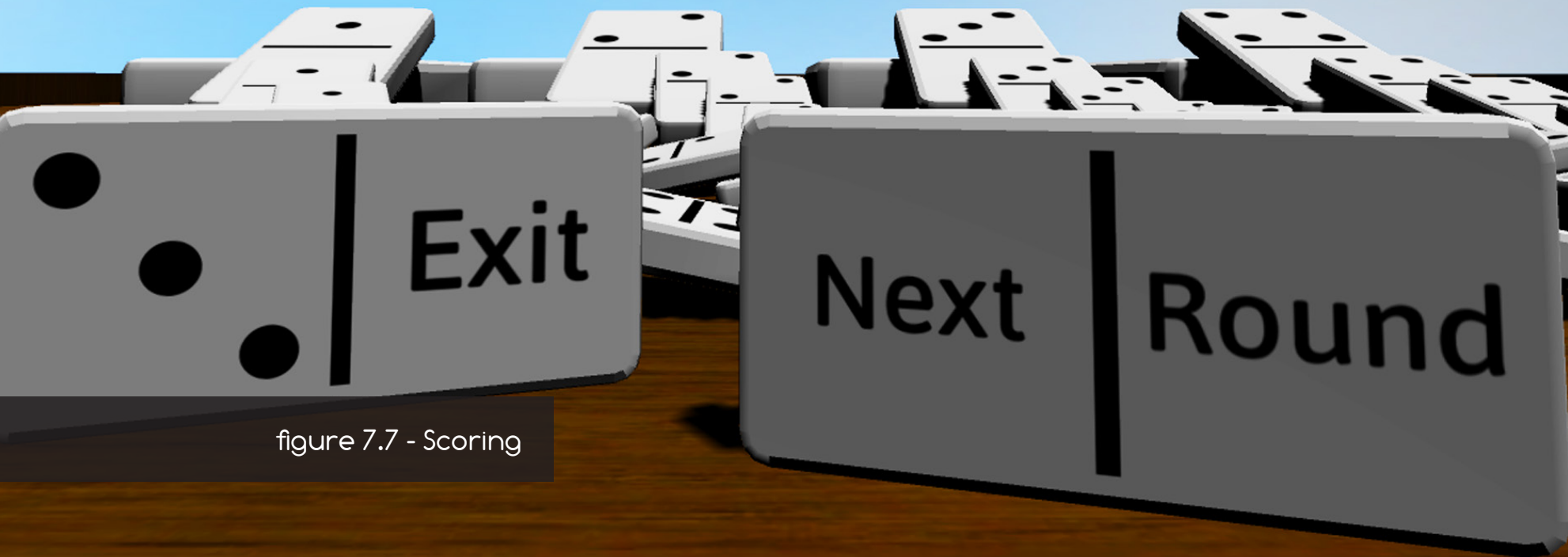


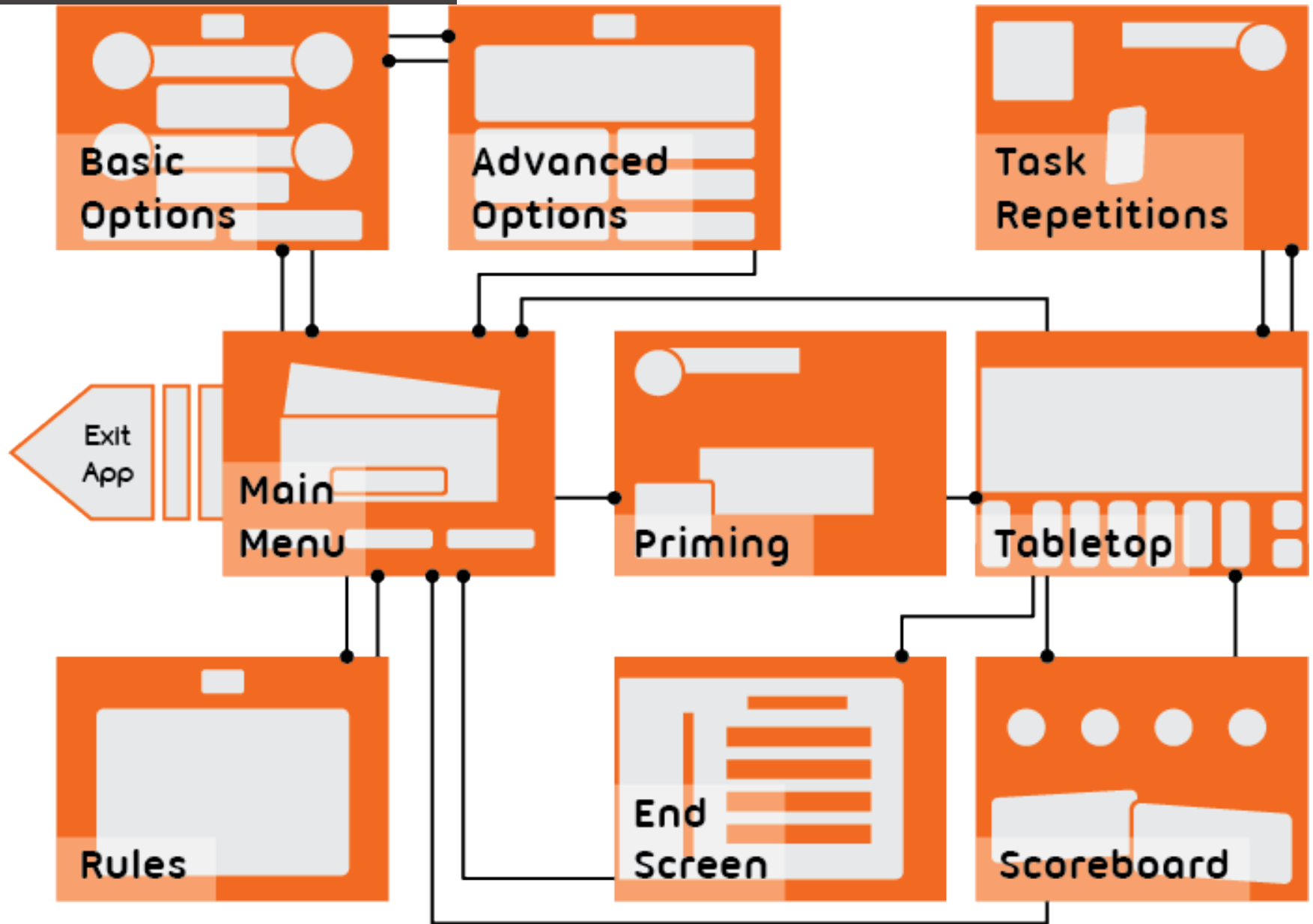
figure 7.7 - Scoring



figure 7.8 - Game Over



figure 7.9 - User Flow WireFrame



7.1.1 12-12

The final version of *12-12* allowed a single person to use William Duncan's device (defaulting player one). This required them to perform strength-training repetitions to begin the game and basic repetitions to play dominoes. Additional players simply had to press a domino to play it.

Interaction with the system was limited by the inaccuracy of the IMU sensors. In the timeframe of this research we were unable to collect consistent enough data from the sensors to accurately read the motions of the player wearing the device. Despite this, the 'OZ paradigm' (Kelley, 1984) implemented for user testing replicated the desired interaction with enough similarity to keep the tests valid.

Natural progression for the system would be to improve the use of sensors to accurately read input movements. Additionally, the multiplayer elements of the game need more detailed testing to ensure the *connective* potential of *12-12*. Once these elements have been mastered, the next step would be to perform proper clinical trials and test the game on a broader audience for an extended period of time.

7.2 Evaluation Through Criteria

This section covers our personal evaluation of the game system's ability to harbour *adaptability*, *connectivity*, and *meaningful interactions*.

Adaptability embodies how well *12-12* adjusts internal parameters to suit the personal needs of each player. Games in *12-12* can be padded out with more waiting time between turns by adding more players. This adjusts the difficulty of the game in a strategic sense, adding to the cognitive load on players, but also grants longer breaks between repetition targets. Increasing the ending score lengthens the game by the amount of rounds the player needs to complete to reach resolution. This is purely an experiential factor and does not influence the player's rehabilitation any more than increasing the amount of repetitions. Such an increase directly affects the physical difficulty of play and is the easiest way to adapt to player progression.

The adaptable functionality of *12-12* allows for precise control over the physical requirements to play. The weak-



ness of this functionality becomes apparent when the physical capabilities of the player are either very limited or highly capable. Severely limited players may not be able to complete a full game of dominoes, even with a low ending score. Catering to these players requires a reduced version of the game that ceases resemblance to typical dominoes. We hypothesise that such a version of *12-12* would be highly reliant on the novelty of interaction to entertain players. As novelty is a temporary phenomenon, alternative means of holding player attention would need to be explored.

Adaptability became the most significant criteria of the three. The abundance of backing literature, in tandem with clinical recommendation and feedback from users made it clear that *adaptability* was an absolute necessity for the success of the system. It was the easiest of the criteria to implement; most likely the result of its clear definition and purpose. Comparatively, the broadness of the other criteria made them more difficult to define.

Connectivity represents *12-12*'s ability to foster social connections between its users. *12-12* takes advantage of the popularity and social nature of traditional tabletop games. Dominoes is a multiplayer game by default, meaning whether the device-user is playing with human or com-

puter players, they are always interacting with another. The use of scoring between rounds encourages competitive play. The application of the device-user's exercises in gameplay was deliberately kept separate from strategizing to keep all players on equal footing.

A limitation of the *connectivity* of *12-12* comes from the lack of network capabilities. Only having one player with a working device in a game discriminates them from other players, as their turns take significantly longer to complete. An ideal setup would involve every non-computer player using a device with their own calibration and exercise scheme. This would increase the wait time between turns, but the pacing of the game would be more consistent and device-users may feel less self-conscious. The lack of persistent player profiles limits the amount of personalisation users can experience through *12-12*, therefore limiting their connection (and investment) with the game.

Meaningful interactions encapsulates how interacting with *12-12* benefits the user. This includes how well *12-12* supports the extrinsic motivations of its players, as well as its ability to communicate these elements to the user. As a rehabilitation game, *12-12* automatically hosts the extrinsic

motivation of self-improvement. It also provides intrinsic motivation to those who enjoy dominoes as a pastime. The inclusion of playful animations and visual effects rewarded players for interactions that progressed the game, thereby encouraging further interaction. Our user testers enjoyed the novelty these features provided.

Meaningful interactions was too broad a criteria to be applied with the specificity seen with *adaptability*. The lack of persistent profiles limited the use of goals or progress tracking, making the user experience less personal. This meant *12-12* relied largely on players' extrinsic motivation to recover from stroke and intrinsic motivation to play dominoes to attract an audience. This was less effective on users like Dannie, who had less experience with dominoes. The abstract nature of dominoes meant the connection between user input and in-game action was arbitrary. While this was advantageous for adapting input exercises, users like Dannie may find the system difficult to understand. Despite *meaningful interactions* having less of an effect on *12-12* than *connectivity* or *adaptability*, the game would benefit from a more focused approach in this regard.

7.2.1 Limitations of the Research

Like many similar papers (Alankus et al., 2010, p. 2121, Chen et al., 2014, p. 8, Flores et al., 2008, p. 383, Holden & Dyar, 2002, p. 70, Nap et al., 2009, p. 260), the findings of this research are also subjective. This is an inherent property of the methods that were chosen. Despite the research being developed with consultation from multiple sources and disciplines, the amount of people involved was comparatively small. The sample size for user testing meant feedback was not reliably representative of the older adult demographic.

Another limitation of this research was the lack of fully functioning sensors. Kelley's 'OZ paradigm' (1984) allowed our user testers to experience the novelty of interacting with the system as if the sensors were functional. However, this means the system is not capable of testing beyond a controlled environment. Significant technical progress needs to be made before the system would be ready for clinical trials.



7.2.2 Final Evaluation

How can digital games facilitate engagement for lower-limb rehabilitation for older adults recovering from stroke?

A person must show active participation and investment in their rehabilitation with energy, enthusiasm and commitment to be “engaged” by it. The criteria used to evaluate *12-12* were established from research regarding engagement. *12-12* met these criteria with varying degrees of success.

Adaptability was the criterion *12-12* fulfilled most completely. Functionality supporting social *connectivity* was implemented but time constraints limited its testing, rendering the effectiveness inconclusive. *Meaningful interactions* was the criterion with the least fulfilment. Engagement is not dependent on the success of all three criteria, therefore the limited integration of *meaningful interactions* did not stop *12-12* from engaging users.

12-12 is capable of facilitating lower-limb rehabilitation through the regular repetition of exercises to play dominoes. The inclusion of a priming phase enables the incorporation of Strength for Task Training (Signal., 2014),

however this functionality is dependent on the patient’s access to a device that can host the appropriate weight. The customisation of these elements allows for *12-12* to be accessed by people with a variety of physical capabilities. The accessibility to *12-12* was enhanced by being a digitized dominoes game, utilizing the game’s simplicity and familiarity with an older audience.

12-12 was received with interest and enthusiasm by our user testers, all of whom could see fellow survivors of stroke benefitting from the system. This is not representative of the user-base, however it does indicate a level of acceptance and eagerness with which similar systems may be met. With further iterations and more expansive user testing, *12-12* could become an effective contributor to the physiotherapy process.



Chapter 8

“Once you learnt, you felt like you had conquered it.”

*- ‘Alex,’ personal communication,
17th June 2016*

New Game +



This final chapter concludes our research. The knowledge that has been acquired thus far indicates certain aspects of the system that should be explored further. This chapter discusses how these aspects might be progressed and provides speculation as to how future research might be applied.

8.1 Future Work

Many elements of the system are dependent on more user testing to prove their effectiveness. Examples such as the game's ability to foster competitive play cannot be proven without repeated testing on numerous people. The following section focuses less on what needs to be proven and more on what can be explored.

In the current model of *12-12*, increasing the amount of repetitions simply makes playing a domino more difficult to achieve. A player who uses the game for an extended period may find having to work harder for the same result frustrating. Changing the visual effects of this interaction to represent the amount of effort required of the player could rectify this. For example; playing a domino from twelve repetitions returns significantly more visual and aural celebration than playing one for four repetitions.

The *adaptability* of *12-12* can be improved by the introduction of a clinical interface that allows for the adjustment of exercises based on what the clinician believes is the most appropriate for their clients to be performing. Ideally this would be accessed remotely. Such an interface would require detailed player analytics that allow clinicians to see their patient's exercise data over an extended period of time, as well as whether they are improving or degrading in their capabilities. Rendering these analytics visible to the player could provide extrinsic motivation for measuring self-improvement.

The addition of player analytics requires custom user profiles. Expansions could be made through the current in-game options menu, on which players are free to choose their username, avatar, the colour of the game board etc. Enabling the player to personalize their experience promotes investment in the system. With persistent player data, adding a 'badge' system that tracks progress on a daily/monthly scale would be possible. Such a feature rewards players for regular interaction or achieving large gradual goals. It could even be possible for badges to be generated by clinicians to tailor them to their patients' goals, creating an internal reward structure for the achievement of extrinsic goals.



Player profiles could expand on *connectivity* through an online version of *12-12*, allowing players to compete from the comfort of their individual homes. The inclusion of network functionality would require a very simple interface. Older adults are the least frequent users of the internet (Ijsselsteijn et al., 2007, p. 18), therefore simplicity is necessary to reduce the chance of intimidating or confusing players. Local multiplayer (offline, sharing a single device) was implemented but remains to be tested. The socially connective potential of games has been acknowledged by many sources to be a strength and worthy of pursuit in serious games research (Blythe et al., 2005, p. 687, Costikyan, 2006, p. 208, Ijsselsteijn et al., 2007, p. 17, Jack et al., 2010, p. 227, Mahmud et al., 2008, p. 405, Miller, 2004, p. 219). This is particularly relevant for games that target older adults (Binstock & George, 2001, p. 299, Gerling et al., 2011, Nap et al., 2009, p. 249).

There are many other aspects of serious game design and human-computer interactions that warrant further research. Traits such as flexible UI elements have been acknowledged to have potential for improving accessibility to technology for older adults (Gerling et al., 2010, p. 67, Gregor et al., 2002, p. 154, McLean et al., 2010, p. 516).

Alternatively, the use of spoken instructions and supporting video to teach gameplay may yield interesting results.

These are but a few ways the system could be improved. They form the next steps that would be pursued with the continued development of *12-12*.

8.2 Conclusion

In this thesis we have explored how digital games can facilitate engagement with lower-limb rehabilitation for older adults recovering from stroke. Many consider physiotherapy to be strenuous and monotonous, resulting in reduced motivation to maintain rehabilitation and ultimately less effective recovery. Serious games research, although relatively new, has shown promise for digital games to encourage players to persist in their recovery. The development of *12-12* has contributed to this field of research, exploring how elements of game design can engage players from an older demographic.

The development of *12-12* was informed by three criteria that were derived from background research on engagement within digital gaming. These criteria were *adaptability*, *connectivity* and *meaningful interactions*. We proposed that embedding these criteria in the game would engage players, promoting continued use of the game system and thereby supporting healthy recovery.

The original weighting of the criteria shifted to favor *adaptability* over the other two, based on responses from user testing. *Meaningful interactions* was lessened by nov-

elty. *Connectivity* was unable to be tested effectively, thus remained unaltered. The importance of usability in addition to these criteria became very apparent. Older adults proved a complex demographic, with immense levels of diversity in physical and cognitive capabilities. Increasing accessibility to the system was paramount and *adaptability* was the most appropriate means of achieving this.

Many elements of the design of *12-12* were informed by background research. Despite the field of serious games being relatively new, the resulting design decisions yielded positive responses from user testers. The limited sample size and time restrictions of this research render these results far from conclusive.

More persistent studies of the effects of systems like *12-12* need to be conducted to prove the positive effects of digital gaming systems in a rehabilitative context. The subjectivity involved with defining engaging gaming experiences may limit what quantitative data can accomplish, however such perspectives may help the field of research mature.

Although the methods chosen for this research were largely subjective, the combination of perspectives from clinicians, user testers and researchers helped reduce bias and validate design outputs. Testing with an expanded



user-base and conducting official clinical trials will further minimize this bias, and is a natural progression for the research to take.

There is a lot of potential for digital game systems to make a difference in the lives of people after stroke. This research has explored how these systems might make the rehabilitation process more engaging, thereby improving recovery and helping survivors of stroke lead more independent lives. The positivity with which the system was received suggests that serious games can be an enjoyable and effective alternative to standard rehabilitation and we urge the pursuit of further research in this area.





Reference List

Literature

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Figures

(All figures were generated by the author unless noted otherwise)

Chapter 3 Hero Image

- Photo courtesy of fellow researcher William Duncan

3.1 – SilverBalance

- Gerling, K., Schild, J., & Masuch, M. (2010). Exergame Design for Elderly Users: The Case Study of SilverBalance. In V. R. L. Shen (Ed.), *Proceedings of the 7th International Conference on Advances in Computer Entertainment Technology*. New York, NY: ACM. Retrieved from https://www.researchgate.net/profile/Kathrin_Gerling/publication/220982782/figure/fig1/AS:305676271276032@1449890310268/Figure-1-Graphical-design-of-SilverBalance.png

3.2 – SilverPromenade

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3.3 - BrooksTalk

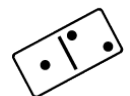
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3.5 - Lokomat in use 1

- Photo courtesy of Ute-Kristina Schäfer, Marketing Manager at Hocoma

3.6 - Lokomat in use 2

- Hocoma (n.d.). *Clinical Partners*. Retrieved from <http://www.hocomaprev.vs98.snowflakehosting.ch/world/en/partners/clinical-partners/>



3.10 - Level Progression (Fruit Ninja)

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3.11 - Rewards (Jetpack Joyride)

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Chapter 7 Hero Image

- Photo courtesy of fellow researcher William Duncan

Chapter 8 Hero Image

- Photo courtesy of fellow researcher William Duncan





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Appendices

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Health and Disability Ethics Committees
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10 February 2016

Dr Brian Robinson
Graduate School of Nursing, Midwifery & Health
PO Box 7625
Newtown 6242

Dear Dr Robinson

Re:	Ethics ref:	16/CEN/5
Study title:	Developing Interactive Devices and Games for Physical Therapies in Stroke Recovery	

This application was reviewed by the Central Health and Disability Ethics Committee and provisionally approved pending receipt of further information. This decision was made through the HDEC-Full Review pathway.

Summary of Study

This study is a joint collaboration between the Victoria University of Wellington School of Design and the Victoria University Graduate School of Nursing, Midwifery and Health and senior physiotherapists at AUT University in Auckland. It is a 'usability' study which will aim to test two things: software and computer controllers in stroke patients as potentially useful rehabilitation aids.

The research team is seeking ethical approval for 4-5 design projects every 3 years for 3 years so for 12-15 projects and around 100 participants. There is not one particular piece of software but students will build on previous students' work so the software and physical controllers may vary over the three years.

The researchers intend to test in the participant's home. A design student will explain the device and watch the participant use the device and record the participant using the device with a sensor and photograph/videos and secondly interview the participant and record data.

Summary of ethical issues (resolved)

The main ethical issues considered by the Committee and were addressed by the Researcher are as follows.

- The committee asked what 3-4 projects are lined up for this year. Dr Robinson explained that one project involved students developing games guiding an astronaut around a screen that would inform other projects. The overall aim is to create a blanket application to cover these students. Dr Robinson explained that the same game will always be used but a different style of mouse will be tested. The games will be made progressively more difficult to help enhance movement. This game 'level 1' will be tested to see whether stroke patients can use the device. The idea is to use upper limb movement to stimulate neural plasticity and students will create a portfolio of games with these devices.

- ❑ Supporting design students with stroke patients who are community dwelling. The committee queried whether the design students might need support. Dr Robinson advised that the students will be in their 20s. The students do not have a health background and a physiotherapist will support them in dealing with health issues ethically. Structure set up where both students and people in the community have protocols in place. Focusing purely on upper limb.
- ❑ The committee asked whether the participants in this study will have a degree of cognitive impairment and if so how will the research team assess this. Dr Robinson advised that they are anticipating that patients who are unimpaired are the ones who will make contact with the researchers. There is currently no formal screening process and the researchers were not intending to recruit through clinicians.
- ❑ The committee asked to see the wording that will be used for the recruitment flyers.
- ❑ The committee noted the answer stated at question p.4.3 on page 22 of the application form that consultation with Māori is not required. The committee reminded the researchers that formal consultation is required MC formal consultation with Māori is required for all research in New Zealand that involves Māori. Dr Robinson thought that the answer may have been stated in error and noted for the committee that they had consulted with Professor Rawina Tumaki, Head of the School of Māori studies regarding the cultural issues of this research programme who had offered useful feedback for the research team. Please provide the name and contact details of a Māori support person who participants can contact. The committee noted that 'Whakama' is a cultural issue for some Māori and that protocols for behaving in people's homes need to be observed.
- ❑ The committee noted that it is difficult for them to give a blanket approval for the ongoing updates to the software and controllers when they don't know what they will be. With this in mind the committee agreed to approve the current study protocol but requested that the research team submit each update as a substantial amendment via Online Forms for this committee to consider. Please include updated participant information sheets with each amendment and include updated version numbers and dates on the updated documents.

The committee requested the following changes to the participant information sheet and consent forms.

- ❑ Page 2, 'What will my participation in the study involve?': The committee noted the statement that the session should take no more than 30 minutes and was concerned that this might set the expectation that participants would have to make this time. In participants who have experienced a severe stroke 30 minutes may be too long to concentrate.
- ❑ Page 2, 'What are the possible benefits and risks of this study?': the committee noted that the information provided here appeared to be a contradictory and could be confusing for participants. On the one hand it stated that people should do rehabilitation for several hours a day and on the other hand the researchers intend to take the devices away after the session. Dr Robinson confirmed that they are not wanting to use the device as a therapeutic device at this stage but to find out whether it might be useable as a therapeutic device. Please make this clear to participants.
- ❑ The committee noted that the research team intend to take and use images but this is not clearly spelt out in the participant information sheet and consent forms. The committee advised that if the researchers are going to use images then they need to tell people clearly and they need to seek consent for that as well.
- ❑ The committee asked how the researchers intend to make sure that any photos taken are unidentifiable. Dr Robinson explained that they will use a standard technique of blurring facial images and images of participant's houses will not be used. Please make this clear to participants.

- ❑ The committee asked what kind of device the researchers intend to use to record the images and noted that there are issues of confidentiality associated with recording. Dr Robinson advised that Victoria University of Wellington School of Design cameras will be used and the images taken will be deleted from the cameras. The committee asked that this information be included in the participant information sheet.
- ❑ Please submit the wording that will be used for the recruitment flyers.
- ❑ Please provide the name and contact details of a Māori support person who participants can contact
- ❑ Please make clear to participants what will happen in this study – for example, that that students will come to their home and please make clear arrangements for the safety of students. For example that they don't travel to the house alone and that they take cell phones with them.
- ❑ Consent form: please only include yes/no boxes for statements that are truly optional (i.e. that a person could still participate if they answer 'no').
- ❑ Please provide a 24 hour contact number for the lead investigator and for the supervisor for this study. While you are not studying participants with acute problems, students will be going to participants' homes in the evening and the requirements are that there is a 24 hour contact number.

Further information requested

The further information requested in order for the Central Health and Disability Ethics Committee to make a final decision is as follows.

- ❑ Please amend the information sheet and consent forms, taking into account the suggestions made by the Committee (*Ethical Guidelines for Intervention Studies* para 6.22).

Timeline for providing further information, and for giving a final opinion

You have 90 days to provide this further information. Your application will be considered to have been withdrawn if this information is not received on or before 10 May 2016. A new application would be required in this case.

The 35-day clock within which a final decision must be made on this study is suspended as of the date of this letter. This clock, on which 16 days remain, will restart on the date on which all of the further information requested above is received by the Central Health and Disability Ethics Committee.

Please remember to track changes made to new versions of documentation.

How to respond to a Provisional Approval

You will need to submit your new or amended documents through Online Forms.

New versions of existing documents :

Steps

Screenshots

1. Go to the Documents Tab to upload the revised documentation requested by the secretariat



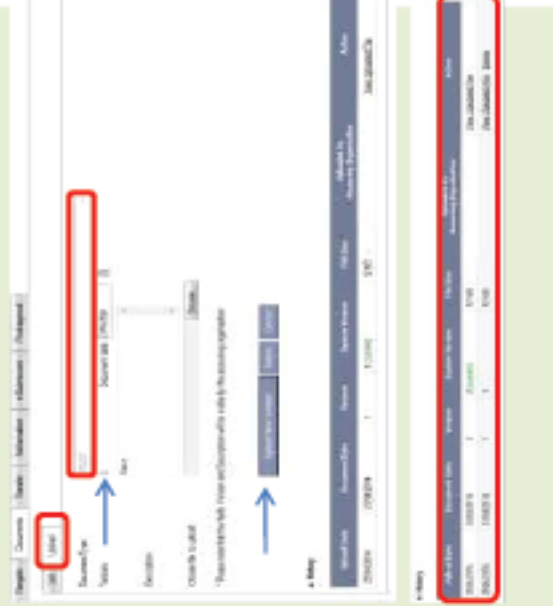
2. To update versions of documents, go to the List tab. Select View/Manage to upload a newer version of the document.

- For example you can upload new versions of the PIS/CF
- Remember to track changes.



3. When you click View/Manage for a particular document it will take you to the upload tab for that document.

- Update the version number and document date.
- Browse to find the new version of the file.
- Click 'Upload New Version'
- Once the upload is complete the history will populate with the new version.




New documents:
Steps

Screenshots


4. For New documents, go to the upload tab.

For example you can upload a word document responding to questions raised by the Committee.




5. Select the document type. Add a version number, document date and add a description if required.

Browse your computer to find the new file and select Upload File.



6. The new document will now be uploaded and visible on the List Tab.

Before submitting check to see all your documents are on the List tab and are displaying the correct version and document date.



To submit:

- Once you have uploaded all new documents or updated all existing documents click the E-Submissions tab.



- Scroll down until you see 'Provisional Approval Response'.

This button will only be able to be used when you have received a 'Provisional Approval' letter.

Please note: only click submit once.



Please don't hesitate to contact the HDEC secretariat if you have any queries. We look forward to receiving your response.

Yours sincerely,



Mrs Helen Walker
Chairperson
Central Health and Disability Ethics Committee

Encl: appendix A: documents submitted
appendix B: statement of compliance and list of members



Appendix A

Documents submitted

Document	Version	Date
Covering Letter: Covering Letter	1	11 December 2015
CV for CI: CI CV	1	11 December 2015
Evidence of scientific review: Peer Review	1	11 December 2015
Protocol: Protocol for Research	1	11 December 2015
Survey/questionnaire: Demographic questions and examples of questions for semi-structured interviews	1	11 December 2015
PIS/CF: Participant Information and Consent Form	1	11 December 2015
Application		

Appendix B Statement of compliance and list of members

Statement of compliance

The Central Health and Disability Ethics Committee:

- ☑ is constituted in accordance with its Terms of Reference
- ☑ operates in accordance with the *Standard Operating Procedures for Health and Disability Ethics Committees*, and with the principles of international good clinical practice (GCP)
- ☑ is approved by the Health Research Council of New Zealand's Ethics Committee for the purposes of section 25(1)(c) of the Health Research Council Act 1990
- ☑ is registered (number 00008712) with the US Department of Health and Human Services' Office for Human Research Protection (OHRP).

List of members

Name	Category	Appointed	Term Expires	Present on 28/01/2016?	Declaration of interest?
Mrs Helen Walker	Lay (consumer/community perspectives)	01/07/2012	01/07/2015	Yes	No
Dr Angela Ballantyne	Lay (ethical/moral reasoning)	01/07/2015	01/07/2018	No	No
Dr Melissa Cragg	Non-lay (observational studies)	01/07/2015	01/07/2018	No	No
Dr Peter Gallagher	Non-lay (health/disability service provision)	01/07/2015	01/07/2018	Yes	No
Mrs Sandy Gill	Lay (consumer/community perspectives)	30/07/2015	30/07/2018	Yes	No
Dr Patricia Herat	Non-lay (intervention studies)	27/10/2015	27/10/2019	No	No
Dr Dean Quinn	Non-lay (intervention studies)	27/10/2015	27/10/2021	Yes	No
Dr Cordelia Thomas	Lay (ethical/moral reasoning)	19/05/2014	19/05/2017	Yes	No

Unless members resign, vacate or are removed from their office, every member of HDEC shall continue in office until their successor comes into office (HDEC Terms of Reference)

<http://www.ethics.health.govt.nz>



Participant Information Sheet



Study title:	A Game for Physiotherapeutic Rehabilitation for Stroke Survivors		
Locality:	Wellington	Ethics approval number:	HDEC16CENS
Lead investigator:	Brian Robinson	Contact phone number:	

You are invited to take part in a study on a digital game system on the recovery process from stroke. Whether or not you take part is your choice. If you don't want to take part, you don't have to give a reason, and it won't affect the care you receive. If you do want to take part now, but change your mind later, you can pull out of the study at any time.

This Participant Information Sheet will help you decide if you would like to take part. It sets out why we are doing the study, what your participation would involve, what the benefits and risks to you might be, and what would happen after the study ends. We will go through this information with you and answer any questions you may have. You do not have to decide today whether or not you will participate in this study. Before you decide you may want to talk about the study with other people, such as family, whānau, friends, or healthcare providers. Feel free to do this.

If you agree to take part in this study, you will be asked to sign the Consent Form on the last page of this document. You will be given a copy of both the Participant Information Sheet and the Consent Form to keep.

This document is 6 pages long, including the Consent Form. Please make sure you have read and understood all the pages.

WHAT IS THE PURPOSE OF THE STUDY?

This study is to develop computer controllers and computer games that can be used by people who are recovering from stroke. This is for rehabilitation that they can carry out by themselves at home.

We want to know how you find using the computer, the controller and the game. Our aim is that these will be easy to use and understand as well as rewarding for you. It is also important that the movements made when using the games will help with stroke rehabilitation.

These devices and games are developed by students as a requirement for a Masters degree. This research is funded by the School of Design at Victoria University of Wellington. Any other questions you have can be answered by Dr. Brian Robinson (463 6155)

This research has been approved by the Health and Disability Ethics Committee.

WHAT WILL MY PARTICIPATION IN THE STUDY INVOLVE?

We asked you to take part in this research because you have experienced a stroke and may have limited use of one of your legs.

The research study will take place either at a Stroke Club or in your home.

If the research study takes place in your home, two research students will come. They will bring mobile telephones with them so that they can contact their research supervisors.

We will ask some questions about you such as how old you are, your ethnic background, how long ago you had the stroke and how the stroke affects you now.

We will show you a computer, a computer controller and a game.

You will be asked to use the computer and the control device to play a computer game.

You can play this game for as long as you like and can tell us when you want to stop.

We will take a video and photographs of you using this computer controller and game. This is to make sure that using the controls and the game in ways that will be useful for stroke recovery and not cause harm. Stroke rehabilitation physiotherapists will review these recordings. We will keep the video and photographs securely in the University. Because other researchers will be interested in our research we may show the photographs or a video of you. Your involvement in the study will only be known by the researchers. All photographs and videos will be taken using cameras belonging to the School of Design. The images and videos will be taken off these cameras and immediately after this session and then kept secure in the University computer system.

If we do use photographs or videos of you for presenting our research we will not show any part of you, such as your face, that can tell other people that you have taken part. If we take pictures in your home, we will also make sure that we do not show anything that identifies your house or that you took part. We will do this by blurring parts of the images and videos. We will ask you for your thoughts on using the computer control and game. We will record what you say. If you tell us something useful that we quote, we will not use your name with what you say".

Your participation requires your concentration using the game or device. We realize that this can be tiring for you so we ask you can tell that you are wanting to rest or to stop the session. You may be invited to take part again if you would like to help us test changes.

WHAT ARE THE POSSIBLE BENEFITS AND RISKS OF THIS STUDY?

We know that people who have had stroke cannot access stroke rehabilitation therapy regularly. They have to travel to clinics or hospital. We also know that rehabilitation is more effective when it is carried out for several hours throughout day, every day.

This study is to support people who have had a stroke to provide stroke rehabilitation therapy in their home. This can be by themselves or with the help of carer support or family members.

We want to find out whether this device or game may be useful in stroke rehabilitation. This research is finding out whether you can use it and what you think of it.

This does not replace any other therapy you may be receiving. We are not using the device and game as part of your therapy at this stage. We want to find out whether this might be useable as a therapeutic device.

While you are using the computer and playing the game you will be required to perform specific physiotherapy exercises from a standing position. If you are unable to do this, there is a seated equivalent that can be performed.



WHO PAYS FOR THE STUDY?

This study is funded by Victoria University of Wellington and the School of Design through medical technology research grants from the Ministry of Business, Innovation and Employment.

You will not incur any costs by taking part and we will travel to you.

WHAT IF SOMETHING GOES WRONG?

If you were injured in this study, which is unlikely, you would be eligible for compensation from ACC just as you would be if you were injured in an accident at work or at home. You will have to lodge a claim with ACC, which may take some time to assess. If your claim is accepted, you will receive funding to assist in your recovery.

WHAT ARE MY RIGHTS?

You are volunteering to take part. You do not have to take part in this study and you can withdraw at anytime.

We can show you the video recording and photographs of you we have collected. We can also give you a copy of what we have recorded you saying to us about using the computer device and game.

It is unlikely that participating will affect your health but if it does, we will contact you immediately.

We will not identify you in any of the student's work or presentations of the work.

WHAT HAPPENS AFTER THE STUDY OR IF I CHANGE MY MIND?

After you have taken part and change your mind about being involved, please contact the researcher (the design student) or the lead investigators (Brian Robinson, in the first instance, or Edgar Rodriguez) and any data, information and images associated with your participation will be destroyed.

We will securely store the information and data you have provided for five (5) years and it will then be destroyed.

We can present the findings of this study at stroke clubs within a year of conducting the study.

We can also send you a summary of the student's thesis describing the outcome of the study.

We may also present this study with other similar studies we are conducting at conferences or in books or journals.

WHO DO I CONTACT FOR MORE INFORMATION OR IF I HAVE CONCERNS?

If you have any questions, concerns or complaints about the study at any stage, you can contact

Dr Brian Robinson, Senior Lecturer, Graduate School of Nursing, Midwifery & Health,
Victoria University of Wellington.
Work phone: (04) 934 9321
brian.robinson@vuw.ac.nz

24 Hour contact numbers:

Dr Robinson: [REDACTED]
If you cannot contact Dr Robinson, please contact
Associate Professor Edgar Rodriguez: [REDACTED]

If you have other questions, concerns or complaints and wish to contact a Māori support person, you can contact:

Katherine Reweti- Russell, Research Advisory Group – Māori, CCDHB
Work phone: (04) 806 2524

If you want to talk to someone who isn't involved with the study, you can contact an independent health and disability advocate on:

Phone: 0800 555 050
Fax: 0800 2 SUPPORT (0800 2787 7678)
Email: advocacy@hdc.org.nz

For Māori health support please contact your health provider and they will refer you to the representative Māori health support group.

You can also contact the health and disability ethics committee (HDEC) that approved this study on:

Phone: 0800 4 ETHICS
Email: hdec@moh.govt.nz



Consent Form



If you need an INTERPRETER, please tell us.

If you are unable to provide interpreters for the study, please clearly state this in the Participant Information Sheet

Please tick to indicate you consent to the following

I have read, or have had read to me in my first language, and I understand the Participant Information Sheet	Yes <input type="checkbox"/>
I have been given sufficient time to consider whether or not to participate in this study.	Yes <input type="checkbox"/>
I have had the opportunity to use a legal representative, whānau/family support or a friend to help me ask questions and understand the study.	Yes <input type="checkbox"/>
I am satisfied with the answers I have been given regarding the study and I have a copy of this consent form and information sheet.	Yes <input type="checkbox"/>
I understand that taking part in this study is voluntary (my choice) and that I may withdraw from the study at any time without this affecting my medical care.	Yes <input type="checkbox"/>
I consent to the research staff collecting and processing my information, including information about my health.	Yes <input type="checkbox"/>
I understand that my participation in this study is confidential and that no material, which could identify me personally, will be used in any reports on this study.	Yes <input type="checkbox"/>
I consent to the research staff taking pictures or video recordings of me and I understand that if used in presentations, these will be altered so that I or my involvement cannot be identified.	Yes <input type="checkbox"/>
I understand the compensation provisions in case of injury during the study.	Yes <input type="checkbox"/>
I know who to contact if I have any questions about the study in general.	Yes <input type="checkbox"/>
I understand my responsibilities as a study participant.	Yes <input type="checkbox"/>
I wish to receive a summary of the results from the study.	Yes <input type="checkbox"/> No <input type="checkbox"/>

Declaration by participant:
I hereby consent to take part in this study.

Participant's name: _____

Signature: _____

Date: _____

Declaration by member of research team:

I have given a verbal explanation of the research project to the participant, and have answered the participant's questions about it.

I believe that the participant understands the study and has given informed consent to participate.

Researcher's name: Scott Brebner Will Duncan

Signature: _____

Date: _____





Designing a System for Stroke Rehabilitation

INFORMATION SHEET FOR PARTICIPANTS

Thank you for your interest in this project. Please read this information before deciding whether or not to take part. If you decide to participate, thank you. If you decide not to take part, thank you for considering my request.

Who am I?

My name is Scott Brebner and I am a Masters student in the School of Design at Victoria University of Wellington. This research project is work towards my thesis.

What is the aim of the project?

This project aims to design a system of physical devices and videogames that help stroke patients carry out their physical rehabilitation. This research has been approved by the Victoria University of Wellington Human Ethics Committee [23011].

How can you help?

If you agree to take part I will interview you in your office, a meeting room in the School of Design's campus or in a public place, such as a café. I will ask you questions about stroke rehabilitation. I will audio record the interview and write it up later. We will construct a set of criteria and designs that facilitate stroke rehabilitation based on the findings from the research. In a second interview, we will seek your feedback about the new designs. Each interview will take 60 minutes. You can stop the interviews at any time, without giving a reason. You can withdraw from the study up to four weeks after the first interview. After this time, we will use the information you provide to design new objects. You can also withdraw your information for the second interview up to four weeks after it occurs. If you withdraw, the information you provided will be destroyed or returned to you.

What will happen to the information you give?

This research is not confidential. We may name you in any reports or publications. Only my supervisors and I will read the full notes or transcript of the interview. The interview transcripts, summaries and any recordings will be kept securely and destroyed 3 years after the research ends.

What will the project produce?

The information from this research will be used in Masters thesis. You may be identified in the report. We may also use the results of this research for conference presentations, and academic reports.

If you accept this invitation, what are your rights as a research participant?

You do not have to accept this invitation if you don't want to. If you do decide to participate, you have the right to:

- choose not to answer any question;
- ask for the recorder to be turned off at any time during the interview;
- withdraw from the study up until four weeks after your interview;
- ask any questions about the study at any time;
- receive a copy of your interview recording (if it is recorded);
- read over and comment on a written summary of your interview;
- agree on another name for me to use rather than your real name;
- be able to read any reports of this research by emailing the researcher to request a copy.

If you have any questions or problems, who can you contact?

If you have any questions, either now or in the future, please feel free to contact either:

Student:

Supervisor:

Name: Scott Brebner

Name: Dr Edgar Rodriguez

University email address: brebnesco@myvuw.ac.nz

Role: Programme Director Industrial Design

School: School of Design

Phone: 04 5636544

edgar.rodriguez@vuw.ac.nz

Human Ethics Committee Information

If you have any concerns about the ethical conduct of the research you may contact the Victoria University HEC Convener: Associate Professor Susan Corbett. Email susan.corbett@vuw.ac.nz or telephone +64-4-63 5480.



Designing a System for Stroke Rehabilitation

CONSENT TO INTERVIEW

Researcher: *Dr Edgar Rodriguez, School of Design, Victoria University of Wellington.*

- I have read the Information Sheet and the project has been explained to me. My questions have been answered to my satisfaction. I understand that I can ask further questions at any time.

- I agree to take part in an audio recorded interview.

I understand that:

- I may withdraw from this study up to *four weeks* after the first interview or up to four weeks after the second interview reviewing the designs, and any information that I have provided will be returned to me or destroyed.
- The information I have provided will be destroyed 5 years after the research is finished.
- Any information I provide will be kept confidential to the researcher and the supervisor. I understand that the results will be used for a *Masters/PhD* report and a summary of the results may be used in academic reports and/or presented at conferences.
- My name may be used in reports.
- I would like a summary of my interview: Yes ☐ No ☐
- I would like to receive a copy of the final report and have added my email address below. Yes ☐ No ☐

Signature of participant: _____

Name of participant: _____

Date: _____

Contact details: _____

Appendix A - Background

Research

Additional Notes on a Research Session with Dr.

Nicola Kayes

Dr. Nicola Kayes, a specialist in the field of neuro-rehabilitation, has conducted studies into understanding the perspective of people suffering from stroke, using that knowledge to help them engage with the recovery process. She has also explored the role of the practitioner in the engagement process and what drives human behaviour in the face of injury and illness.

Kayes acknowledged the role of technology in regards to connectivity. It is certainly possible to engage in fun and entertainment without social connectivity. Anyone can experience film, music, games etc. by themselves and find it enjoyable. But a rehabilitation system that lacks any substantial connection to the user's personal clinic will not be as effective, as discussed in the literature. The connections between a patient and their goals, progress and motivation, are too important to bypass. Without the

greater context of recovery, and the system's connection to it, it is merely another niche mode of entertainment.

Kayes elaborated on this by explaining that patients who could not make a connection between the technology and their rehabilitation goals became frustrated by it. They had specific expectations on what the technology was supposed to accomplish, and when their expectations were not met, the patients stopped using the technology.

One last note Dr. Kayes made was the influence anxiety, depression and mental fatigue has on patients. It is common for survivors of stroke to be cognitively affected in such a way. This influences their ability to regulate their behaviour, meaning they struggle with developing and maintaining goals, identifying barriers, accepting and processing feedback and self-monitoring. Normally these skills are inherent and unconscious, but a stroke can remove that property, requiring renewed self-regulation from the survivor. The significance of this comes from the connection between self-regulation and self-motivation.

Further discussion with Prof. Taylor and Dr. Signal highlighted that they found the clinical tools they used were not effective at measuring small changes. They stressed the importance of granting patients with a clear sense of



progression. It is that sense of progression that keeps people motivated to continue, despite how small the changes are.

Additional Notes on a Research Session with Dr. Nada Signal

Dr. Nada Signal is a physiotherapy expert and researcher. She has conducted research into developing physiotherapy practice and has explored the benefits of “strength for task training” (STT). STT involves the “unilateral progressive resistive strength training of a relevant muscle group on the affected side immediately followed by locomotor task-specific training” (2014, p. 50). Dr. Signal’s time with us was spent discussing clinical reasoning for appropriate rehabilitation, and the factors that contribute to such reasoning.

A lot of therapy is task-specific training with little time being dedicated to aerobic and strength training. Task-specific information can be incorporated organically into the media of the intervention, allowing for the clinic time to be applied more effectively.

Additional Notes on a Research Session with Prof. Denise Taylor

Prof. Denise Taylor is a physiotherapy specialist and researcher. In our brief meeting she discussed the importance of repetition in rehabilitation. Over the course of a patient’s rehabilitation they are expected to conduct thousands of repetitions of the same movement. It is significant that each repetition is performed properly and that the patient does not lose interest.

Prof. Taylor declared variation of task to be a key element for maintaining patient interest. If the practice structure has elements that are random or varied, then they are more likely to hold the patient’s attention. This is apparent in many games that employ operant conditioning (Skinner, 1963) through random/semi-random reward structures to increase user play time.

Observation at NeuroRehab Results

Physiotherapy Clinic

Patient completed laps around the clinic. Every second lap he held a basket in his hands. The clinician walked the patient over padded mats, layering more on top to increase the difficulty of the task. The soft footing of the mats required the patient to apply greater control over their movements to retain their balance. The clinician engaged the patient in conversation during the task to distract them.

These simple tasks were designed to replicate everyday interactions the patient would experience. The tasks were reduced to their basic components and despite being physically challenging for the patient, there was little mental stimulation. The conversation provided by the clinician was the only mental distraction. The patient was observed to be focussing primarily on their movements.

The patient walked between a set of parallel bars at elbow height. On reaching the end of the bars, they turned 180 degrees and returned to their starting position. This action was repeated with the clinician providing verbal support and instruction.

We were informed of the significance of physical balance in physiotherapeutic training. Balance is required to participate in more complicated exercises and is paramount for regaining independent mobility. The parallel bars used in the exercise reduce the risk of patients falling and injuring themselves. As patients advanced in their capabilities, the bars were removed from training. This had to occur before the patient learned to become dependent on the bars for support. The only way for the patient to develop is to challenge them.

The doctors at the clinic reiterated the importance of effective lower-limb training early in the rehabilitation process. If a patient is capable of regaining their ability to stand and walk, they regain a significant portion of their independence. Even minimal lower-limb mobility can be useful, unlike upper-limb where tasks tend to demand more manual dexterity from people.

The most common phrase from Dr Taylor and Dr Signal was “it depends.” It depends on the patient. It depends on their circumstances. This increased the importance of having an adaptable system and it is from this meeting that ‘adaptability’ became a definite criterion.

An Interview with Samantha Ogilvie

Samantha Ogilvie is the Quality and Training Manager at the Wellington Hospital, as well as a researcher in rehabilitative care and procedures. Her research involves comparing two groups of patients with hemiparesis of the arm; one of which will undertake a period of rehabilitation using computer games and the other conventional therapy of passive exercises. She was able to provide insight to the type of experience a survivor of stroke might have in their day-to-day life.

Ogilvie provided us with a detailed example of a user profile based off a patient she had worked with in real life. From this profile and examples gathered from literature, it was possible to establish a set of user profiles that reflect the types of personalities we might encounter.

Another user profile we were introduced to reinforced the importance of task-specific training. This particular patient was a fond golfer whose balance was affected by a stroke, removing his ability to tee off the green properly. He was still capable of performing his short game and resultant showed a lot of interest in a digital game that let him play golf from home. Regardless of the mechanics of

the game, it was the personal relevance of golf that caught his attention.

Ogilvie stated that lower-limb rehabilitation tends to be more effective than upper limb. Whether or not this is because it is innately easier, more important or receives more time than upper limb is uncertain. Lower-limb functionality has a large impact on an individual's ability to tend to basic needs of life, e.g. walking, using the lavatory, getting in and out of bed etc. In contrast, upper limb functionality affects higher quality of life, e.g. playing a musical instrument, gardening, tinkering etc.. Lower-limb functionality enables more than just basic mobility; it is tied to one's sense of individuality and their ability to enjoy life.

When asked about the sorts of games she had observed older adults interacting with, Ogilvie claimed many were capable of handling those with a reasonable cognitive challenge such as chess, cards and tetris. Only those who had been significantly cognitively affected would not be able to play. Instead they played simpler games, such as bowls. She doubted such people would be capable of acquiring the skill-set necessary to learn a digital game, indicating our game may have a cognitive threshold for

suitable players. Ogilvie also mentioned that the younger side of the older generation tend to be more accepting of digital media and it makes sense to focus on them. While the oldest patients may not be capable of learning new technology, it is not the most relevant thing to them at their stage in life.

Appendix B - Expanded

Concepts

Four Seasons

This concept stemmed from the idea of familiarity. It used three standard playing decks, removing the face cards and using four suited counts from ace to ten. The lack of face cards meant the form of cards was not as relevant, and it evolved into a tile game, complete with four new suits: the four seasons.

The game was played by each player taking turns to place tiles on their respective suit. As tiles can only be played on those of lesser value, the amount of playable tiles diminishes with each turn, making the game a race. A scoring system between rounds gave players an overarching goal. The primary experiential goals of Four Seasons were control, strategy and the thrill of competition and luck.

The main mechanics explored through playtesting were making the ace flexible (to be played at value “1” or “11”), ‘5-go-low’ (where playing a five allowed the next tile to be of lesser value) and ‘consecutives’ (where having three tiles of consecutive value forced the rest of the tiles of that

suit to be consecutive in order of play). Variation of the size of players’ hands, the size of the deck and the way scoring was calculated were tested. Four Seasons was enjoyable to play and simple enough to learn as it borrowed all its mechanics from existing card games. This concept was the first attempt at striking a balance between confidence through familiarity of gameplay, and excitement through new content.

Interaction with the game system were depicted by basic user interface (UI) elements that represent the player’s real world movements. As card/tile games are generally played around a table with a player’s hands (opposed to feet), there was a large disconnect between the exercises and gameplay that cannot be avoided. Expressive UI elements were the simplest manifestation of the player’s exercises in-game. They could be accompanied by images of the proper exercise form etc. Unfortunately this did not support meaningful interactions as well as it could.

As Four Seasons was a multiplayer game, it promoted local connections with peers who play together, as well as give the clinician a chance to engage with their patients in a non-explicit physiotherapeutic environment. If network elements were introduced, the system could provide con-

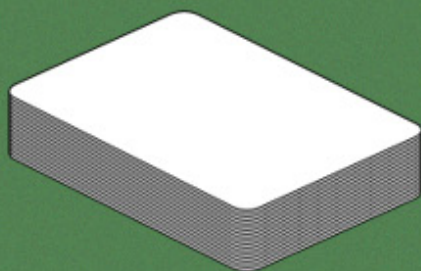
Four Seasons



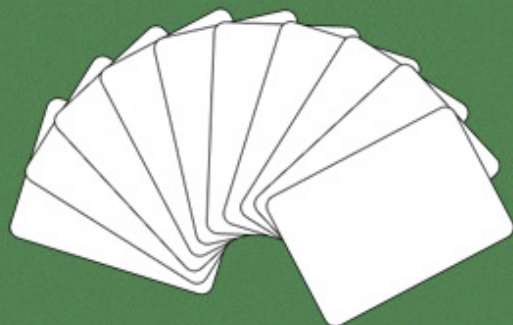
figure B1 - Four Rules



2-6 players



120 card deck
(3 standard decks
without face cards)



Each player starts the
round with a hand of
10 cards



= 4 points

At the end of each round,
players gain a point for
every remaining card in
their hand



Cards needed for
hand of 10 = 6



Cards left = 5



The game ends when there aren't
enough cards left in the deck to
top up every players hand to ten.
The player with the lowest score
wins (like golf).

Paxton	Janet	Bruce	Sophie
3	2	5	4
6	5	9	9
11	10	14	16
16	14	19	22



figure B2 - Four Seasons Gameplay

Each player plays one card per turn. Cards may only be played on the stack of their corresponding suit.

Players continue to take turns playing cards until they no longer have cards of higher value than those in play. At this point they must pass, and remain out of the round until its conclusion.

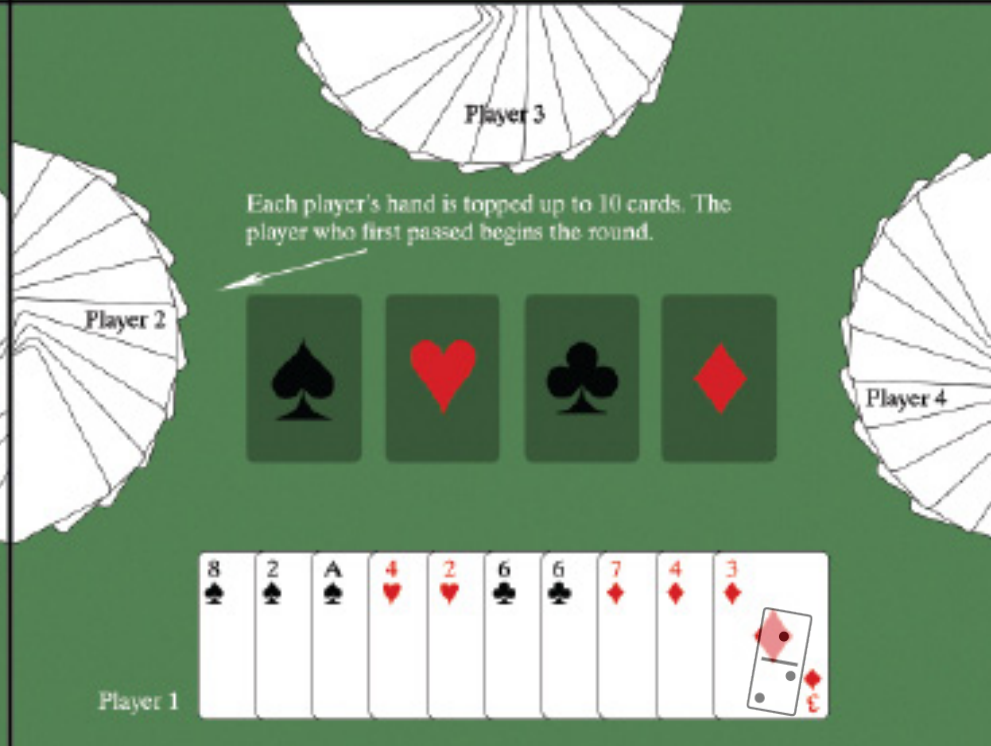
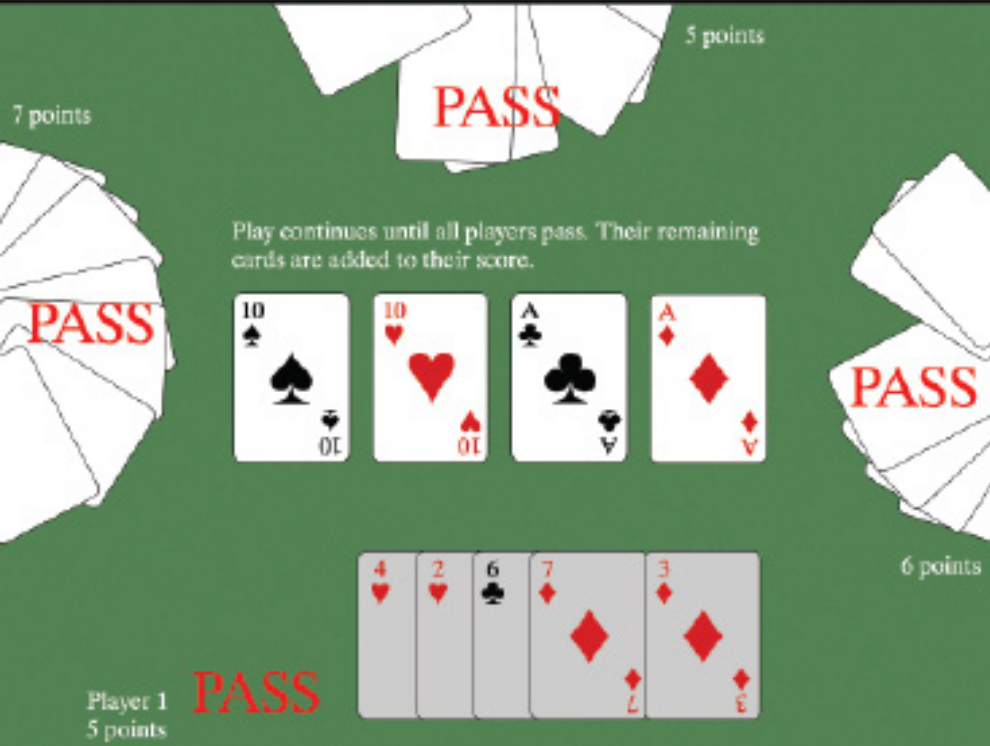
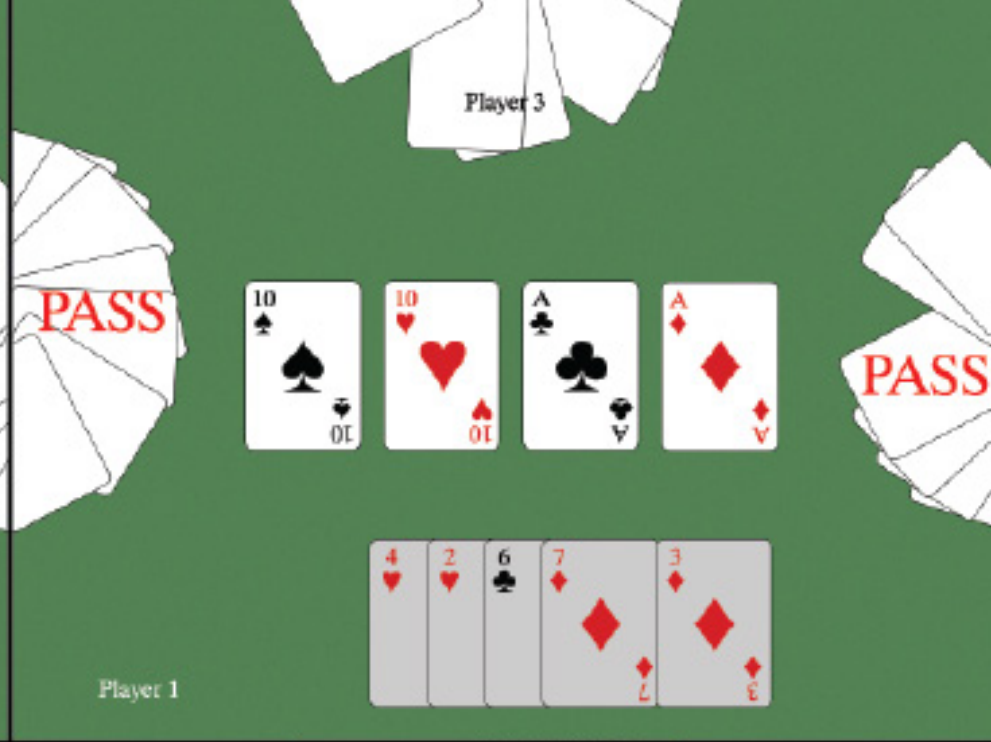
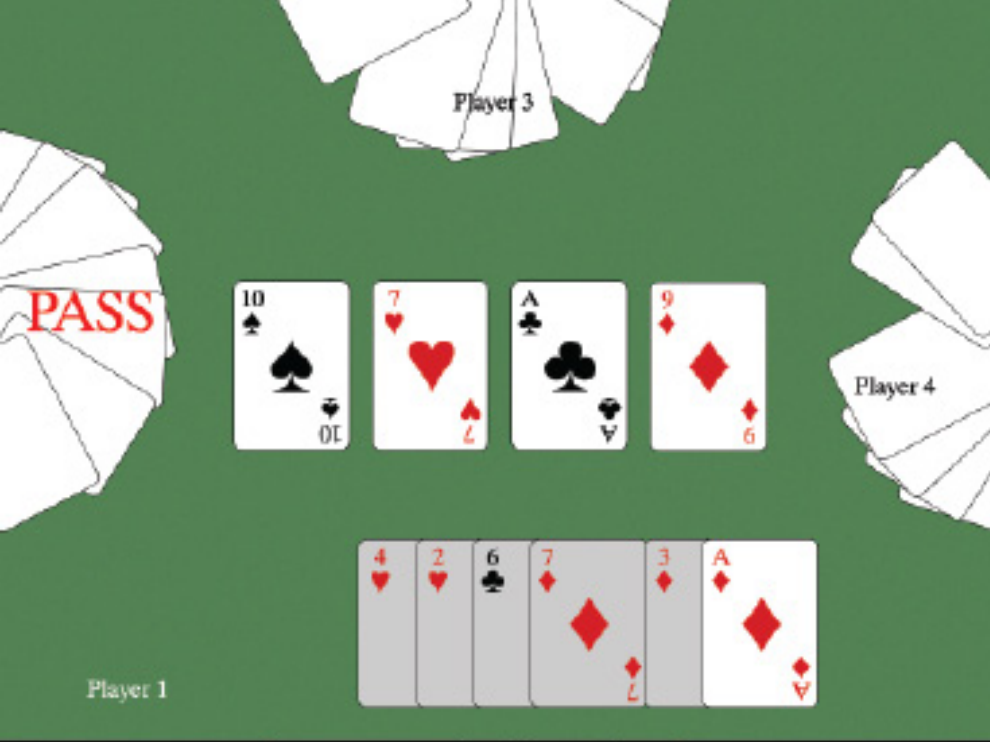
Cards may only be played if they are of greater numeric value than that which they are being played upon*, e.g. only a 5 or higher can be played on a 4.

*Ace's value is 1 when starting a pile. If the pile already has a card on it, then the ace's value changes to 11.



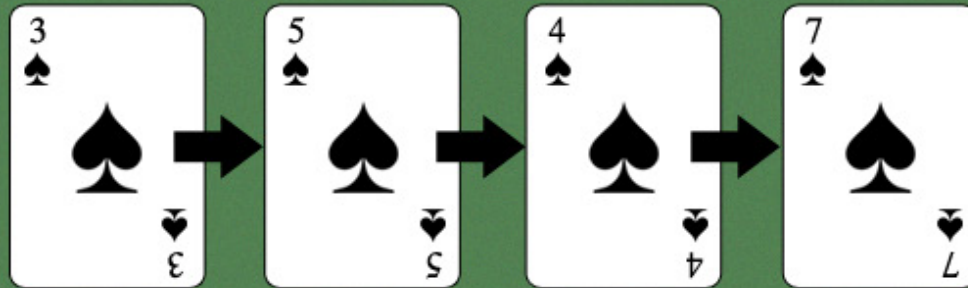
10 ♠	5 ♠	7 ♥	4 ♥	2 ♥	6 ♣	7 ♦	3 ♦	A ♦
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Alternative Rules

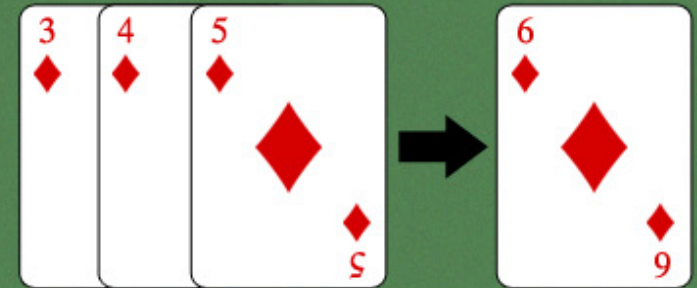
“5 go low”



If a 5 is played, the next card of that suit may be of lower numeric value. If an ace is played, the person who played it may call whether it is valued 1 or 11.

This rule can be either optional, or forced, i.e. if a 5 is played the next card **MUST** be lower, else players wanting to play that suit must pass.

“Consecutives”



If three cards of suit are played in their natural counting sequence (this includes ace, two, three), then the next card must follow that sequence, and every card thereafter, until the end of the round. The pile reaches its maximum at ace after ten.

figure B3 - Four Seasons Alternative Rules

nections with players in separate home spaces where each player would require a separate device. A potential barrier was that players were required to understand how to set up and join a networked game.

Lastly, the adaptability of the system would come down to the calibration of the device and the responsiveness of the UI, making it very flexible.

Plane Concept

This concept could manifest as either a 2D or 3D game, depending on how much input the player is able to give the system. The player performed regular exercises to keep the plane aloft as they delivered packages to different airports.

The rate of altitude loss and distance between airports varied depending on how frequently and how many repetitions the player needed to complete. In the 3D version of the game it was possible to have basic steering controlled by exercises too. This would depend on how much variety the player has or needs to train. If the player only had access to one sensor, some movements such as thigh

adduction and abduction became less viable. Additionally, the more controls attached to movements, the more accurately the device had to trace and separate them.

The adaptability of the system came from its flexibility of input. As long as the motions were mapped to the same axis for the plane, they remained meaningful. Cosmetic player customisation could also be included to appeal to a wider audience. The game focused heavily on single player and although multiplayer elements could be added, they would not affect the core gameplay.

Dominoes Concept

The game would simply be a digital recreation of classic tabletop dominoes. The two variants of dominoes that were examined were Tiddlywinks and The Mexican Train Game. Both rule sets embodied the criteria for success in different ways. Tiddlywinks had forceful play but is in short, snappy rounds; good for people with a shorter attention span. The Mexican Train Game had a less binding play-style and games tended to be a lot longer.



The betting aspect included in Tiddlywinks added competitive flair to gameplay and suited the shorter rounds. Networked players would require tabletalk functionality to enhance the social aspects of the game. The Mexican Train Game tends to cover a large table area and would require a comprehensive navigational tools for a digital version.

The strength of using dominoes came from the familiarity it had with an older audience and the simplicity of play (even card games have four suits to keep track of). The game would promote connectivity through local multi-player or over a network. Unfortunately the familiarity of dominoes meant playing the game using lower-limb exercises required abstract thinking from players for the interactions to be meaningful. It is likely such interaction could be viewed as a novelty, therefore needed to retain enough of its charm between games to enable repetition. The system could be adaptable through tweaks to basic game rules (e.g. size of hand, size of deck, amount of players etc.) and providing a large array of more advanced options.

Mountain Climbing Concept

Players adventure in bright, colourful environments to conquer mountains, temples, caverns etc. This concept held one of the strongest metaphors for the recovery process. The gameplay represented the physical exertion the players will experience in a light-hearted manner.

Gameplay was broken down to several simple phases. The first is planning the route, and requires cognitive effort from the player. Adding hazards provided challenge (e.g. some ledges can only be crossed once). The second phase required players to strafe to reach their desired route. The third phase, and primary gameplay, were the bouts between ledges. Climbing from ledge to ledge required several repetitions of an action that moves the player from handhold to handhold. The ledges functioned as rest points between climbs.

The adaptability of this game manifested in the level design. The more physical and cognitive exertion needed from the player, the longer and more complicated the levels needed to be. There could be small elements of avatar customization to increase player investment, but this was not the focus. The connectivity of such a game was lacking as the gameplay focused on singular interaction. The

gameplay, through the representation of player movement and the goals they were overcoming, would make interaction highly meaningful. This could be enhanced with an achievement system where the players retrieve treasures from their expeditions that represent personal goals (e.g. complete one hundred repetitions in a single expedition).

Perpetual Motion Concept

This concept revolved around removing forward motion from the player's control, making gameplay more reactive. It had the advantage of being able to be visually represented in a variety of ways. The exercise focused of this concept was using rotary motion to steer.

The pacing of the game was relatively peaceful to be suitable for a survivor of stroke, therefore gameplay did not focus on racing. Rather, motions were gentle and fluid, such as gliding, and obstacle/collectables had a large warning period so the player could react accordingly. The inclusion of an escape mechanic, such as a jump for obstacles, could be a good way of including diversity in the exercises required, as well as giving a player a way out if they are finding the steering exercises difficult.

The placement of obstacles and the speed of the player's avatar kept the system adaptable to different levels of skill and mobility. The game could include an endless mode where players can set personal records for endurance. The interaction consisted of held motions and is thereby only suitable for dynamic motion in-game, rather than rigid lane-based movement seen in games such as Temple Run. This dynamic motion gave meaning to the player's interactions as they were able to see a direct connection between their exercises and the motion depicted in-game. Connectivity was not addressed by this game as it was strictly single-player. Leaderboards for in-game accomplishments were not appropriate due to each player's device being calibrated to their physical limitations.

Painting Concept

This concept was directed at players whose mobility has been severely restricted. The game functions as a colouring book for adults. Players complete detailed vector illustrations by tapping on the area they wish to paint and completing repetitions to fill it with colour. The gameplay did not focus on action but instead provided a more relaxing experience.



Navigating the painting was suited to typical tablet interactions (dragging pan, pinching zoom etc.). Exercise repetitions behaved as a brush stroke, painting within the lines of the image. The pacing was completely under player control, meaning they could start, stop and save whenever they felt like it. Resultantly, this makes adjusting the size of the player's brush pointless. The game could keep track of various thresholds, alerting the player when they had done enough for the day.

The adaptability of this concept was largely under player control. They chose when to start and stop, and how complex the image they wished to paint was. This ran the risk of people with less motivation leaving exercises incomplete, but if the experience was relaxing enough, the exercises would not be as strenuous on the player. The ideal motion for painting was a simple back-and-forth movement to grant a connection between the player's movements and that of the on-screen brush strokes. The connectivity of the system came after the painting was complete, where players could email it to friends and family. Otherwise it was a strictly individual experience.

Sports Concept

Taking a page out of the Nintendo Wii's book, these were two visualisations of the same idea. Preference was given to the golf theme due to its popularity among older adults. It also functioned as a motivator for regaining lost mobility to play the game in real life.

Aiming was controlled by rotary motion and the power of the stroke came from either a lift and hold motion or several rapid repetitions. The golf variant recorded past play statistics to establish a player handicap that contextualised and motivated self-improvement. As play continued on a shot-by-shot basis, players could move at a pace that suited them.

The play experience was adaptable by the amount of holes, goals, hoops players attempted to complete and the difficulty of each shot. In golf it was a selection of different par courses; in football it was the distance of the shot and skill of the goalie. The meaning of each exercise was established through clear visual links between the exercise performed and the in-game result. Supporting UI could be used if players wish to see how their actions are being measured. Connectivity could be established through online leaderboards (albeit at the same risk of

not being truly representative). Alternatively, the turn-based nature of golf allowed for multiple people, either locally or through a server, to partake in the same course together. Generative courses were set with a par or recommended handicap average so users of similar skill could play together.

Sneaking Concept

This concept explored the stronger use of fantasy elements in gameplay while maintaining clear translation of player motions to in-game outcomes. The game's appeal came through the caricature that is the player's avatar and their melodramatic attempts to sneak along a noisy and obstacle-ridden passage.

Movement was controlled by two distinctive exercises. The more elongated of the two was used for the basic sneaking step for moving past sleeping persons. The tighter of the two was used for the hunched step for moving through illuminated areas. Switching between the two exercises provided variation to the player's routine. The exaggerated motions in-game provided a comedic interpretation of the player's actions.

The adaptability of the game relied on the player's successful calibration of the system. The exaggerated movements of the player's avatar removed any expectation they had to achieve similar motion; they simply needed to meet their calibrated bounds. Connectivity was established within the bounds of a clinic session where each player with a device joined the game. The player with the lowest calibrated range of motion led the group and each player had to synchronise their actions with the leader. Players who moved too far out of synch with their colleagues bumped into them, making noise. The purpose of this exercise was to bond members of the clinic together through mutual success and failure.



Second Concept Matrix Evaluation Expanded

Criteria

Multiplayer: the game's allowance for multiple people to play together in a single session. This could be over a network but local multiplayer was more valuable.

User profiles: the game's ability to provide personal profiles that tracked player progress and integrated it into gameplay.

Logical motion mapping: how clearly the player's real-world actions were related to their in-game results.

Ease of learning: how simple the game was to learn.

Adaptable difficulty: how well the game catered to variable player skill.

Variable input: the game's ability to respond effectively to a range of input motions.

Variation of task: the range of different motions that were incorporated into a single play session.

Replayability: the quality of experience and novelty the game retained through subsequent playthroughs.

Single player value: the quality of the game's play experience that did not require interaction from multiple human players.

Appendix C - User Testing

Strengths

Written feedback addressed the effectiveness of the animations in smoothing out the flow of the game, suggesting that the inclusion of more animations and dialogue that clarified the areas in need would be beneficial. The conversational language used in the tutorial made the experience more 'relatable' and easier to understand. Maintaining a personable interface would be important with the introduction of the medical aspects, as it was desirable for players to view the game as a means of entertainment, not as a medical tool. Being able to select a player icon was another popular feature that allowed the players to invest a small part of themselves in the experience. Having a wider selection of icons would enhance the effectiveness of this feature, appealing to a broader range of tastes.

Weaknesses

The sparse nature of the main menu felt too empty compared to the tight layout of the gameplay UI. Players also found the prompt text appeared too rapidly and detract-

ed from their sense of freedom within the game. Having the option to extend the time and/or turn off prompting would be useful. It was mentioned that the pre-game aspect of the tutorial was overwhelming as it depicted too much information that was not explicitly related to how to play (such as navigating the 'Options' menu). Several players found the pacing too slow when more than two people were playing. It was important to clearly portray how and when a round finished, and to distinguish between the causes.





USER TESTING QUESTIONNAIRE

(Please answer as many or as few questions as you wish)

1. I understood the rules of the game.

Strongly disagree 1 2 3 4 Strongly agree

2. The game was easy to learn.

Strongly disagree 1 2 3 4 Strongly agree

3. Interacting with the game was easy to understand.

Strongly disagree 1 2 3 4 Strongly agree

4. I understood what I could and could not do during my turn.

Strongly disagree 1 2 3 4 Strongly agree

5. It was clear when my actions were successful.

Strongly disagree 1 2 3 4 Strongly agree

6. It was clear when my actions were *not* successful.

Strongly disagree 1 2 3 4 Strongly agree

7. The game was fun and engaging.

Strongly disagree 1 2 3 4 Strongly agree

8. The game was challenging.

Strongly disagree 1 2 3 4 Strongly agree

9. The next time I play, I would be able to play it better.

Strongly disagree 1 2 3 4 Strongly agree

Please turn over.

10. I would like to play this game again.

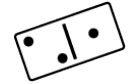
Strongly disagree 1 2 3 4 Strongly agree

A. What was your favourite part? Why?

B. What parts did you not enjoy? Why?

C. What parts of the experience did you find confusing?

D. Are there any features you would like to be included? What are they?



INTERVIEW QUESTIONS (over the phone)

Inclusion Criteria:

- ☐ Have you experienced a stroke before/have cared for someone who has?
- ☐ Did you experience left or right hemiplegia?
- ☐ What is your shoe size?
- ☐ How has your stroke affected your arms or legs?
- ☐ How has your stroke affected your walking?
- ☐ Can you stand independently and lift one foot while standing?
- ☐ Do you have any muscular or skeletal related pain?
- ☐ Can you tell me how fast you can walk?
- ☐ Will a caregiver be with you during the sessions and interviews?

Recovery:

- ☐ What are your recovery goals?
- ☐ What do you do for stroke therapy in your own home?
- ☐ In the last week, on average, how much time do you spend each day on this?
- ☐ Do you use any devices to assist you with home therapy?

Technology:

- ☐ How much time do you spend using computers, the internet, smartphones, or tablets each day?
- ☐ Do you find technology easy or difficult to use?
- ☐ Which bits are easy, which bits are difficult?
- ☐ Have you played digital games before?

USER TESTING INTERVIEW

(For each question we will be looking for an answer in regards to the media and the device itself, prompting if necessary)

- A. What parts of the experience did you enjoy? Why?
- B. Was there anything you did not understand or enjoy? Why?
- C. Are there any other features you would like to see included? What are they?
- D. How does this experience compare to your usual rehabilitation?
- E. At any point, did you experience pain or discomfort?
- F. Can you comment on the look of the shoe?

Additional User Information: “Bernie”

Bernie plays Crib, Euchre and Poker with their friends at the stroke club, meaning they still have the capacity to play complex games. Despite this, Bernie’s confidence with using the tablet limited their ability to interact with it. They did not appear to understand elements of the UI and quickly gave up. Their rejection of the system was likely a mix of reasons. The tutorial was rather word heavy and could have been intimidating. The flat design of the UI was too subtle, with interactive elements needing to be bolder (Bernie was not the only participant who had difficulty identifying buttons). It could have also been the result of Bernie’s limited attention span or willingness to learn something new. Due to their minimal input in the post-test interview, the best we can do is speculate.

The significance of Bernie’s test is that it is an example of our designs failing. It became apparent that the type of system that Bernie would be capable of interacting with differs greatly from what we presented. Adjustments could be made to the interface and core mechanics of the game to suit someone of their abilities, however the system would resemble something quite different at this point. Functionality that achieves this could be implemented, yet setting up the options to reach such a state

would require external help. It would be simpler to claim that there is a threshold of cognitive capability that needs to be met for the current system to be usable.

User Test 1 – Additional Notes

ALEX

- Owning a personal computer system is too expensive for many older adults.
- Tapped ‘play’ before it was available in tutorial.
- Was not confident enough to hold iPad and play at the same time; needed table nearby.
- Thought the system would be best suited for people who were recently in hospital from stroke.
- Needed clarification of how the score worked in-game.
- Didn’t understand the counting down of reps on priming. Wording could be clearer.
- Wasn’t sure about “When you’re ready” button.
- Animation needs to present the back and forth, not just one direction.

- Tried to press exit button to leave tutorial prompts.
- “You’re not a dummy. You can still make your brain work.”
- Thinks have a version available at the club would be competitive. “They love it at club when they have one another on. They love competition.”
- The system needs to be brought on in stages. “Not bang all together.”
- “If you’re expected to do it in a hurry I don’t think it would be any good.”
- Early stages of stroke need to have slower pacing.

BERNIE

- Tapped simulate to no response when it was visible beneath the tutorial text.
- Was dragging over buttons which nullified their functionality.
- Tried pressing greyed out buttons in the tutorial.
- Instructions for one handed use should be included.
- Seated version of exercises is definitely necessary.

CHARLIE

- Highlighting the area of description is necessary in the tutorial.
- Direction of motion for exercise needs to be clearly established.
- Prompt to take first step (first rep) necessary to get dominoes moving forward.
- Blank tiles did not register as a match with other blank tiles.
- Shifts in turn phases need to be clearer.
- Toggle-able visual aids on the interface would be beneficial.
- She could make cognitive connections between similar tasks. E.g. reading the game instructions vs. reading letters in her mail.
- “We need to be able to work out the technology and be able to do it for yourself.”
- The game removes the fiddly interaction with placing the dominoes in the right place. Instead, it focuses on training the brain to recognise the numbers.
- “When there isn’t a number on the tile, my brain doesn’t see that end of the tile at all.” May take a couple



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USER TESTING INTERVIEW

(For each question we will be looking for an answer in regards to the media and the device itself, prompting if necessary)

- A. What parts of the experience did you enjoy? Why?
- B. Was there anything you did not understand or enjoy? Why?
- C. How do you think the system could be improved?
- D. At any point, did you experience pain or discomfort?

of games down the track to learn this. It doesn't necessarily mean it's a bad thing.

- There were points where she wasn't sure if she had done the right thing but she liked that it made her think. It put her out of her comfort zone. "We need to be pushed to get the brain to do these things."
- "The more that we can do for ourselves the better."
- Can relate aspects of the game to other real-world actions like using the telephone or the toaster. "The phone's not so scary after all."
- Make it clear that doubles are required to start.

DANNIE

- Grey buttons caused more trouble for not being clear enough.
- Prompting from hand to table exercise needs to be a thing.

User Test 2 – Additional Notes

General

ALEX

- Emphasised how some survivors of stroke may not have access to adequate facilities, meaning home-based rehabilitation is the only viable option they have.
- Would not have been able to perform the exercises without using the table for support.
- Someone who is less able needs to start with less exercise, less weight, set by clinician.
- Believed most important point to introduce the system was early on in the recovery process. "Get them in the earliest stages of the rehab."

CHARLIE

- Had TIAs (Transient Ischemic Attack) in 2009, 2010 and 2011.
- Having a physical version of the instructions (for both game and orthosis), printed on sturdy material,

e.g. laminated card, would provide security. Users may not be confident trying to get help from the machine and having the card available as a fall-back would avoid embarrassment.

- The card would “[remind the user that they] are okay to continue.” “Just knowing that the card is there might remind me of what is going on. I might not even need to read it.”
- Enjoyed the experience because it is “new, exciting and helpful.” It allowed her to see where she is at (with her own capabilities).

Media Specific

ALEX

- Once you accomplished something in game, it felt like you’d learnt something.
- Wording of selection prompt to start exercises needs to be more obvious. Needs more clues for what to do.
- Indication to put on weight/take weight off need to be clearer - diagram may suffice.

- Bug: double control no longer triggers.
- Open face arrows purpose is not being communicated. Was not sure which the open face was.
- “When you’re ready...” should be reworded to “Press me when you’re ready.”
- Started doing exercises on Clear Space screen.
- Enjoyed the novelty of the dominoes moving forward in response to her movements.
- Interpreted highlighted dominoes as buttons.
- Acknowledged it would come easier once you got used to it.
- Need clearer visual representation of separation between table (played dominoes) and the dominoes in hand.
- Explanation for BLOCKED (Everybody passed) needed.

CHARLIE

- Looking down while concentrating made her feel dizzy. Had to sit down after tutorial and have a glass of water.

- Wanted visualisation of the exercises in addition to the written prompt to remind her which exercise to do when.
- Before priming, break the exercise down into a step by step process: explain how it works with accompanying animation, add suggestions if needed (e.g. you can hold the edge of the table if it helps you keep your balance), let them practice the motion with supportive messages (e.g. “a little higher”) and once they get it right it counts as their first repetition towards 15. There should be the option to remove this functionality once the player feels they have mastered the exercise’s form. A similar process would take place before the main phase as well. For something like sidestepping, mention to lead with the weaker foot (the foot that did the strength training reps).
- Having a button that loads this demonstrative information would be necessary. “It’s okay. We’ll show you to help you remember.”
- Addition supportive information should be included: “If you feel tired or dizzy, take your time to sit down and drink some water.”
- Mixed mediums of communication is necessary. Charlie is more confident with written instruction but

other people she knows are more dependent on diagrams or spoken instruction.

- Expressed excitement to play. Used the game as a test of where her abilities were at.
- Talked of how the offer to play a game made her feel wanted as a person.
- Everything comes back to independence.
- “We are not a forgotten cause. You’re still a person and should be treated like a person.”
- The option to request help from the game, or exit it entirely, felt like a failsafe if she messed anything up in the game.
- Acknowledged the beginning of strategy. Thinking about what her opponents held in their hands.
- Felt words, numbers and movement were the most important things to be exercising.
- Don’t put time pressure on anything. The player must know that they control the pace.
- Liked that it encouraged her to read. If they are still processing one piece of information, all other information presented at this point will be missed.



- The offer to play a game made her feel included - “It all boils down to feeling needed, wanted and independence.”
- “Just because I’ve had a stroke doesn’t mean I’ve lost the plot.” “We’re not a forgotten cause.”
- Found the bright aesthetic appealing.
- “It might be repetition, but every time you’re doing it you’re getting better, getting faster.”
- “Let people know if they can’t do it, it’s okay” - You can ask for help at any time.

- By the end of the game he was acting without the aid of prompts.
- Got muddled by which exercise to do when.
- Make sure prompt to remove sole and put sole on is explicit.
- Found moments of gameplay (starting a round with a double) confusing from lack of experience with dominoes.

DANNY

- “It’s stimulating in both ways” - in reference to cognitive and physically.
- Also needed clearer reminder imagery for which repetitions he was supposed to be doing.
- Was tired after game - “starting to break out a sweat.” Necessitates having a build up into more difficult exercises. Completed 30 leg raises and 55 sideways steps and believed the maximum he could accomplish would be roughly double.

Appendix D - Additional Online Resources

- Tiddly-Wink Domino Rules, 2016. Retrieved from <http://www.domino-games.com/domino-rules/tiddly-wink-rules.html>
- Stroke Foundation of New Zealand, 2016. Retrieved from <http://www.stroke.org.nz/>
- Stroke Central Region, 2016. Retrieved from <http://www.strokecentral.org.nz/>
- Stroke Recovery Association of BC, 2016. Retrieved from <http://strokerecoverybc.ca/>
- 7 Steps to Stroke Recovery [Video file], 2014. Retrieved from <https://www.youtube.com/watch?v=GH-JL42xFuz8>

