UNIVERSIDADE
LUSÓFONA

Pedro Miguel Alves Fernandes

Dynamic Difficulty Adjustment to Improve Player Experience in Games for Rehabilitation

Orientador: Professor Doutor Pedro Pinto Neves

Universidade Lusófona – Centro Universitário de Lisboa
Escola de Comunicação, Arquitetura, Artes e Tecnologias da Informação
Lisboa
2023

www.ulusofona.pt

UNIVERSIDADE
LUSÓFONA

Pedro Miguel Alves Fernandes

Dynamic Difficulty Adjustment to Improve Player Experience in Games for Rehabilitation

Dissertação defendida em provas públicas na Universidade Lusófona – Centro Universitário de Lisboa, no dia 19/12/2023, para a obtenção do grau de Mestre em Design de Jogos e Media Jogáveis, perante o júri nomeado pelo Despacho de Nomeação n.º: 506/2023, de 11 de dezembro de 2023, com a seguinte composição:

Presidente: Professor Doutor Filipe Luz da Universidade Lusófona – Centro Universitário de Lisboa

Arguente: Professor Doutor Carlos Martinho do Instituto Superior Técnico

Orientador: Professor Doutor Pedro Pinto Neves da Universidade Lusófona – Centro Universitário de Lisboa

Co-Orientador: Professor Doutor Phil Lopes da Universidade Lusófona – Centro Universitário de Lisboa

Universidade Lusófona
Escola de Comunicação, Arquitetura, Artes e Tecnologias da Informação
Lisboa
2023
www.ulusofona.pt

Acknowledgements

This work was only made possible by the support and guidance of Professor Pedro Neves and Professor Phil Lopes.

This work was funded by Fundação para Ciência e Tecnologia under grants UIDB/05380/2020 (HEI-Lab), and EXPL/COM-OUT/0882/2021 (PlayersAll project).

Abstract

[EN] Applied game design aims to take advantage of the elements of games and their design to create activities that increase motivation and engagement, providing benefits to topics such as education, health, and rehabilitation. This dissertation reports on the design and development of a virtual reality singleplayer game to complement upper-limb rehabilitation: *Village Druid*. The game aims to provide a valuable contribution to the rehabilitation treatment without abandoning any of the defining traits of games such as player agency or re-signification. Another relevant challenge identified in the research done for this project had to do with how the poor handling of difficulty would result in negative experiences that affect the player's motivation and engagement with the treatment. The chosen solution for this was the implementation of a dynamic difficulty adjustment (DDA) system. In this dissertation are described the main design decisions for a serious game for rehabilitation (*Village Druid*) and how it uses DDA to accomplish its goals - and solve the challenges identified. Also, the dissertation reports on the playtesting sessions conducted with a prototype of the game featuring DDA (Prototype 2.0). These playtesting sessions featured stakeholders of the project, and the goal was to evaluate how the DDA system adapted the game's difficulty according to their performances and how they perceived the system. The contributions of this dissertation are the discussion of the results from the playtesting sessions - how they demonstrate that the inclusion of the DDA system in the prototype improved the player experience; and the compilation of three game design patterns derived from the design solutions created for *Village Druid*. Future study discusses how the DDA system could be expanded and tested.

Abstract

[PT] O propósito do Game Design Aplicado é criar atividades que usam aspetos dos jogos e do design de jogos para aumentar motivação e envolvimento, o que é benéfico em áreas como a Educação, Saúde, e Reabilitação. Esta dissertação relata o processo de design e desenvolvimento de um jogo de realidade virtual para jogador-único (*singleplayer*) que serve de meio complementar de terapia de reabilitação do membro superior: *Village Druid*. O jogo pretende contribuir de forma relevante para o tratamento de reabilitação sem prescindir das características fundamentais dos jogos: agência e re-significação. Outro desafio relevante identificado durante a investigação realizada para este projeto relaciona-se com a má-gestão de dificuldade do jogo para os jogadores, que pode resultar em experiências negativas que afetam a motivação e envolvimento dos jogadores com o seu próprio tratamento. Para ultrapassar este desafio, optou-se pela implementação de um sistema de ajuste dinâmico de dificuldade (*DDA*). Esta dissertação descreve as principais decisões de design para o jogo sério para reabilitação (*Village Druid*) e como este utiliza DDA para cumprir os seus objetivos – e resolver os desafios identificados para o jogo, dado o seu propósito. A dissertação dá igualmente os resultados obtidos em sessões de playtesting realizadas com um protótipo do jogo que implementa DDA (Protótipo 2.0). Estas sessões de playtesting tiveram como jogadores-teste clientes e terapeutas de reabilitação do projeto. O objetivo das sessões era avaliar como o sistema de DDA adaptou a dificuldade do jogo de acordo com a avaliação dos jogadores e qual foi a sua perceção do sistema. O contributo desta dissertação reside na discussão dos resultados das sessões de playtesting – como demonstram que a inclusão do sistema de DDA no protótipo melhoraram a experiência do jogador, bem como a compilação de três padrões de design de jogos derivados das soluções de design criadas para o *Village Druid*. A secção de trabalho futuro debruça-se sobre como o sistema de DDA poderia ser alargado e sofrer mais validação.

Contents

Chapter 1

Introduction

Serious games, or products of applied game design (Schmidt et al., 2015), that are produced to complement rehabilitation treatments aim to positively impact engagement and retention (Mader et al., 2016). However, these projects often fail to create experiences that provide these expected benefits due to a misunderstanding of what games are and what critical elements constitute them (Mader et al., 2016). Creating a game that successfully contributes to rehabilitation while maintaining its features as a game to improve engagement and retention is a significant design challenge. Directly facing this challenge is important in order to avoid creating entertaining games that don't contribute to the treatment or games that, by missing key features of games, fail to generate engagement in the treatment they are integrated in.

Upper-limb rehabilitation treatments often involve several sessions with a therapist or health professional where the rehabilitation patient, alternatively termed the client, performs specific beneficial physical exercises repeatedly for their recovery. These activities, although effective, can be repetitive, tiring, and monotonous (Mader et al., 2016). These conditions lead to a lower engagement from the client with the treatment, eventually impacting its retention and resulting in clients dropping out of therapy (Mader et al., 2016). For these reasons, (upper-limb) rehabilitation is a field that stands to benefit from the use of serious games - integrating existing exercises in games (Mader et al., 2016). Serious, or applied, games propose the use of games in a manner that will positively impact areas such as education, health, and rehabilitation (Schmidt et al., 2015). These games are meant to improve, and maintain, the player's engagement and retention as they learn a certain topic or perform certain activities that are relevant for their health (Hendrix et al., 2018). However, this concept sometimes provides lackluster results because the 'game' aspect of a serious game is ignored (Mader et al., 2016) - with key elements of games such as player agency and re-signification (Schmidt et al., 2015) missing; which results in lower engagement and retention from the players (Hendrix et al., 2018; Mader et al., 2016). Also, in the case of rehabilitation, different interfaces may be required for the game to properly contribute to the client's treatment and recovery.

With the advent of virtual reality (VR), new ways of interaction emerged, introducing users to 3D virtual environments they could 'physically' interact with through handheld controllers or hand tracking. With these interfaces, an opportunity emerges where a serious game - through applied game design - could provide clients of an upper-limb rehabilitation treatment with an engaging experience that has them perform movements or exercises that contribute to their recovery in the rehabilitation treatment.

As mentioned, the game aspect should still be preserved (Mader et al., 2016), as otherwise such a 'game' would simply be simulating the exercises that would performed without the game - missing out on the potential benefits a serious game can bring to motivation and retention (Mader et al., 2016). Also, a critical concern that must be addressed in the design of any serious game is the element of difficulty (Hendrix et al., 2018); this concern is especially relevant in a game dedicated to rehabilitation because the players' ability to play the game will be directly linked to their current condition as clients of a rehabilitation treatment.

This dissertation reports on the design process and playtesting results of a prototype for a virtual reality (serious) game that, through serious, or applied game design (Schmidt et al., 2015), aims to complement upper-limb rehabilitation while investing in the design of systems that commit to its defining elements as a game; intending to treat the clients as players. This prototype features a dynamic difficulty adjustment system, with a focus on exploring its impact on the player experience - positive or negative. The dissertation includes the following chapters: Related Work, Design Concept, Design Process, and Testing; ending with a Conclusion.

Chapter 2

Related Work

2.1 Introduction

This dissertation reports on the design process followed when creating a virtual reality (VR) game that complements upper-limb rehabilitation treatments as a product of applied game design (*Village Druid*), along with the implementation and testing of a dynamic difficulty adjustment (DDA) system on a prototype of the game; discussing on the effects it had on players' experiences while playing. Related theory gathered focuses on the main topics of this dissertation: applied game design and serious games (including how they have been explored for rehabilitation games), and difficulty and DDA systems; gathering knowledge on the ways to analyse, measure, and change difficulty in games, along with descriptions on the different methods of implementing DDA systems and their benefits/risks. This chapter also gathers a definition of 'game' since it relates to the goals for the rehabilitation game's design, taking advantage of elements often missing from serious games, and contextualizes design decisions made for the game.

2.2 Applied Games

The goal of this work was to design a VR game that contributed to upper-limb rehabilitation treatments while the treatment's clients could enjoy it simply as a game - becoming players. To inform the design of the game and how it could contribute to the rehabilitation efforts, the topic of serious games and applied game design was explored, along with the concept of 'therapeutic games' which describes how a game can contribute to the therapy it aims to assist (Mader et al., 2016); a definition of games was also found to better understand what features from games tend to be missing when they are used in instances of applied game design.

Applied game design, also termed serious games (Schmidt et al., 2015), relates to the potential of utilizing games for a variety of purposes which originally comprised primarily education and learning, but have also come to include many other topics such as training, public health, civic participation, activism, and more. One of these topics is rehabilitation, and using games to complement rehabilitation therapy. Mader et al. (2016) state that "One of the most problematic issues in healthcare is the patient's lack of adherence to the therapy". Serious games in this context have been explored due to the need of improving patients' motivation to follow their therapeutic protocol (Mader et al., 2016); with applied game design in this topic attempting to turn existing exercises - which tend to be repetitive and monotonous -

into games in an effort to maximize the patient's motivation (Mader et al., 2016).

However, the main concern that arises, that dictated the (applied game) design process that would be used for the *Village Druid* game, is that these games often only partially implement features typical of a game, missing elements such as agency and narrative. This results in gamified activities that simulate the rehabilitation exercises that would be done without the game; exercises that are designed to be effective in a therapy context and tend to be tedious and repetitive on their own, affecting the client's motivation which in turn affects the effectiveness of the serious games (Hendrix et al., 2018) and the treatment's retention in general (Mader et al., 2016). The approach that is followed in the design process of *Village Druid*, and that this dissertation reports on, relates to Mader et al.'s description of a "therapeutic game" and how its design needs to have "a gameplay from which meaningful, motivating play sessions will emerge", while still providing a "very specific therapeutic effect"(Mader et al., 2016). Their article describe the use of gameplay and game actions that directly contribute to therapy while sustaining the player's motivation as 'therapeutic gameplay'[1] (Mader et al., 2016), and define games that produce "a direct, expected, and intended therapeutic effect on patients playing them" as 'therapeutic games' (Mader et al., 2016). The design process followed for designing *Village Druid* also included the integration of its stakeholders, both health professionals and rehabilitation treatment clients, in its development. Health professionals validated the game's contribution to the rehabilitation treatment and playtesting sessions were performed with clients as required by Mader et al. (2016). Also, the health professionals were integrated in the design process through participatory design, providing their input when creating the activities that would constitute the meaningful ('therapeutic') gameplay where clients/players perform "at least one action that is beneficial for his/her health" (Mader et al., 2016).

To better understand what elements tend to be missing from most rehabilitation games, one can look at Waern's definition of a game: a "(designed or emerging) system of rules, goals and opposition, which has as its primary purpose to allow people engage with it for paratelic reasons, while agreeing that the actions performed are re-signified" (Waern, 2012). A better understanding of what features and traits complement a game is relevant for more successful applied game design, as it allows to leverage those same elements to create a more engaging experience, which will lead to a more positive impact on its users and greater retention (Hendrix et al., 2018; Mader et al., 2016). Two relevant terms mentioned in Waern's definition are paratelism and re-signification. Paratelism refers to an activity being done for its own sake, but with explicit goals, while re-signification refers to how a game confers multiple overlapping meanings to activities in that game; it entails the literal meaning of an action that is represented in the game, the meaning of that action as abstracted into the game rules, and its internal meaning generated through play (Waern, 2012). These elements (agency, narrative) were also taken into consideration throughout the design process to create the *Village Druid* game (see 3.2.3 and 3.2.2).

2.3 Difficulty in Games and its Systems

As the game being designed was meant to complement rehabilitation therapy treatments, maintaining the player's motivation and engagement was paramount (Hendrix et al., 2018; Mader et al., 2016).

[1] As an example of this 'therapeutic gameplay', Mader et al. (2016) describe an activity where the player has to collect ten apples and to do so must execute a specific movement that contributes to the improvement of their health conditions.

One of the major concerns identified in this regard was difficulty, since any friction regarding the challenge of the game would affect the player's experience - and would most likely relate to their condition as a rehabilitation treatment client. For this reason, different difficulty systems were explored, resulting in the selection of a dynamic difficulty adjustment (DDA) system.

To implement a DDA system, it is important to understand what characterises 'difficulty' and what techniques may be used to measure it, along with gathering relevant information regarding DDA systems and their risks/benefits. In Dagmara Dziedzic & Wojciech Włodarczyk's article: "Approaches to Measuring the Difficulty of Games in Dynamic Difficulty Adjustment Systems" (2018), the authors describe different types of difficulty systems, including DDA (see 2.3.1), provide descriptions of relevant terms to discuss DDA systems (see 2.3.2 and 2.3.3), and propose three possible approaches for measuring difficulty when developing such a system (see 2.3.4). This article provides the main guidelines for the design of the DDA system featured in *Village Druid*, and the terms proposed in the article (see 2.3.2 and 2.3.3) are used throughout this dissertation. Another article analysed,"Exploring Dynamic Difficulty Adjustment in Videogames", speaks about the positive benefits of DDA, along with the risks that need to be considered when implementing it (Sepulveda et al., 2019); the article also provides relevant suggestions and good practices that proved valuable in the development of *Village Druid*'s design and its employment of a DDA system. Lastly, Hendrix et al.'s "Implementing Adaptive Game Difficulty Balancing in Serious Games" (2019), also provides insights into how a DDA system can be relevant for improving engagement in a serious game, and features an implementation method for DDA systems (Hendrix et al., 2018) that mirrors the process followed for *Village Druid*, listing the following steps - here employing the terms used by Dziedzic and Włodarczyk (2018):

1. Identify the *performance indicators*;
2. Identify the *game parameters*;
3. If an implementation of the game already exists, identify the two types of features;
4. Identify how many different mechanics there are, and if they require identifying new specific features;
5. Decide how the *performance indicators* are used to calculate difficulty;
6. Determine the starting values for the used features.

2.3.1 Difficulty Systems

Digital games most often have one of two difficulty systems: 1) a single difficulty system where every player will have the same difficulty settings and progression, or 2) multiple static difficulty levels such as: easy, medium, and hard. Both of these systems are characterized as 'game-centered design' (Dziedzic & Włodarczyk, 2018). The parameters of the game, and their progression, are static and independent of player behaviour - treating "every player equally and ignoring differences in their abilities and preferences" (Dziedzic & Włodarczyk, 2018); instead, they are determined independently by human experts (e.g. game designers) (Dziedzic & Włodarczyk, 2018). Hendrix et al. (2018) describe these experts' goals as an attempt to "be in line with most players within the target audience" [2]; and, when

[2]Hendrix et al. (2018) mention the use of "achievements, timing, or scoring" as a means to avoid limited "succeed or fail" outcomes, with players having the opportunity to adopt more challenging playstyles in search of an achievement or a higher score.

discussing the "common affordance" of multiple static difficulty levels, they describe it as 'player-driven difficulty selection' as players "directly attempt to match the level of challenge to their perceived skill" (Hendrix et al., 2018).

These two approaches, however, have some weaknesses. Simply, it is not possible to have a single difficulty level that is fit for every player (Sepulveda et al., 2019), and the use of multiple static levels of difficulty means that there will inevitably be gaps where some players find themselves and end up feeling abandoned (Dziedzic & Włodarczyk, 2018; Sepulveda et al., 2019). Additionally, these modes' game-centered (Dziedzic & Włodarczyk, 2018) difficulty progression will likely also mismatch some players' learning curves (Dziedzic & Włodarczyk, 2018; Sepulveda et al., 2019), and having the player change the difficulty because of this will affect the game experience (Sepulveda et al., 2019). A related concern raised by Hendrix et al. (2018) that is especially relevant for the context of *Village Druid* as a game to complement rehabilitation, is that the subjective assessment that is required from the multiple static difficulty model can affect the critical early stages of engagement as players try to discover their ideal difficulty "through a frustrating cycle of trial-and-error" (Hendrix et al., 2018). As an alternative, the third and last system listed by Dziedzic & Włodarczyk are dynamic difficulty adjustment (DDA) systems that specifically adapt the game to the player as they play; these are characterized as 'player/user -centered design', referring to games that are designed "so that they can meet the expectations of players" (Dziedzic & Włodarczyk, 2018).

Dynamic Difficulty Adjustment

DDA systems are designed to ensure the difficulty of a game can match each individual player by modifying some elements of the gameplay that affect its general difficulty according to the player's performance or their affective states (Dziedzic & Włodarczyk, 2018). Dziedzic and Włodarczyk (2018) argue that a DDA system in a game allows it to reach more players, whether it be a commercial production, games with a purpose, serious games, educational games, and - especially relevant for this dissertation - rehabilitation games (Dziedzic & Włodarczyk, 2018); stating that "games with challenges adjusting to the skills of players can reach a larger audience, be more interesting for the players and educate them more effectively" (Dziedzic & Włodarczyk, 2018). This relates to DDA systems' association with player-centered design, as it aims to provide a balanced and engaging experience to every player by adjusting the gameplay to the skills of each individual player (Dziedzic & Włodarczyk, 2018). A successful implementation of a DDA system, that accurately balances the game's difficulty level (based on its difficulty conception) to a player's skill has great potential to positively impact player retention and increase engagement, allowing for a better game experience (Dziedzic & Włodarczyk, 2018; Hendrix et al., 2018; Sepulveda et al., 2019) [3]. The benefits a DDA system can bring to player retention and engagement are important for serious games and products of applied game design as these often require a minimum amount of time - and engagement - from players to deliver any relevant outcomes (Hendrix et al., 2018). These benefits, however, are conditional to a successful and careful implementation of the system[4], as a

[3] Sepulveda et al.'s article is not focused on rehabilitation or even applied game design, as one of the benefits mentioned in creating a successful DDA system is monetization, referring to "game developers, from independent ones, to 100 billion dollar businesses" (Sepulveda et al., 2019). Hendrix et al. (2018) explicitly state that the end-goal for retention and engagement in entertainment games is linked to monetization.

[4] Depending on the complexity and requirements to successfully manage a game's difficulty, a DDA system may entail the use of procedural techniques to extend or adapt the game's content (Hendrix et al., 2018).

poor implementation can result in the direct opposite to the benefits mentioned and a structure that leads to its overuse can result in a higher processing consumption that may affect the game's performance (Sepulveda et al., 2019).

2.3.2 Game Parameters & Performance Indicators

Two relevant features to understand when discussing DDA systems (see 2.3.1) are *game parameters* and *performance indicators*. Game parameters describe the selected elements of the game that will be controlled by the DDA system to affect the complexity or difficulty of a task (ex. damage of enemy attacks, amount of hit-points available) (see 2.3.3). Performance indicators are used to assess how much difficulty a player had in completing a task (ex. number of lives lost, average rate of coins gained) (Dziedzic & Włodarczyk, 2018; Sepulveda et al., 2019); this is done by comparing the value - related to the player - collected by the indicators to their expected value for the activity (Sepulveda et al., 2019). Therefore, as part of a DDA system, the performance indicators help determine when and how the DDA system should adapt the game parameters under its control to better fit the player's skill[5]. For this to work, both types of features need to be directly related (ex. the number of lives lost will be affected by the damage of enemy attacks), and specific to the game where the system would be implemented (Dziedzic & Włodarczyk, 2018; Sepulveda et al., 2019). Since at the beginning there is no player data, the initial difficulty must be set according to some criteria that will also affect the expected values for the performance indicators (Sepulveda et al., 2019) [6]; this needs to be carefully determined as it heavily influences the experience when playing the game for the first time (Hendrix et al., 2018).

- **Game Parameters:** variables that affect the game's difficulty (ex. damage per hit)
- **Performance Indicators:** variables that illustrate the player's performance (ex. number of lives lost)

2.3.3 Task Complexity vs Task Difficulty

Another important distinction when discussing difficulty and DDA (see 2.3.1) is between *task complexity* and *task difficulty*. The first relates to an objective characteristic of the task (its structure), and the later relates to the interaction between the task and the task performer (Dziedzic & Włodarczyk, 2018). As examples of these, one can consider how many correct moves are needed to complete a chess match, and the speed of the enemy characters in a first-person shooter, respectively.

- **Task Complexity:** objective characteristic of the task (ex. how many correct steps till victory in a chess board)
- **Task Difficulty:** interaction between the player, the task, and the context (ex. movement speed of the enemies in a first-person shooter level)

Understanding these two terms correctly becomes relevant when designing the activities featured in *Village Druid* that integrate the real-world rehabilitation exercises, and how/what the dynamic

[5] An example of this for a multiplayer player-versus-player (PvP) game would be a matchmaking system where, according to their measured skill, the player will be placed in matches with different players; this is known as skill-based matchmaking (or matchmaking ranking).

[6] These initial levels of difficulty and expected values can be searched for through methods such as the use of an AI agent designed to play the game at a 'medium level', or the acquisition of real player data featuring a post-playtest survey that identifies the individuals from the group of participants that had fun (Sepulveda et al., 2019).

difficulty adjustment system should change to effectively adapt their difficulty to the player.

2.3.4 Measuring Difficulty

When creating a DDA system (see 2.3.1), a method is needed for measuring the difficulty - which in turn will help determine how to manipulate it. In their article, Dziedzic & Włodarczyk describe three different approaches to measure difficulty, explaining that there is no 'superior' method since the most adequate one to be implemented will depend on the structure of the game and the purpose of the DDA system[7] (Dziedzic & Włodarczyk, 2018). As the authors state in their article: "The first two are separable and relate to gameplay itself, while the third one is related only to the player and can be used independently of the first two (together with them or completely separate)" (Dziedzic & Włodarczyk, 2018).

The first method relates directly to a game's structure, being mainly tied to 'task complexity' (Dziedzic & Włodarczyk, 2018) (see 2.3.3). This method is best applied to games that have a structure based around player turns or rounds where the players' possible actions are relatively limited (ex. Chess, Hearthstone). Specifically, the method measures the performance of the player based on the analysis of their movements and their possible consequences according to the game's structure, and influences the difficulty by commanding the moves/actions of the adversary or challenge that the player is facing (ex. the length of the shortest path to success determines the difficulty of the game) (Dziedzic & Włodarczyk, 2018) [8].

The second alternative is through the use of features of the game, being directly based on the game parameters and the player's performance indicators (Dziedzic & Włodarczyk, 2018) (see 2.3.2). The difficulty is changed through the game parameters and the player's difficulty performing the task is measured through the performance indicators; both of these features must be "adequate and sufficient to measure and manipulate the difficulty felt by the player" (Dziedzic & Włodarczyk, 2018).

The third and final proposal is by performing a direct examination of the player and their feelings, analyzing the difficulty perceived by the player instead of through elements of the gameplay; that is, instead of relying on performance indicators, the game utilizes questionnaires and physiological tests to determine when and how it needs to adapt itself (Dziedzic & Włodarczyk, 2018). For both this method and the use of game features, Dziedzic & Włodarczyk list as suggested game types: arcade games, shooter games, racing games, and platformers (Dziedzic & Włodarczyk, 2018).

As mentioned, it is not possible to determine the overall most effective method for measuring DDA, since the system's implementation varies according to the game where it will be used. A DDA system that does not directly take into account aspects of the player (their performance or their feelings) won't be able to fully adapt to them [9], and a system that tracks the performance of the player should also take into account the player's feelings as well; as they may be being successful but still feeling the

[7] Dziedzic & Włodarczyk state that it is difficult to find a game where all three techniques of measuring difficulty can be equally implemented and assessed, meaning it is impossible to determine which method is the best one (Dziedzic & Włodarczyk, 2018).

[8] These DDA systems often employ algorithms such as *MiniMax* or *Alpha-beta Pruning* to evaluate the player's actions and its possible consequences according to the game's structure (Dziedzic & Włodarczyk, 2018).

[9] Over-reliance on task complexity can lead to an unbalanced difficulty system as it may provide different levels of challenge in the same level of difficulty. The example provided by Dziedzic & Włodarczyk is the differing rates of success when children may try to multiply "six times eight" versus "six times ten" despite both operations having the same structural complexity (Dziedzic & Włodarczyk, 2018).

game is too demanding. Also, a system that only takes into account players' feelings may lead to wrong results as it would have a vulnerability similar to the system of multiple static difficulty levels that leads to 'player-driven difficulty selection' (Hendrix et al., 2018) (see 2.3.1) where players may misjudge their own skills and negatively affect the effectiveness and engagement of the game.

2.4 Conclusion

Village Druid is to be a product of applied game design, aiming to complement rehabilitation as other serious games have in the past, while achieving other goals that are an essential part of games, such as re-signification (Schmidt et al., 2015), which those same serious games are often found lacking (Mader et al., 2016). Regarding *Village Druid*'s difficulty, the goal is to utilize a DDA system. As the game is meant to be used by clients of rehabilitation treatments, it is important to avoid the traps regarding difficulty that surround the methods of single or multiple static difficulty levels. These static formats will not fit all players and do not have a way of adapting to them (Dziedzic & Włodarczyk, 2018; Sepulveda et al., 2019), leading to inevitable mismatches in the game's difficulty and the player's skills that will have negative effects in their engagement and retention; both essential to a rehabilitation treatment, especially if this occurs during the early stages of engagement with the game (Hendrix et al., 2018). A DDA system has the opportunity of adapting the game's challenge to the player, providing a more balanced experience that can positively impact player retention and increase engagement (Dziedzic & Włodarczyk, 2018; Hendrix et al., 2018; Sepulveda et al., 2019), which are important for serious games to have enough time to deliver any relevant outcomes (Hendrix et al., 2018). However, this system needs to be carefully considered, as different methods exist to successfully integrate it into a game's structure - which determine how difficulty may be measured (Dziedzic & Włodarczyk, 2018); through the research made, it is evident that there is no overall superior method for measuring difficulty in games (Dziedzic & Włodarczyk, 2018). Lastly, as part of the DDA systems, important concepts that relate to its structure and implementation were also gathered. *Game parameters* and *performance indicators* are features of the game that determine how the DDA system affects the game's difficulty, and how it measures the player's skill, respectively (Dziedzic & Włodarczyk, 2018). And the terms *task complexity* and *task difficulty* (Dziedzic & Włodarczyk, 2018) help understand how an activity's difficulty may be characterised, helping better determine how the different features may affect or represent the difficulty of a game.

The gathered theory helps inform the design of a (serious) game for rehabilitation (*Village Druid*) and its implementation of a DDA system towards the goal of creating a game that effectively complements rehabilitation and provides a balanced experience to each individual player - positively impacting the clients' engagement and retention.

Chapter 3

Design Concept

3.1 Introduction

Village Druid is a virtual reality (VR) singleplayer game designed as a complementary means of upper-limb rehabilitation, and also useful for occupational activities, being developed as part of the *PlayersAll* exploratory research project. It is being made through a co-creation process that involves the project's stakeholders (rehabilitation clients and therapists) in its development by organizing playtesting sessions where they play the game and give their valuable feedback. This dissertation reports on the design process followed to achieve the goals set for *Village Druid*, including the implementation of a DDA system, and discusses the results gathered from a playtesting session; results related to the specific goals of the *PlayersAll* project are not directly discussed in the dissertation.

Village Druid is to be an exploration of how applied games can be more game-like, and to see if such a direction proves to be beneficial in some way to the treatment where they would be integrated (more positive experience, increase in motivation, decrease treatment drop-out rates). This chapter looks into what were the main goals set for *Village Druid*'s design and what were the main challenges identified when first approaching these goals.

3.2 Goals for Village Druid

Village Druid aims to complement treatments of upper-limb rehabilitation, meaning it has to integrate in its design the recognized exercises typically performed in a standard upper-limb rehabilitation session with a therapist. Considering its objective of being a more game-like applied game and its requirement to contribute to upper-limb rehabilitation, a set of main goals were defined for the game's design, each discussed below.

3.2.1 Integrating the rehabilitation

When designing *Village Druid*, the goal was to diverge from the more common approach seen in applied games when considering the integration of 'real-world treatments'. Games to assist in rehabilitation are often less focused on providing the user with a fun game, but rather a competent rehabilitation regimen (simulating the exercises as they exist outside the game) disguised as a gaming experience

(Mader et al., 2016). The design process explored for *Village Druid* echoes the proposal that such experiences should be developed with a fun experience (through the gameplay) in mind so that it is capable of retaining the focus of the player while contributing to their rehabilitation (Mader et al., 2016). The player will play a game, and by playing it they are also performing the exercises relevant for their treatment (see 3.1).

*The player performs the exercises **by playing the game**,*
*instead of performing exercises **to play the game***

Figure 3.1: Screenshot from an activity in *Village Druid*'s prototype where the player must grab a vial and rotate their wrist to pour the liquid into the cauldron.

3.2.2 Re-contextualizing the rehabilitation

The rehabilitation elements integrated in the design of *Village Druid* must be re-contextualized as natural parts of the game and its setting to take advantage of its features as a game (Schmidt et al., 2015), instead of having them as interruptions to the 'game' for the sake of the treatment. This is achieved through a narrative context that justifies and re-contextualizes the activities that are constituted by the adapted rehabilitation exercises. *Village Druid*, specifically, is set to provide a fantasy narrative context where the player takes on the role of a druid that brews potions for their village. Simple examples of this re-contextualization of actions/exercises performed in rehabilitation treatments would look like this:

- "Move your arm" ⇒ "Draw the spell"
- "Open and close your hand" ⇒ "Grab the ingredients"
- "Move your wrist" ⇒ "Pour the solvents"

3.2.3 Creating a game

The design of *Village Druid* must allow for the player to make meaningful choices inside the game, instead of it simply being a linear gauntlet of rehabilitation exercises that the player must do to 'win the game'. For this, *Village Druid* must accommodate the possibility for the player to make choices that can impact not only its narrative (see 3.2.2), but what activities they are doing in the game as well (see 3.2.1).

3.3 Design Challenges

Village Druid must be a more game-like applied experience that contributes to upper-limb rehabilitation. After having set the goals that represent this objective (see 3.2), the next step was to identify the main challenges to tackle when attempting to design a project with these intentions. The first main concern identified had to do with the apparent conflict between *Village Druid* being designed as a game that allowed for meaningful choices and the requirement of a more repetitive - and controlled - structure to contribute to rehabilitation (see 3.3.1). The second main concern related to how the difficulty of the game would be managed, since rehabilitation treatments are planned specifically for each individual clients and the same client's ability can vary from one session to the next[1] (see 3.3.2).

3.3.1 Game Structure

Structure may be repetitive

The game is integrating exercises that are used in upper-limb rehabilitation and adapting them into the activities done in the game. These exercises are intended to be performed repeatedly in rehabilitation sessions, however, one of the main issues of rehabilitation treatment is that same monotonous repetition (Mader et al., 2016).

Village Druid must find a way to successfully guarantee the players perform the activities that integrate the exercises repeatedly - providing relevant contributions to rehabilitation - while giving that repetition meaningful context in the game and avoiding player frustration or boredom.

Players affecting variety

One of the goals of *Village Druid* is to provide more player control (see subsection 3.2.3) - extending to the activities that integrate the rehabilitation exercises. However, this control needs to be balanced to avoid situations where a player may choose to do one activity more often then 'necessary' or completely avoid another.

Village Druid must find a way to allow the player to have meaningful control over their experience without compromising the intention of the game to be a complement to rehabilitation through the variety of activities (exercises) it provides.

Treatment times can vary

Players of *Village Druid* are expected to also be clients of rehabilitation treatments, with the game possibly being employed by therapists during the treatment sessions themselves. However, rehabilitation treatments are highly personalized and can vary in the number of sessions and their length. This variability could affect players' experience with the game and their motivation, which in turn can have consequences for the treatment itself (Hendrix et al., 2018; Mader et al., 2016). Additionally, *Village Druid* should ensure it can be easily integrated into rehabilitation plans, as the likelihood of its adoption will greatly decrease otherwise.

[1] This concern was raised by therapists, integrated in the co-creation process, when discussing the design for the game.

Village Druid must have a structure that works with varying session times and number of sessions, providing a positive experience to players that is not easily compromised by varying treatment schedules.

3.3.2 Game Difficulty

Participants differ in ability

Village Druid is meant to be played by clients of rehabilitation treatments. However, there is a wide range of conditions and levels of impairments when considering upper-limb rehabilitation. In a standard therapy treatment, it is the role of the therapist to assess the ability of the client and propose exercises that are properly accessible to them. If the game has a static level of difficulty that cannot change, then it becomes less or completely inaccessible to several possible players (Dziedzic & Włodarczyk, 2018; Sepulveda et al., 2019).

Village Druid and its activities must have a difficulty that can be adapted to each client that is playing the game in order to make it accessible to a wider variety of players with varying levels of impairment to their upper-limb[2].

Participants' ability can fluctuate

A concern raised by health therapists when discussing the creation of a game where clients could do rehabilitation exercises is that the level of ability from patients normally varies from one session to the next, sometimes even in the same session. This means that if the difficulty is not adaptable, then players may suddenly have disproportionately unbalanced experiences between the game's difficulty and their ability.

Village Druid must offer the possibility - or be able - to change the difficulty of the game and its activities to correspond to the player's ability, both at the start of a session and during the session.

Difficulty progression can abandon players

Being used in a rehabilitation context, there is no way to accurately predict the rate at which participants recover from their physical ailment, meaning that a static difficulty progression in *Village Druid* (activities' difficulty increasing over time) will be guaranteed to leave players behind (Dziedzic & Włodarczyk, 2018; Sepulveda et al., 2019). Should this happen, forcing the player to change the game's difficulty level can lead to significant negative effects to their motivation to play the game (Sepulveda et al., 2019), which in turn can affect the rehabilitation treatment's retention.

Village Druid needs to somehow have a difficulty progression that acknowledges players' varying rates of physical recovery and learning with the game.

[2]There will inevitably be exclusion criteria that dictate what minimum conditions clients must have to be able to play the game.

3.4 Conclusion

The goals set for the design of *Village Druid* (see 3.2) are directly related to the intentions of the *PlayersAll* project. Upon defining these goals, main challenges for the success of the (serious) game's design were identified 3.3. These relate to the game's identity as a more game-like applied game for upper-limb rehabilitation therapy, meaning it must have characteristics more often expected of a 'commercial' game while respecting the requirements needed for it to effectively contribute to the players' therapy.

Essentially, *Village Druid* must be a game that contributes to the clients/players' rehabilitation while integrating and re-contextualizing the repetitive exercises done in standard rehabilitation sessions. It must also be adaptable to clients with different schedules for their rehabilitation treatment and their varying individual degrees of ability. It is these requirements for *Village Druid*'s design that made it an interesting target in which to implement a dynamic difficulty adjustment system and to test the effects such a system has on players' experiences with a game of this type.

Chapter 4

Design Process

4.1 Introduction

As was determined in chapter 3, designing the *Village Druid* game presents a heightened design challenge due to the requirements to have more game-like elements that allow the player to control the game while still successfully emulating the controlled and repetitive nature of standard rehabilitation treatments. Another significant challenge of *Village Druid*, and serious games in general (Hendrix et al., 2018), is the management of difficulty. This thesis reports on playtesting sessions featuring the game's stakeholders which verified whether a DDA system is able to tackle the concerns regarding difficulty identified for *Village Druid*'s design (shared by other games for rehabilitation) (see 3.3.2) and contribute to a more positive experience for participants. The dissertation furthermore discusses these results.

This chapter looks into the design decisions that were made to accomplish the goals for *Village Druid* and directly tackle the design challenges identified. The main topics discussed are a modular game structure, and a dynamic difficulty adjustment system. As these design decisions were explored and proposed, three game design patterns were developed that illustrate the design solutions in an abstract format to allow for easier implementation in other projects; they can be seen in appendix A and constitute a design research contribution of this dissertation.

4.2 Modular Game Structure

To answer to the challenges identified regarding *Village Druid*'s game structure (see 3.3.1), a modular structure was implemented that integrates the requirement of repetition from the rehabilitation exercises being emulated in the game (see 3.2.1) and allows for an effective re-contextualization through the use of the narrative (see 3.2.2). In *Village Druid*, the player performs the exercises by playing the game (exercises are integrated in the gameplay), and it treats them as players by giving them the opportunity to affect what they do in some meaningful way. Through the narrative, the player takes on the role of a village's druid that has the responsibility to concoct magic potions that help with the village's problems. Their role is to make magic potions when a request from a villager reaches their hut; through this, it is possible to contextualize the repetition inherent to the game, as the village will need the druid's help (their potions) more than once (see figure 4.1). The act of making the potions, following the steps of the recipes (see 4.2.2), is where the player performs the activities that integrate the exercises. It is in the selection of

the potions that the player has the opportunity to affect their experience in the game, having control over which recipe (and activities) they will do from a batch of three possible recipes provided to them; this contributes to the goal of making *Village Druid* more game-like than other applied games (see 3.2.3).

Request X		
Recipe 1	**Recipe 2**	**Recipe 3**
Activity A	Activity D	Activity C
Activity B	Activity C	Activity D
Activity D	Activity A	Activity B

Figure 4.1: In the game, the druid (player character) will be getting request for potions. They then have to select one of three possible recipes, each featuring a different sequence of activities (each activity can only appear once per recipe).

This modular structure also provides several benefits for the use of a DDA system (described in section 4.3) and the overall experience of difficulty. The recipe-to-recipe modular structure provides a moment in between recipes where the player can interrupt their session to rest, striving towards a game that matches its difficulty to the player's skill while giving them the opportunity to have a break from the challenges as suggested by Sepulveda et al. (2019). Also, the difficulty changes made by the DDA system are enacted in this transition from one recipe to the next, following the recommendation of Dziedzic and Włodarczyk (2018), where if a game has distinct stages of gameplay (such as waves of enemies in tower defense games), the intervention should occur after each stage (Dziedzic & Włodarczyk, 2018). Having the updates to difficulty occur only during these specific instances instead of in real-time also brings benefits to processing demands that could arise from the DDA system[1] (Sepulveda et al., 2019); and since no activity can appear on the same recipe twice, each instance of any activities will have its difficulty updated according to the player's most recent performance, keeping the system responsive to player performance.

By having a clear division of 'phases' in the game, the DDA system can provide streamlined experiences for the players where the DDA system manages the difficulty (see 4.3.1) and ensures variety in the game - answering the concerns raised regarding more player choice (see 4.3.2).

4.2.1 Player Choice

Allowing for player choice is made possible by the implemented modular structure, as it provides a more controllable environment where the game can adapt to the decisions afforded to the player while maintaining its viability as a complement to rehabilitation. These advantages can be seen in the narrative (see 4.2.2) and the choices it can provide to the player, and in the management of the activities' variety when giving control to the player regarding what recipes - and activities - they will choose (see 4.3.2).

[1] The frequency of the updates needs to be properly measured - and considered according to the genre of the game itself, as a higher frequency of updates makes the system more adaptable but more demanding (Sepulveda et al., 2019).

4.2.2 Narrative Structure

Each step of the modular structure is contextualized through the narrative. The request the druid (the player) gets is the call to action to create a potion, to create a potion they have to select one recipe, and to follow the recipe they have to follow its steps (perform the activities). The repetitive structure (a requirement for the assimilated exercises to contribute to rehabilitation) is contextualized through the druid having the responsibility of creating potions for their village; they get a request from the villagers to create a potion (see 4.2), select one of the viable recipes, and follow its steps.

The druid ***gets a request*** $\Longleftrightarrow$ Narrative Context

The druid ***chooses a recipe*** $\Longleftrightarrow$ List of Exercises

The druid ***follows the recipe*** $\Longleftrightarrow$ Performing the Exercises

Figure 4.2: The 'villager' non-playable character (NPC) requests a potion from the druid (the player). Screenshot from a prototype of *Village Druid*.

Through the modular narrative structure, some techniques are also used to effectively manage a narrative that can accommodate decisions by the player. While this specific topic is not a focus of the dissertation, design patterns related to these design choices were made and catalogued in appendix A (sections A.2 and A.3), featuring specific examples of how they can be applied in *Village Druid*.

4.3 Dynamic Difficulty Adjustment

The Dynamic Difficulty Adjustment (DDA) system provides an effective answer to the concerns raised regarding the difficulty directly (see 3.3.2) and helps preserve *Village Druid*'s contribution to the rehabilitation treatment while still allowing for meaningful player choices (see 3.3.1). Subsections 4.3.1 and 4.3.2 describe the two components that constitute *Village Druid*'s DDA system, managing the difficulty of the activities and their variety (both influenced by the player).

4.3.1 Managing Difficulty

This component of the DDA system for *Village Druid* manages the difficulty of the activities according to how much difficulty the player has performing them[2]. Given the differences between the

[2]The difficulty of the activities is changed by updating the game parameters and the player's difficulty in the activity is assessed by the performance indicators (see 2.3.2).

activities, the game parameters and performance indicators are tailored to each of their designs[3].

With these variables implemented, the system has the goal of measuring the difficulty experienced by each player when performing each individual activity and, through the game's modular structure (see 4.2), update their difficulty in the next iteration accordingly. Implementing this system directly tackles the concerns related to difficulty identified in 3.3.2. If the player performs the activities well (according to the performance indicators), the difficulty increases in the next iteration, if they then have more difficulty than desired, the activity's difficulty will be lowered.

Iteration 01		-> DDA updates difficulty ->	Iteration 02	
Activities	Difficulty		Activities	Difficulty
Activity A	medium		Activity A	hard
Activity B	medium		Activity B	easy
Activity C	medium		Activity C	hard

Figure 4.3: After the player performs an activity, the DDA system updates that activity's difficulty for its next iteration according to the performance indicators.

Village Druid begins with all activities in a default level of difficulty (possibly modified by the therapist through the monitoring interface), and once players start completing the activities the DDA system begins adapting their difficulty to the player (see figure 4.3). This adaptation works by changing the level of difficulty of the activities between the levels *low*, *medium*, and *high* according to player performance[4]. This management continues throughout the game, being able to adapt to possible fluctuations in player skill on a recipe-to-recipe rate. Having the possibility to set the starting difficulty of the activities makes it more accessible to a wider variety of players (dealing with the challenge identified in 3.3.2), and the DDA system's ability to then update the difficulty in a recipe-to-recipe basis according to the difficulty measured on players allows it to respond to fluctuations on players' abilities (see 3.3.2) and to manage the possible difficulty progression according to the ability of the players (see 3.3.2).

4.3.2 Managing Variety

For each request, the player must select one of three proposed recipes containing a sequence of activities (that integrate the exercises). These recipes are different from each other and no recipe has the same activity twice. Since *Village Druid* has more than three activities, no recipe has the player doing all activities in one sequence. This is by design, as it is intended for the player to feel they have control over what they do in the game; in this case having the power to select the recipe - from the provided batch - that they may find most interesting.

At the same time, however, the game must assure that each activity is performed a similar number of times for it to meaningfully contribute towards their rehabilitation treatment (see the design challenge identified in 3.3.1). The solution devised to mitigate this issue is through the DDA system managing the probability each individual activity has in being selected for a recipe, in an attempt to

[3] Due to their design, the method used to measure difficulty in Village Druid's activities (see 2.3.4) is through the game features (Dziedzic & Włodarczyk, 2018).

[4] There are a limited number of difficulty levels (currently three), and, as mentioned in 3.3.2, there will inevitably be exclusion criteria that apply to some rehabilitation clients.

nudge towards and eventually ensure the player picks the avoided activity.

Draw 01		Activities Done	Draw 02	
Activities	Draw %		Activities	Draw %
Activity A	50%	☑	Activity A	35%
Activity B	35%	☐	Activity B	45%
Activity C	40%	☑	Activity C	35%
Activity E	35%	☑	Activity E	35%

Figure 4.4: The likelihood of activities being selected for recipes varies according to whether they were selected by the player or not. The draw chance of the activities cannot go bellow its starting value (the values utilized in this figure are an example).

All activities in *Village Druid* have a variable that represents their probability of being featured in a recipe[5]. For the first batch of recipes (see 4.2), all activities start with this variable at the same default value. This variable then begins to change as the player picks what recipes they will do. Activities that are not featured in the recipe selected by the player get an increase to their probability of being in the subsequent recipes (see figure 4.4); alternatively, activities that were featured have their probability decreased - not going below the default value. This conditional probability, where the less an activity is performed by the player the more likely it is to be featured in the following recipes, means that: as the player avoids doing an activity its presence in the recipes will gradually increase; first being featured in two of the three recipes and eventually on all the recipes of the batch.

This allows for the game to provide meaningful choices to the player that affect what they do, while at the same time the DDA system indirectly manages the frequency with which the activities are performed to preserve the contributions the game can make for rehabilitation. As the player chooses from the offered batch, the gradually increasing frequency with which the disregarded activity appears on the recipes avoids the perception that the player is suddenly forced to do an activity they might not particularly enjoy. This solution led to the creation of a design pattern called "Softly Erase Comfort Zone" which can be viewed in appendix A (section A.1).

4.4 Conclusion

The design implemented for *Village Druid* is meant to directly tackle the main challenges in achieving the project's goals. *Village Druid* aims to integrate and re-contextualize upper-limb rehabilitation in a game (see 3.2), and its design's challenges were about overcoming conditions that either compromised its success as a game or its effectiveness as a complement to rehabilitation (see 3.3). In order to tackle this, two main design choices were made: 1) the game would feature a modular structure, and 2) it would implement a DDA system. The modular structure allows for the integration and re-contextualization - together with the narrative (see 4.2.2) - of the repetitive nature required by the therapy exercises integrated in *Village Druid* as an applied game for rehabilitation (see 3.3.1). The DDA system, working through said modular structure, can effectively tackle the challenges concerning the game's difficulty raised in 3.3.2 - concerns that are shared by other (serious) games, and reach a compromise between

[5] Each activity can only be featured once on each recipe.

giving power to the player and ensuring the game's contribution to rehabilitation.

Following the design of *Village Druid*, work on a new prototype began: 'Prototype 2.0'. The goal was to measure the effect a DDA system can have on the players' experience when playing a prototype of an applied game for rehabilitation; in this case, *Village Druid*. The DDA system described for *Village Druid* in this chapter is only partially implemented in Prototype 2.0, featuring the component that manages the activities' difficulty (see 4.3.1) - the other component is not utilized as all participants will simply play the same recipe twice as part of the prototype (DDA affects the difficulty of the activities in the second recipe). In the next chapter, Prototype 2.0 and the results of its playtesting sessions are discussed.

Chapter 5

Testing Prototype 2.0

5.1 Introduction

By implementing a prototype of the *Village Druid* game that features a Dynamic Difficulty Adjustment (DDA) system (Prototype 2.0) it is possible to conduct playtesting sessions of said prototype and system with participants that represent the stakeholders for the game. These sessions provide valuable information regarding how a system like this impacts the players' experience, and how they themselves perceive its influence on the game they are playing. The results and accompanying observations from the conducted playtesting sessions may demonstrate why - and how - the inclusion of these systems in games for rehabilitation can be beneficial for its users.

Village Druid's Prototype 2.0 features a DDA system (see 5.2) and was tested with a total of 11 participants, including health therapists and rehabilitation clients with intellectual disability[1]. Participants were deliberately kept unaware of the DDA system[2] as it was important to observe if it could affect the players' experience without being detected (Sepulveda et al., 2019). In this chapter, a description of the playtesters and their general experience with the prototype, the levels of assistance required by the participants for the activities in the prototype, an analysis of the DDA system's performance and player perception, and a review of the players' general first reactions to the game's fantasy narrative context is provided. Detailed experimental issues observed in the game's activities during playtesting, along with proposed corrections to their design, can also be found in appendix C.

5.2 The Prototype

Prototype 2.0 features four activities designed with rehabilitation therapists and implements a dynamic difficulty adjustment (DDA) system. Players have to perform the four activities twice (two sequences/'recipes'). The DDA system in the prototype works, for each player's session, by evaluating how much difficulty they had in each activity - through its specific performance indicators - of the first recipe and then changing their difficulty in the second accordingly via their game parameters. The participants of the playtesting sessions were not informed about the DDA system. Each activity's performance indicators and game parameters, along with screenshots of the activities, can be seen in appendix B.

[1] The inclusion of the participants in the playtesting sessions was sanctioned by the author's host institution's ethics board.
[2] Therapists who participated as playtesters were not part of the co-creation and design of *Village Druid* and its activities.

The prototype starts with a tutorial that introduces its modes of interaction, and includes the fantasy narrative context part of *Village Druid* - re-contextualizing the actions and events experienced in it. More details regarding Prototype 2.0 and how these specific elements were implemented can be seen in appendix B.

5.3 Playtesters' game familiarity

Participants were categorized into two groups: the health therapists (subsequently referred to as therapists), and the rehabilitation clients (subsequently referred to as clients) with intellectual disability (ID). There were seven therapists (M = 2, F = 5) with an average age of 25 (SD = 7,4), and four clients (M = 1, F = 3) averaging at 41 (SD = 14,4) years old.

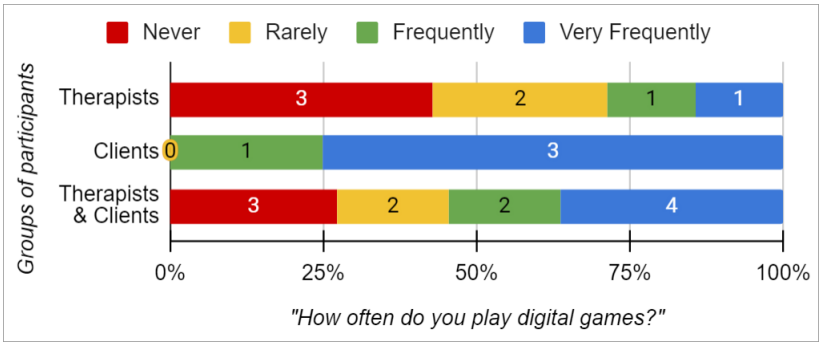

Figure 5.1: How frequently the participants played digital games, where N = 7 and N = 4 for therapists and clients respectively. Options were: *Never*, *Rarely*, *Frequently*, and *Very Frequently*.

In the pre-playtest questionnaire, when asked about how frequently they played digital games (see figure 5.1), three of the four clients answered 'very frequently', with the fourth answering 'frequently'. Of the therapists, only two of the seven participants answered that they played 'frequently' and 'very frequently', with the others being split between 'never' (N = 3) and 'rarely' (N = 2). Also, when asked about the frequency with which they utilized VR (see figure 5.2), 91% (N = 10) of all participants answered 'rarely' (one specified that they had 'only interacted once'), with one participant having 'never interacted' with VR. While this would affect how easily the participants might interact with the game, *Village Druid* cannot 'presume' its players are familiar with the interface, and so this proved to be a valuable opportunity to measure how autonomous inexperienced VR players could be while playing the activities of Prototype 2.0 and how the DDA system might affect their experience with the game.

5.4 Levels of assistance

As mentioned in section 5.2, players performed the same four exercises twice, with these two sequences being presented as 'recipes' in the game's context. In order to better assess how the DDA system in Prototype 2.0 may have affected the experience of the players, in terms of how much difficulty they felt playing the game, the level of assistance participants required for each activity was measured. This information, for each individual player, would then be compared to the registered changes to difficulty that were performed by the DDA system in their session. The levels of assistance were defined in three

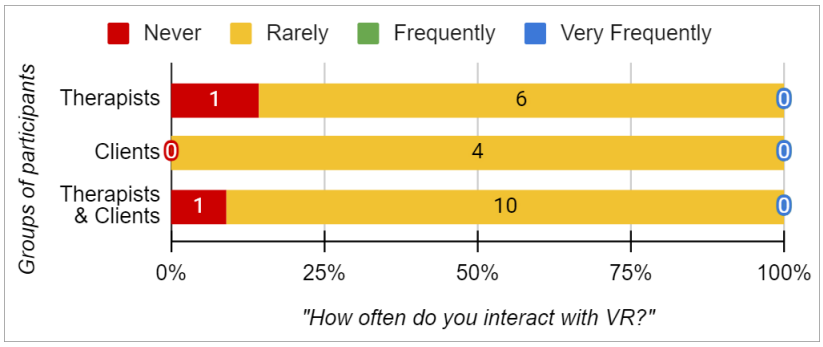

Figure 5.2: How frequently the participants utilized virtual reality (VR) technology, where N = 7 and N = 4 for therapists and clients respectively. Options were: *Never*, *Rarely*, *Frequently*, and *Very Frequently*.

levels: 1) none (no assistance required), 2) self-adapted (no assistance required but visibly struggled), and 3) intervened (participant required assistance from the experimenter).

After the playtesting sessions, the data gathered regarding the levels of assistance recorded for each exercise on both recipes was separated into the two groups of participants mentioned in section 5.3 (see figure 5.3). General results indicate that once participants completed the exercises for the first time they were generally capable of performing them more comfortably on the second recipe, despite an increase in difficulty for most cases (see section 5.5). However, the overall levels of assistance recorded in the exercises of the first recipe demonstrate that they are not immediately accessible to players; meaning that either the exercises were too confusing in their initial version on the first recipe (no intervention appeared to have been directly caused by an activity's difficulty), or that the instructions for the activities were simply not clear. A more thorough analysis of the levels of assistance recorded for each of the two groups of playtesters and additional observations can be found in sub-sections 5.4.1 and 5.4.2.

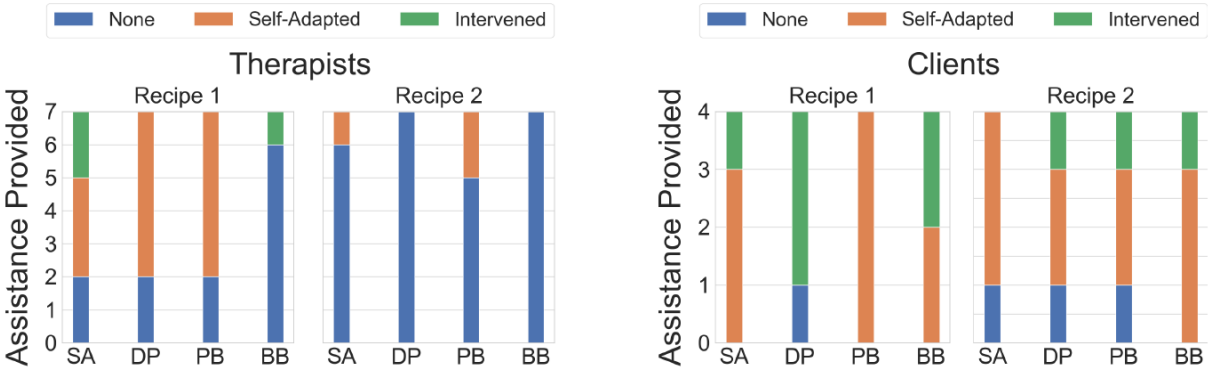

Figure 5.3: Instances of experimenter assistance provided to players, where N = 7 and N = 4 for therapists and clients respectively, over the course of the activities. **None**: no assistance required; **Self-Adapted**: visibly struggled but accomplished task without experimenter interference; and **Intervened**: experimenter actively helped verbally or actively.

5.4.1 Therapists

In the therapists' group, from a total of 28 exercises performed for the second recipe (four exercises done by seven separate playtesters), there were no requests for assistance and only three instances of 'self-adapted' were observed. This shows a clear improvement from the three instances of 'intervened'

and 13 instances of 'self-adapted' recorded for the first recipe (see figure 5.4). Very few participants in this group required experimenter intervention; reasons for 'intervention' consisted solely on participants not remembering or not knowing the instructions for the activity - either having misunderstood or ignored them. Most instances of 'self-adapted' also related to this issue, though participants eventually guessed the goal of the activities or remembered to look at the book (in-game) where they could read the instructions.

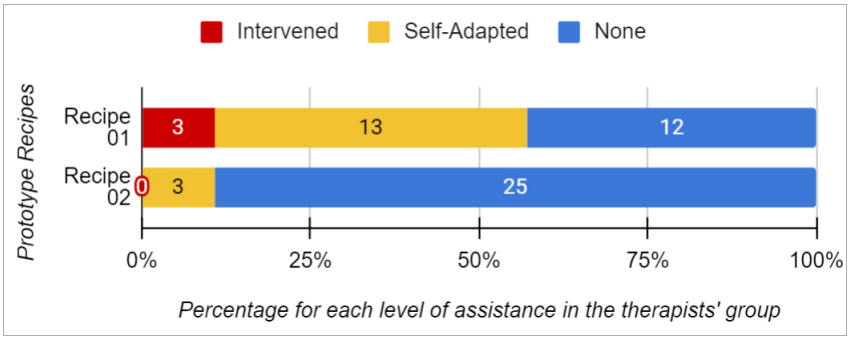

Figure 5.4: Percentage of each level of assistance for both recipes in the therapists' group, where N = 7.

The improvement in autonomy observed from therapists in the second recipe makes sense as participants had by then completed one iteration of the activities and remembered how to do them once they appeared a second time. However, the number of 'self-adapted' instances recorded for the first recipe shows that the activities were not immediately accessible to players (see appendix C). Also, the number of players that tried to 'guess' how to do the activities instead of looking at the instructions besides them demonstrates that they were not aware of its existence, something that must be fixed in future iterations of the prototype.

5.4.2 Clients

In the clients' group, the level of assistance recorded was higher considering the population size. In a total of 16 exercises performed by the clients in the second recipe (four exercises done by four separate playtesters), there were only three instances where players comfortably performed the activities. There was still an improvement from the first recipe, as most instances consisted of 'self-adapted' scenarios and instances of 'intervened' decreased from six to three (see figure 5.5). Intervention in this group mostly related to repeating or explaining the instructions to participants as some could not read or fully understand them[3]. Nonetheless, the *Draw Points* and *Bubble Burst* activities also caused trouble for this group of participants by demanding more precise movement and cognitive effort, respectively (see appendix C). Most instances in the second recipe were categorized as 'self-adapted' since, despite appearing to largely understand the goals of the activities, participants still appeared to struggle while performing them - possibly doubting if they were doing them correctly.

The main necessity that is made evident with this group is the introduction of narration since some participants could not read. Also, as was observed with the therapists' group, additional noticeable redundant channels of information are a valuable addition to consider - with this including channels that

[3]First reads of the exercises' instructions (in both recipes) for participants who could not read were not counted as interventions

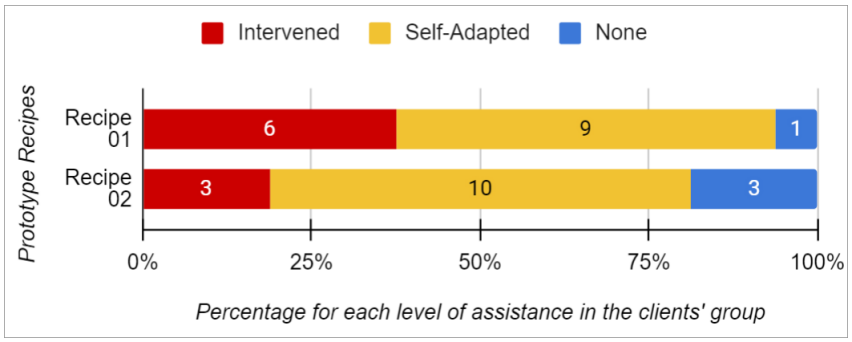

Figure 5.5: Percentage of each level of assistance for both recipes in the clients' group, where N = 4.

also transmit the information through audio - so that participants can easily remember what they have to do at any given point.

5.5 Performance of the DDA

The DDA system assessed how much difficulty players had performing the exercises through the performance indicators specific to each activity and then had their game parameters updated in their second iteration (in the second recipe) accordingly. Participants were not informed about the system's existence. The performance of the DDA system was evaluated in how adequately it managed the difficulty for players (see 5.5.1) and how/if they perceived the dynamic difficulty in the prototype (see 5.5.2).

5.5.1 Balancing difficulty

The system correctly adjusted the difficulty for each player according to the performance indicators set and the values they recorded from players; players who struggled with the first iteration of an activity - according to the performance indicators - were met with a second iteration of lower difficulty, and players who did well were met with an increase in difficulty in the second recipe. The effects of the DDA system, by lowering the difficulty for the participants that struggled, will have contributed to the general decrease in assistance required by participants (see figure 5.3); on the other hand, by increasing the difficulty for those who performed the activities successfully, the game managed to lead these players towards making more demanding movements when they were considered 'ready' - even if they did not notice it (see 5.5.2) - without leading to an increase in the level of assistance. In a total of 44 activities in the second recipe (four activities performed by 11 separate participants), the difficulty of the activities was only lowered in 12 instances, otherwise having been increased (see figure 5.6).

Of all the instances where the difficulty of the activities were lowered, only one occurred in the therapist group, with the rest occurring with the clients (see figure 5.7). Most of these had to do with clients requiring assistance as they couldn't remember how to do the exercises (requesting an additional read of the instructions) and had troubles interacting with the game via the handheld controller interface (more information regarding issues observed during the activities in appendix C).

ACTIVITIES (N = 4)	DIFFICULTY					
	Therapist (N = 7)		Clients (N = 4)		All Participants (N = 11)	
	Increased	Decreased	Increased	Decreased	Increased	Decreased
Solvent Action	7	0	2	2	9	2
Draw Points	7	0	1	3	8	3
Push Ball	6	1	0	4	6	5
Bubbles	7	0	2	2	9	2
Total	**27**	**1**	**5**	**11**	**32**	**12**

Figure 5.6: Changes in difficulty for the four activities in the second recipe of Prototype 2.0, where N = 7 and N = 4 for therapists and clients respectively.

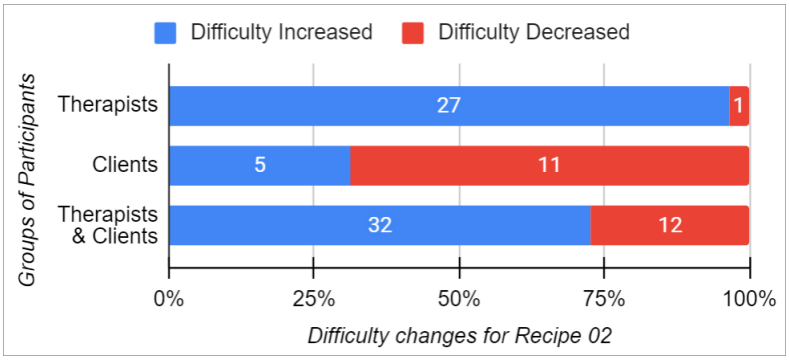

Figure 5.7: Percentage of activities in the second recipe where difficulty increased and decreased for participants, where N = 7 and N = 4 for therapists and clients respectively.

5.5.2 Players' perceptions of the DDA

The participants were not informed regarding the existence of the DDA system in the prototype in order to observe if the changes it made went unnoticed, in accordance with Sepulveda et al. (2019). In the post-playtest questionnaire, participants were asked if they thought the difficulty of the activities had changed throughout the game (players were not informed that the prototype featured a DDA system). From all 11 participants, only three can be said to have perceived the difficulty changes that the DDA system performed in their sessions: one therapist and two clients (see figure 5.8). The therapist recognized that all the activities became 'objectively harder' but stated that they did not 'feel' more difficult to do, and from the two clients, one stated that the activities got easier (all activities got easier) and the other stated that only some increased in difficulty (three of four activities increased in difficulty) [4]. Every other participant answered that the difficulty stayed the same, despite no activity actually having maintained the same level of difficulty from the first recipe to the second.

While the participants were asked if the activities changed in difficulty, it is possible that some may still have answered according to how much difficulty they had performing the activities; the fact the therapist felt the need to specify that the activities got "objectively" harder could hint at this misunderstanding. Likewise, the client who answered that all activities got easier may have been answering according to how they felt while doing the activities that did - objectively - become easier. Considering these questions, either participants did not realise there were changes and felt the difficulty stayed

[4]These participants did not explicitly state that the prototype featured a dynamic difficulty system, only that the difficulty had changed.

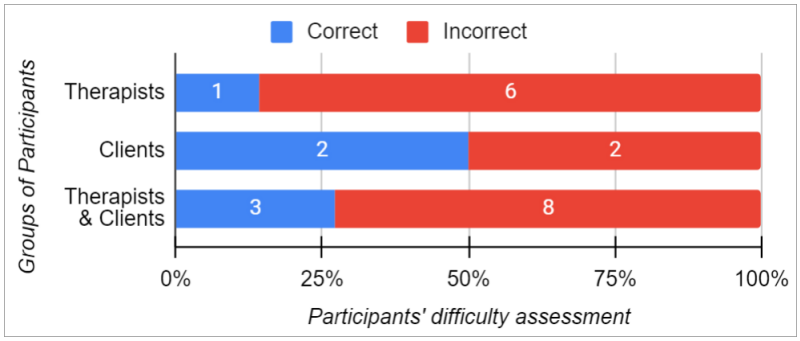

Figure 5.8: Percentage of participants that correctly assessed the changes in difficulty that occurred in the second recipe, where N = 7 and N = 4 for therapists and clients respectively.

exactly the same, or they recognized the changes and felt that they maintained the level of difficulty for themselves.

Sepulveda et al. (2019) mention that one of the biggest challenges when changing the difficulty is avoiding the player noticing the change, stating that the changes need to be made at times where the player "is not aware" (Sepulveda et al., 2019). Similar to Dziedzic & Wlodarczyk's suggestion of performing the changes in between 'phases' when the game's structure allows it (Dziedzic & Włodarczyk, 2018), Sepulveda et al. (2019) name as examples of the occasions when to change the difficulty: "when the player is dead, change of scenes, features or elements the player has not yet seen" (Sepulveda et al., 2019). They mention that changes should be subtle, and that there must be a limit to how much a variable can change, and a limit to how often they happen (Sepulveda et al., 2019). In *Village Druid*, the difficulty level of the activities can only change by one[5] and only happens from one recipe to the next. Players noticing changes to an activity may be problematic if they observe that the difficulty was lowered for - and because of - them, however it is unclear if players noticing an activity got harder while not feeling any additional difficulty may actually be a positive result; considering it may be a demonstration of their improvements through the rehabilitation treatment.

5.6 Player Perception of the Narrative

All clients showed enthusiasm with the narrative despite some slight misunderstandings regarding their character's role in the game (whether they were a druid or a druid's apprentice). During the focus group with the therapists that playtested Prototype 2.0, a few expressed a more conditional opinion regarding the appropriateness of the fantasy narrative setting of *Village Druid*, suggesting that a context more focused on simulating real world scenarios might be more effective and relevant for 'specific clients'. Nonetheless, all therapists considered the narrative context along with the rest of the game contributed to a positive experience for them and especially the clients.

The lack of consensus regarding the player character's role in the narrative may be in part due to the narration provided to the clients who could not read during playtesting, having slight variations from one to the next; however, since this confusion was also observed in participants that could read, it shows that a revision to the text is necessary to improve its clarity. Regarding the questioning of the

[5] On a further stage of development it is intended to include additional levels of difficulty in order to make the changes more subtle from one level to the next, as per Sepulveda et al. (2019).

fantasy context's 'appropriateness' by some therapists, these observations were recorded though they do not affect the fantasy narrative context's inclusion in *Village Druid*, as this is part of the game's attempt at re-contextualizing the rehabilitation treatment and exploring its effects. An additional observation made during playtesting was that the *Draw Points* and *Ball Path* exercises are not completely integrated in the narrative context of the game; subsequent versions of the exercises will take the narrative more into account so that they make sense and have meaning in the context of the game's world (see appendix C).

5.7 Conclusion

Village Druid's Prototype 2.0 featured DDA and was playtested by a group of participants that represented its stakeholders. No participant had significant experience with VR, and nearly half of all participants had little to no experience with digital games. As mentioned in section 5.3, this proved a valuable opportunity to observe how autonomous inexperienced users can be while playing the prototype and how a DDA system might contribute to accessibility. In order to hypothesise about the DDA system's contribution to the players' experience in the game, the difficulty variations were recorded along with the levels of assistance required by each individual for every activity in Prototype 2.0; also, observations about the players' behaviour added additional context to these results.

Overall, the levels of assistance needed by participants for the second recipe decreased from the first (see image 5.3). This was especially the case for the therapists, where no intervention was required for the second recipe (see image 5.4) despite nearly all of the exercises' difficulty having increased. Here, the DDA system accurately assessed the players' difficulty in performing the exercises during the first recipe and increased it accordingly for the second recipe (see image 5.7). Regarding the clients, the levels of assistance only slightly improved, with just three instances (three of a total of 16 exercises) leading to intervention (see image 5.5). These cases mainly had to do with confusion and lack of guidance for participants since there was no information in audio form and most of them could not read. Still, all participants were able to successfully complete all the activities despite most cases being classified as 'self-adapted'. The levels of assistance observed from clients improved in the second recipe, where over two-thirds of all exercises done by the group had their difficulty lowered by the DDA system (see image 5.7). Interestingly, for both groups, the changes done by this system appear to have gone unnoticed by all but three participants (one therapist and two clients), answering that "the exercises did not change in difficulty" (see image 5.8). The therapist that noticed the changes specified that the exercises' difficulty "objectively" changed, but that they had not felt more difficulty doing them; this explicitly demonstrates that the DDA system successfully changed the difficulty according to the player's measured skill (lack of difficulty according to the performance indicators) when performing the exercises, and delivered a balanced difficulty experience.

The Dynamic Difficulty Adjustment system appears to have had the following results:

- Increased difficulty for participants that completed the exercises with relatively low difficulty without leading to an increase in the levels of assistance.
- Decreased difficulty for participants that had more difficulty completing the exercises - making them more accessible and contributing to lower levels of assistance.
- Performed changes to the game while being undetected by most participants.

Future testing should make sure that playtesters understand the difference between "the exercises increased in difficulty" and "the exercises were more/less difficulty to do", making a distinction between an 'experienced' difficulty and 'objective' difficulty. Also, if participants do think the difficulty of the activities changed, they should be asked what they think the criteria was - to determine if they 'spotted' the DDA system. Lastly, as suggested by Sepulveda et al. (2019), future iterations of the prototype could use the tutorial section to set the activities' starting difficulty before the players do them; possibly placing their difficulty at 'easy' instead of 'medium'.

Chapter 6

Conclusion

This dissertation reports on the design of a virtual reality singleplayer game (*Village Druid*) that aims to contribute to upper-limb rehabilitation through the use of applied game design while reclaiming the more significant characteristics of games that are often missing in games for therapy (Mader et al., 2016). Through the research of related theory and analysis of the goals for the game, along with the challenges that stood in their way, the implementation of a dynamic difficulty adjustment system was determined to be the best choice regarding the management of difficulty in *Village Druid* - since it tackled the concerns regarding static difficulty levels (Dziedzic & Włodarczyk, 2018; Hendrix et al., 2018; Sepulveda et al., 2019) and variety (see 3.3.1).

As the design of the game progressed, a modular structure was devised that allowed for the successful integration of the activities performed in standard rehabilitation treatments and the re-contextualization of the repetitive nature of these activities through the use of a fantasy narrative. This same structure, along with the strategies used around it, also allowed for the affordance of player agency through the use of strategies that would then be proposed as game design patterns, constituting a contribution of design research from this dissertation. Taking this structure into consideration, the DDA system was designed to both control the difficulty of the activities in order to tackle common concerns regarding static difficulty levels and progression, and to indirectly manage the variety of activities performed by the player in a method that would allow them to make meaningful choices that affected what they did in the game while preserving its contributions to the player's rehabilitation treatment.

A prototype was then developed, Prototype 2.0, that featured activities that would be performed in Village Druid and a partial implementation of the DDA system - featuring the component that managed their difficulty. For playtesting this prototype, a group of playtesters that represented the stakeholders, featuring rehabilitation clients and health professionals, was gathered. As part of the playtesting sessions, they answered a playtest questionnaire where their previous experience with digital games and virtual reality was assessed, played the prototype where they performed the same sequence of activities twice[1] - with the levels of assistance being gathered, and then answered a post-playtest questionnaire regarding their perception of the DDA and the narrative context provided by the game.

The results gathered in the playtesting sessions seem to indicate that the inclusion of the DDA system in *Village Druid* had a positive impact on the players' experience. The system correctly adapted

[1] The DDA system changed the difficulty of the activities in the second sequence according to the players' performance in the first; the changes made were recorded.

the game parameters according to the values recorded by the performance indicators, of which the reference levels seemed to have been relatively well determined - not leading to the opposite change in difficulty. The levels of assistance in general lowered in the second sequence where the DDA system both raised and lowered the difficulty of activities according to players' performances. While increased player experience likely played a factor in the lower levels of assistance for the second sequence - as players had already interacted with those exercises, the difficulty still lowered for some players who - in the post-playtest questionnaire - answered that the difficulty had not changed; a sentiment shared by most players, including those for whom the difficulty increased. Players not noticing that the difficulty was adapted to them while improving in autonomy is generally a positive result, however, in the context of rehabilitation it is unclear if players observing their improving condition as they successfully perform harder activities would be a more positive alternative. The report in this dissertation provides a practical example of how DDA systems can positively impact player experience, as it successfully adapted it to the players' performance - while remaining undetected for most of them - and kept players engaged and motivated in the game.

6.1 Future Work

Future work could explore if players being aware of the increasing difficulty as they perform the activities successfully could lead to a positive experience; as part of this exploration it would be necessary to determine how this player awareness might be controlled to only provide positive results. Additional future work could be related to expanding the DDA system designed for *Village Druid* by including a system that takes into consideration the player's perception of difficulty as described by Dziedzic and Włodarczyk (2018); since a player can successfully complete an activity at a certain difficulty while still considering it too demanding or stressful - which would affect motivation and engagement.

Bibliography

Dziedzic, D., & Włodarczyk, W. (2018). Approaches to measuring the difficulty of games in dynamic difficulty adjustment systems. *International Journal of Human–Computer Interaction*, *34*(8), 707–715.

Hendrix, M., Bellamy-Wood, T., McKay, S., Bloom, V., & Dunwell, I. (2018). Implementing adaptive game difficulty balancing in serious games. *IEEE Transactions on Games*, *11*(4), 320–327.

Mader, S., Levieux, G., & Natkin, S. (2016). A game design method for therapeutic games. *2016 8th International Conference on Games and Virtual Worlds for Serious Applications (VS-GAMES)*, 1–8.

Schmidt, R., Emmerich, K., & Schmidt, B. (2015). Applied games - in search of a new definition. *Entertainment Computing-ICEC 2015: 14th International Conference, ICEC 2015, Trondheim, Norway, September 29-Ocotober 2, 2015, Proceedings 14*, 100–111.

Sepulveda, G. K., Besoain, F., & Barriga, N. A. (2019). Exploring dynamic difficulty adjustment in videogames. *2019 IEEE CHILEAN Conference on Electrical, Electronics Engineering, Information and Communication Technologies (CHILECON)*, 1–6.

Waern, A. (2012). Framing games. *DiGRA Nordic 2012, Tampere, Finland, 6th-8th June 2012*.

Appendix A

Design Patterns

A.1 Softly Erase Comfort Zone

"You may choose any of these cards - you can trust the dealer."

A.1.1 Name and designation of the pattern

Softly Erase Comfort Zone: the game has a run- or mission-based structure where the player is periodically presented with a choice of a small number of content portions to play. The portion selected by the player at each juncture becomes a stage in that player's progression in the overall game, and when the player is finished with that portion the game provides another choice of content portions, of which the player will select a portion which will become the next stage in progression, until a satisfactory number of content portions has been played and the player completes their attempt at finishing the game. The content portions are divided into types, which represent different playstyles or player preferences. The number of content portions presented for player selection at each juncture are less than the total number of playstyles, and the game progressively makes already-played styles unavailable for selection - nudging the player towards exploring previously unexplored styles of content to preserve wholeness of the experience and variety.

A.1.2 Design Problem

By definition, games are strongly oriented towards providing players with challenge, choice, and variety. Providing choice means modelling multiple non-trivial solution paths for progression through the game, with each path reflecting a particular approach to play or putting more pressure on certain player skills and less pressure on others. Choosing a path can cause a player to become stuck in a comfort-zone, only engaging with a certain type of playable content out of all the content available in the game, and with a rigid, possibly rote playstyle. In this situation, the player is having a worse experience from missing out on variety and challenge when these are offered by the game, and design and development work on the modelling of multiple solution-paths is being wasted. Outright forcing the player to vary their play will remove their sense of agency in the game.

A.1.3 The pattern as a game design solution

The game's progression mechanics are designed to gently encourage players to move outside their comfort zone with successive choices of what content to play next. The game's content is divided into several content styles, which map to player preferences. The game also presents the player with an explicit choice of what content to play next. The number of available choices at each juncture is meaningfully smaller than the total number of choices. This allows the game to exclude content that is being played too much. This can be achieved with a probability system for determining available choices, where the player choosing a content type progressively decreases the probability of that content becoming available. This can also be achieved deterministically, by eliminating previously played content from the selection.

A.1.4 Examples

Village Druid

In Village Druid, the player follows recipes to create potions, and these recipes consist of a sequence of activities/exercises - determined by an algorithm. The player is presented with three possible recipes, and must choose one to perform. The player may attempt to develop a playstyle where they deliberately avoid a specific exercise that they find more challenging, but the algorithm generating the recipes will gradually increase the probability of that exercise being featured up to the point of being present in all three recipes. Through this, the player will naturally be led to playing the whole variety of activities the game has to offer - which is relevant for its contributions to the rehabilitation.

Hades

In *Hades* (Supergiant Games, 2018), the player must progress through a number of rooms to complete a run. These rooms have a type which describes the challenge and reward in them; each type can mean advantages or disadvantages to different playstyles. Players will attempt to evade certain rooms that are not good for their playstyle, but the game will adapt its generation to eventually present the player with situations where they will have to start choosing between rooms that they haven't interacted with yet. If the player avoids a mini-boss encounter in the first area, they are more likely to be presented with the miniboss encounter again later down the run - possibly facing a choice between two rooms guaranteed to have minibosses.

A.2 Generic Story Callbacks

"You can now see them because you took the red pill. Or did you pick the blue pill? If it was the blue one then that's why."

A.2.1 Name and designation of the pattern

Generic Story Callbacks: In its linear narrative structure, the game will do callbacks to 'apparently' influential decisions the player made in simulated branching moments of the narrative. Whatever

choice the player makes does not affect the progression of the narrative or a selection of contents; however, by referencing these 'inconsequential' decisions as the context for the generic event that is being presented to the player, the narrative is now framed according to the player's actions.

A.2.2 Design Problem

Narrative and Interactive Storytelling are powerful means of expression for games. Certain kinds of game experience naturally lend themselves to narrative framing and failing to provide this framing significantly harms player engagement. In games with these kinds of experience, players expect narrative agency, where their narrative choices significantly alter subsequent story events (the course of the interactive story in what narrative choices become available and their framing). Design complexity and development costs scale exponentially with modelling for narrative agency, as player choices require rich short-term and long-term feedback (involving additional work in creating storytelling assets) as well as modelling a branching story while providing quality of narrative (narrative causality between events). Developers run into a bottleneck in being able to accommodate branching narrative agency, and each branch may lose in story quality due to complexity.

As a means to provide a feeling of narrative agency with reduced development cost throughout the game, developers can simulate agency through techniques such as re-convergent narrative. However, if these simulations occur only at specific 'critical' moments, and the rest of the game consists of events that don't mention the player's choices or actions in any meaningful way, the player may begin to see the strings behind the simulation - ruining the illusion, possibly frustrating the player as they feel they are being tricked while making meaningless choices.

A.2.3 The pattern as a game design solution

The experience of games and other works in interactive media have a first-pass/second-pass quality. Users can make one attempt to explore the interactive work and still have a meaningful experience in subsequent attempts, where the experience is reconfigured by user interaction in each of those attempts. Story quality and a manageable degree of development complexity can be preserved in games that suggest a need for player narrative agency by sacrificing second-pass quality to first-pass quality. This is achieved by writing story-events that are relatively non-specific (a subsequent story event fits with any number of preceding player choices) and by providing universally adaptable or generic call-backs as long-term feedback. Essentially, the player makes branching choices, but the feedback is non-branching while also high-quality (shows narrative causality), thus preserving the player's feeling of agency on a first pass. The player would have to make multiple passes to fully model the way in which choices are ultimately non-branching, but even then might still enjoy the game, provided the generic callbacks are well-crafted.

A.2.4 Examples

Village Druid

On critical narrative events, the player is given the responsibility to choose one of three possible recipes with different effects to solve a problem. This choice is presented as being instrumental to the resolution of the crisis, and the decision made by the player will be referred to later as the cause of a

'fallout event'. This event would have been present whether the player chose that specific solution or not. A re-contextualization of the mission is made to mention the player's 'critical' decision, strengthening the illusion that their actions influenced the outcome of the narrative in a more significant manner.

Until Dawn

At the start of the game *Until Dawn* (Supermassive Games, 2015), players are given the opportunity to choose what they fear the most from a set of themes presented to them (clowns, scarecrows, zombies, gore, etc.). These elements are all present in the game; however, as the player sees them when they progress through the game, they become under the impression that the events of the game changed based on these initial choices regarding what they fear the most. Players are left under the impression that the choices they made at the start lead to the game being tailored specifically to them - as they see these elements as call-backs to the fears they answered. The scares of the game will function as call-backs to the choices the player made at the start of the game, leading them to believe the game adapted specifically to them when in reality it is exactly the same for every player.

A.3 Critical Path Self-contained Agency

"I'm glad you defeated the bad guy… by the way my kitchen is on fire, could you help me out a bit? It would mean a lot."

A.3.1 Name and designation of the pattern

In interactive storytelling, longer story arcs are more sensitive in terms of generating development complexity and preserving story quality (narrative causality). If there is a narrative to the game, players will feel the need to meaningfully intervene in the narrative. This can be achieved by letting players influence smaller relatively self-contained sub-arcs within the larger narrative, while limiting or removing their influence on the overarching arc of the game's plot.

The game's narrative structure, based on episode or mission selection, defines different segments according to their relation to the main storyline. These mean the game can employ a feeling of control over the narrative by the player in a limited number of segments while the majority of content is completely independent from it - presented as 'one-off' adventures/situations.

A.3.2 Design Problem

In a mission-based game, giving every mission the same weight in terms of impact on the overall experience particularly as it regards narrative choices means factoring the outcome of each mission with every other mission. This can detract from the game's expressiveness by taking away structure (all missions are equal) and harms development costs and the preservation of story quality (narrative causality) in the experience.

A technique games can use to achieve this is by categorising the game's missions according to their relation to the main storyline. Should there be optional missions, there can be missions that are directly related to - and perhaps unlocked by - the decisions made by the player, and missions that are independent and self-contained. The latter means there is no need for a meaningful connection and

recognition of the players actions in the main narrative and, therefore, can be featured in greater amounts at a lower production cost.

A.3.3 The pattern as a game design solution

By limiting long-term feedback to a critical path this feedback can be made linear and non-branching. Conversely, short-term feedback can be made to branch. This implies having a chain of core missions featuring continuity in narrative and outcomes as distinguished from secondary missions which are more self-contained both as stories and as tests of player skill.

A.3.4 Examples

Village Druid

The game categorises mission themes according to their relation to the main narrative thread. These are critical, fallout, and filler. And from critical to filler their relation to the main narrative thread disappears. This means that: while critical missions will mention what the player did in the previous ones of the same kind, fillers - the most numerous - will not, as they pertain to one-off self-contained events.

Cyberpunk 2077

Cyberpunk 2077 (CD Projekt Red, 2020) features several different types of quests. There are 'Main Quests' (story or campaign quests), which are the largest in the game and connect the beginning and end of the game's plot - with several choices along the way. 'Side Quests' tell stories that can have some dimension and slight effects on some main quests' outcomes - despite existing outside of the main story-line. And lastly, 'Street Stories' and 'Minor Quests' are very short side quests that tell creative and self-contained stories. Through these different systems, the game provides a variety of missions that the player can interact with without their numbers posing the daunting task of having to be allays accounted for when progressing the game's main narrative.

Appendix B

Design of Prototype 2.0

B.1 Tutorial

As an introduction to its modes of interaction (moving the handheld controllers and pressing its buttons), *Village Druid*'s Prototype 2.0 features a tutorial where the player performs two trivial (zero challenge) activities that feature the general actions/movements that they will perform in the activities of the game. The first consists of the player grabbing a group of ingredients and dropping them onto the cauldron that is in front of them, and the second step has them do a highly simplified iteration of the 'Ball Path' exercise (see section B.3.3). The tutorial is contextualized in the game as actions the druid (player) needs to perform to prime the cauldron for brewing their potions.

B.2 Narrative

Prototype 2.0 presents an initial implementation of the fantasy narrative context for *Village Druid*. The player is given instructions and context for the actions they are performing through a non-playable character that interacts with the druid (the player) as a fellow villager. They explain how to perform the activities to brew the potions and give player the scenarios that explain the situation that requires a potion from the druid. The two sequences of activities the player needs to perform in Prototype 2.0 are re-contextualized as the two potions that the player needs to make in order to solve the two issues that the villager NPC will approach them with. Along with these elements, the virtual environment is already modeled as the druid's hut, and inside are assets that allude to their occupation along with the objects that the player will interact with in the game (cauldron, vials, book).

B.3 Activities

Prototype 2.0 features four activities (described below) that were designed with the cooperation of rehabilitation therapists, integrating movements that are often practiced in standard rehabilitation treatment sessions. Before any of the activities start, the NPC explains how to do that specific activity, and during the exercises the player can access written instructions in-game by looking at a book located to their left side.

One key feature of all the activities is that the players cannot fail, they will always complete the

exercise successfully. However, the difficulty with which they perform them is measured by each activity's specific performance indicators, with this information being used to determine how the activities' difficulty should vary - by changing the values of their game parameters (in their second iteration).

B.3.1 Solvent Activity

The player has a selection of solvents in vials that they can pour into the cauldron where they are making the potion for the village. The activity requires the player to grab the vials - exercising the opening and closing of their hand - and pour varying amounts of each solvent into the cauldron - exercising their wrist rotation. The quantities that need to be poured for each solvent can vary from 0% to 100%, and the higher the difficulty of the activity the higher the total amount from all solvents that needs to be poured. This exercise works broad upper-limb movements and opening and closing of the player's hands as they reach for and handle the vials with the solvents (see B.1).

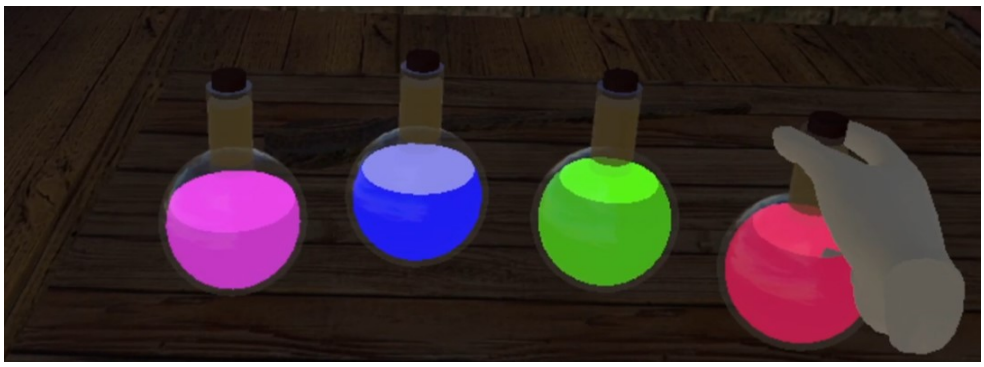

Figure B.1: Screenshot of the *Solvent Activity* activity from the prototype of *Village Druid*.

Script for the activity: The player can see what percentage they need from each solvent, they then need to pick the correct ones from the potion rack which is positioned to their right[1]. The player can grab a vial by holding the trigger button on the controller of the hand they are trying to grab it with. Once they grabbed it, they can bring it over the cauldron and begin rotating their wrist to pour the solvent inside the vial. Above the cauldron, the player can see progress indicators color coded to each solvent, informing them of how much of the intended quantity they have currently poured. The activity ends when the intended quantities of each required solvent are poured into the cauldron[2].

Performance Indicator: Average wrist rotation angle while pouring.

Difficulty Parameters:

- **Solvent Number:** the number of different solvents that need to be poured into the cauldron;
- **Pour Time:** the total quantity of solvent that needs to be poured from all required vials;
- **Rotation Angle:** the rotation angle necessary to consider that a solvent is being poured into the cauldron.

[1] Future versions of the prototype will eventually allow for the position of the potion rack to be customizable.

[2] No penalty or negative performance assessment is given to the player for pouring the wrong solvent, nor for over-pouring the requested solvents.

B.3.2 Drawing Points

The player is shown a path in a pane in front of them that they must trace with their index finger (exercising the opening and closing of their hand) by moving their arm (exercising its movement). The path has key numbered dots to illustrate the path the player must follow. The exercise records how thoroughly the player follows the path with their index finger; they can take a break from the exercise at any time. Reaching the final key numbered dot in the path completes the exercise. The higher the difficulty the bigger the path that needs to be traced. This exercise works the fine motor skills of the player, as they meticulously follow the path without skipping progress (see B.2).

Figure B.2: Screenshot of the *Drawing Points* activity from the prototype of *Village Druid*.

Script for the activity: The player can see the path that must be traced in front of them in a vertical pane. The path has several key points that are numbered from 1 to X, with 1 marking the start. The player raises their hand and with their index finger they must trace the path starting from the key point 1. As the player traces the path it is marked as progress, and should the player stop tracing the path their progress is saved. If the player resumes the path in a point that skips some progress, the progress skips to that point and the skipped path is recorded by the exercise. The activity ends when the player reaches the final point while tracing the path.

Performance Indicator: Percentage of the path that was skipped.

Difficulty Parameters:

- **Trail Size:** defined in centimeters in-between a set interval;
- **Anchor Points:** points that define the trail between them and allows for the calculation of splines between both points for curvatures;

B.3.3 Ball Path

In a pane in front of them, the player is shown a path that loops with a ball that they must push with their index finger (exercising the opening and closing of their hand) by moving their arm (exercising its movement) - akin to pushing a marble along a flat surface track. The player only has to keep contact with the ball as its path is predetermined, moving automatically while the player is touching it. The player can stop touching the ball at any time and won't lose progress. Completing a full lap with the ball completes the exercise. The higher the difficulty the longer the path to push the ball through. This

exercise works the fine motor skills and broad upper-limb movement of the player, who has to consistently "push" the ball in order for it to follow its course by moving their arm in the process (see B.3).

Figure B.3: Screenshot of the *Ball Path* activity from the prototype of *Village Druid*.

Script for the activity: The player can see the path in front of them in a vertical pane, and somewhere on the path is the ball that they must push by touching it. The player raises their hand and with their index finger they must keep contact with the ball for it to keep moving through the predetermined path. If the player stops touching the ball it will stay still in its current location and the player can resume the exercise at any time. The exercise records how long the player takes to lead the ball through its path. The activity ends when the player pushes the ball through the path all the way around back to its starting location.

Performance Indicator: Time taken to complete the exercise.

Difficulty Parameters:

- **Track Size:** defined in centimeters in-between a set interval;
- **Ball Size:** defined in centimeters defining the diameter of the ball;

B.3.4 Bubble Burst

Above the cauldron in front of the player will appear pink and blue bubbles that the player must pop with the respective hand. If the player doesn't pop the bubbles they will keep floating upwards until reaching a maximum height where they will pop on their own. The player has to pop the bubbles with the respective hand to add to a score (each color has its own score); if they pop a bubble with the wrong hand or that bubble pops on its own by reaching the maximum height the score for that bubble's color will be decreased by one. Reaching a concurrent score of X points for both colors completes the exercise. The higher the difficulty the more likely the bubbles are to appear in the opposite side of their respective arm, increasing the needed range of motion. This exercise works the player's hand-eye coordination, impulse control, and broad upper-limb movements as they attempt to pop the bubbles with their respective arm (see B.4).

Script for the activity: The player can see bubbles appear in two columns above the cauldron, slowly floating upwards. The player raises their hand to pop the bubbles, making sure to pop each of the two colors with the respective hand. If the player pops a bubble with the wrong hand or lets that bubble pop on its own upon reaching the maximum height, the score for that bubble's color gets decreased by

Figure B.4: Screenshot of the *Bubble Burst* activity from the prototype of *Village Druid*.

one. The exercise records how many bubble the player pops with the wrong arm. The activity ends when the player makes the score of both colors equal to the max value X.

Performance Indicator: Percentage of bubbles that were popped with the wrong hand + percentage of bubbles that popped on their own by reaching the maximum height.

Difficulty Parameters:

- **Bubble Number:** maximum score required for both colors to complete the activity;
- **Opposite Bubble Probability:** probability of blue & pink bubbles appearing on the opposite side of their respective hand;
- **Bubble Speed Velocity:** velocity at which the bubbles float upwards;
- **Maximum Height:** the maximum height bubbles can reach as they float upwards;

Appendix C

Assessment of Prototype 2.0's Activities

C.1 Solvent Action

Overall, the *Solvent Action* activity (see B.3.1) was the second favourite among all participants - being the runner-up behind *Bubble Burst*; therapists, specifically, praised the movements that it had players do naturally. This activity appears to be the most effective at re-contextualizing the actions with the fantasy context, possibly explaining the increased interest from participants in general. Despite these positive reviews, the activity still demanded instances of assistance. The two issues identified during playtesting that contributed to requests for assistance were: 1) unintuitive UI and 2) misplaced objects related to the activity.

C.1.1 Unintuitive UI

Players questioned why they always had to completely fill the progress bars - which represented the percentage of the intended quantity that had been poured - when they were asked for 'small' or 'medium' quantities; in some instances, on the therapists' group, players demonstrated frustration stating that 'the quantity doesn't really matter if I just have to fill up every bar'. The semi-structured interviews, performed after playtesting, revealed the vast majority of players did not realise they poured different quantities for each solvent - or that they had to pour more solvent in total for the second recipe (if the difficulty was increased by the DDA system)..

Solution: The activity will simply ask players to pour specific solvents until the intended quantity is reached - represented by the progress bars above the cauldron. These bars fill up at different rates, demanding different amounts be poured until reaching the intended quantity[1]. This also makes the activity more accessible for participants like those in the group of rehabilitation clients with ID, who struggled to understand the meaning of the requested small/medium/large quantities.

C.1.2 Misplaced Objects

The vials with solvent that the player had to pour into the cauldron were positioned in an uncomfortable angle to the players. Besides discomfort, this also resulted in some players simply not being

[1] Overpouring is ignored by the activity.

aware of the existence of the solvents; while most players eventually found them by looking around confused at places they thought were 'not relevant', some cases ended up requiring intervention to indicate were those objects were located. This second consequence may have been aggravated by the players' unfamiliarity with VR, as many of them simply refrained from moving their head while playing the game.

Solution: The position of the solvents will be moved forward so that they are to the side of the cauldron and not the side of the player. This makes them much more noticeable upon starting the activity, and facilitates accessing the vials (which is not meant to be a challenge in the activity).

C.2 Draw Points

The *Draw Points* activity (see B.3.2) appeared to demand the most effort from participants. This was expected to a certain extent as it required fine-motor skills by having players carefully trace a path with their in-game index finger, but players appeared to 'struggle' more than was intended, leading to the highest number of interventions recorded. Also, the activity was described as similar to *Ball Path* by some participants, which questions the value of *Draw Points* as its own separate activity considering *Ball Path*'s more positive reception. Overall, this activity appears to have the most issues: 1) excessive difficulty spike, 2) lacking meaningful context in the game, and 3) is prone to accidents from the players - affecting the assessment of their performance.

C.2.1 Difficulty Spike

The participants were observed to put disproportionately more effort in this activity than the rest. The preciseness of the movement required was demanding and the size of the paths they had to follow were too long. Some players even appeared to be intimidated by the complexity of the path in the higher difficulty version of the activity (in the second sequence).

Solution: The path players must trace will be widened to be more accessible to players - not requiring such precise movement to progress, and the paths will be shortened to not appear as daunting to players in higher difficulties.

C.2.2 Lacks Context

The activity is not successfully contextualized with the game's context. The player is told to follow a line/path that appears to have no meaning in the game, making it seem more like a chore than a meaningful activity from their role as a druid in the game; this could affect motivation.

Solution: The paths the player must follow in the activity will be changed to look like symbols and runes that can be presented with a context directly related to the narrative of *Village Druid* - similar to how the vials in *Solvent Action* relate to the player's role as a druid.

C.2.3 Prone to Accidents

The design and implementation of the *Draw Points* activity was vulnerable to accidents from the players. A small number of players skipped significant amounts of progress in the path without noticing, which would then be recorded by its performance indicators; this could subsequently lead to the dynamic difficulty adjustment system making changes that might not reflect the players' abilities.

Solution: Fixes to this issue would revolve around some assurance that players could only progress from where they last were on the track. However, this would result in an activity that is near identical to *Ball Path*, as the ball in that activity effectively serves that exact purpose. Since participants already expressed they felt the two activities were alike, unless the *Draw Points* activity is reworked to have more distinct characteristics compared to *Ball Path* (or vice-versa), the most logical decision will be to remove the *Draw Points* activity since it had the most issues.

C.3 Ball Path

The *Ball Path* activity (see B.3.3), compared to *Draw Points* (with which participants drew similarities), had much more positive results. While some issues were identified in the activity - leading to instances of 'self-adapted', there was only one instance of 'intervention' recorded in all the playtesting sessions. If in subsequent testing participants still feel *Ball Path* and *Draw Points* are too similar, the more positive reception of this activity justifies the removal of the latter to avoid confusion. The problems identified for *Ball Path* were: 1) the goal and elements of the activity were unclear, and 2) the actions in the activity were not successfully contextualized in the game. While the former is to blame for the levels of intervention recorded in the activity, the latter may affect the motivation of players as was observed in the more extreme case of the *Draw Points* activity.

C.3.1 Unclear Goal and Progression

The ball is not easily noticeable from the track it is on or from the background itself. Also, there is no indication of the goal of the activity when playing it, or in what direction the ball is supposed to move.

Solution: Properties of the ball that players need to push in the activity, namely brightness and color, will be changed to more strongly contrast from the background and the path itself. The final position intended for the ball and the direction in which it will move will be clearly indicated during the activity via an icon for the goal and arrows for the movement's direction.

C.3.2 Lacks Context

The activity is not successfully contextualised in the game, as the player pushes a ball through a meaningless path.

Solution: The proposed solution for this issue is the same as *Draw Points*, since the concern is the same and the exercises are similar in design. The paths the ball must follow should be changed to resemble runes or symbols that the player can associate to their actions in the game as a druid that is making magic potions, or the fantasy setting in general.

C.4 Bubble Burst

The *Bubble Burst* activity (see B.3.4) was the favourite among participants. From the therapist group, only one participant struggled with the activity as they skipped the instructions and immediately requested assistance once they couldn't progress (they required no assistance in the iteration of the second

recipe). For clients, while the activity caused a lot of positive excitement and enjoyment, it required assistance as some participants simply forgot what hand to use for what color or that it mattered. Also, due to the excited state of participants while playing the activity, some felt the need to get up from the chair to catch bubbles that were floating away - this was observed in both groups though mainly with clients; encouragement of this action is highly problematic as it can disrupt the VR headset's calibration for the playsession. The issues identified were: 1) a lack of clear noticeable instructions during the activity, and 2) disruptive player behaviour directly caused by the activity.

C.4.1 Lack of Instructions

Some players forgot or confused what hand had to be used to pop each color of bubbles, leading to them either popping the bubbles indiscriminately or popping them with the opposite hands without realising they were making no progress.

Solution: The activity, while being played, will feature visual aids that show to the player what hand they must use for what color. Popping the bubbles will also have some specific audiovisual feedback to indicate when they are popped with the correct hand or not.

C.4.2 Disruptive Player Behaviour

While playing the activity, some players understood that they could get up from the intended sited position due to how high the bubbles in the activity could go.

Solution: The maximum height that the bubbles can float to will be lowered so that players can always reach the bubbles while sitting down until they pop on their own. In order to balance this change's effect on the activity's difficulty, the velocity at which the bubbles float upward will also be lowered.

Universidade Lusófona – Centro Universitário de Lisboa
Escola de Comunicação, Arquitetura, Artes e Tecnologias da Informação
Lisboa
2023