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**Social Anxiety in VR-CBT**  
Transformative Insights for College Students

MASTER DISSERTATION

**Élton Gonçalo Rodrigues Camacho**  
MASTER IN INFORMATICS ENGINEERING



UNIVERSIDADE da MADEIRA

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FACULDADE DE CIÊNCIAS EXATAS E DA ENGENHARIA

MASTER OF SCIENCE DEGREE IN INFORMATICS ENGINEERING

# Social Anxiety in VR-CBT: Transformative Insights for College Students

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# Resumo

Os problemas de saúde mental são um sério obstáculo para os estudantes universitários, tornando as tarefas da vida quotidiana difíceis e stressantes, afetando negativamente as suas notas académicas, competências sociais e até mesmo levando à dor física. A perturbação de ansiedade social, um problema comum entre os estudantes universitários, leva o indivíduo a evitar interagir com outros e a ter um medo constante de julgamentos negativos. As intervenções digitais têm mostrado resultados promissores para a prestação de cuidados de saúde mental a estudantes universitários, particularmente através da integração da tecnologia de realidade virtual (VR) para simular cenários imersivos da vida real. Neste trabalho, exploramos como um jogo baseado em VR-CBT (Cognitive Behavioral Therapy de Realidade Virtual) pode transmitir eficazmente conceitos e práticas de CBT, ao mesmo tempo que analisamos as implicações e os desafios de design da criação de uma experiência transformadora para o jogador. Para tal, doze estudantes universitários com idades compreendidas entre os 18 e os 25 anos foram recrutados para participar num estudo no qual testaram o artefacto e responderam a questionários pré e pós-intervenção, juntamente com uma entrevista semiestruturada no final. Avaliámos o ganho de conhecimento do participante em CBT, o ganho de literacia em saúde mental e a experiência de jogo. Os resultados demonstraram uma experiência positiva para todos os participantes, tendo sido observado um aumento tanto no conhecimento sobre a CBT como na literacia em saúde mental, sugerindo que esta abordagem foi capaz de aumentar o envolvimento, a literacia em saúde mental e a aplicação prática da CBT. Embora sejam necessários refinamentos no design e na metodologia, especialmente no equilíbrio de alguns elementos do jogo e na avaliação do efeito da intervenção a longo prazo, este estudo contribui para a compreensão do potencial do papel de VR-CBT para a ansiedade social num contexto universitário.

**Keywords:** Realidade Virtual · Cognitive Behavioral Therapy · Jogos · Saúde Mental · Ansiedade Social

## Abstract

Mental health issues are a serious obstacle to college students, making everyday life tasks difficult and stressful, thus negatively affecting student's academic grades, social skills and even leading to physical pain. Social anxiety disorder, a common issue amongst college students, leads the individual to avoid interacting with other people and to possess an ongoing fear of negative judgements. Digital interventions have shown promising results for providing mental health care to college students, particularly through the integration of virtual reality (VR) technology to simulate immersive real-life scenarios. In this work, we explore how a game based on VRCBT (Virtual Reality Cognitive Behavioral Therapy) can effectively convey CBT concepts and practices while also analysing the design implications and challenges of creating a transformative player experience. To this end, twelve college students aged 18-25 were recruited to participate in a study where they tested the artifact and completed pre and post intervention questionnaires, along with a semi-structured interview at the end. We evaluated the participant's knowledge gain in CBT, mental health literacy gain, and gameplay experience. The results showed a positive experience for all participants, with an observed increase in both CBT knowledge and mental health literacy, suggesting that this approach was capable of enhancing engagement, mental health literacy, and practical CBT application. While refinements in design and methodology are required, especially in balancing some game elements and evaluating the intervention's effect long term, this study contributes to understanding the potential of VRCBT's role for social anxiety in a college context.

**Keywords:** Virtual Reality · Cognitive Behavioral Therapy · Games · Mental Health · Social Anxiety

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# 1 Introduction

Approximately 35% of college students claimed to have at least one mental disorder in a study from the "WHO World Mental Health International College Student" project [1]. These mental conditions usually happen prior to college entry and their early detection and treatment are essential to protect students from experiencing difficulties in their academic and social lives during their college years [2]. Between 2013 to 2021, depression and anxiety among college students in US campuses rose 135% and 110% respectively, with COVID-19 pandemic further reinforcing this trend [3]. Lower levels of well-being were also observed among every ethnic group, with increased rates of depression, anxiety, eating disorders and suicidal thoughts [3]. Among these disorders, anxiety stands out as the most common issue in college students with social phobia affecting students earlier on than panic disorder, generalized anxiety disorders (GAD) and post-traumatic stress disorder (PTSD) [4].

Social anxiety disorder (SAD) is one of the most predominant mental disorders with symptom onset in childhood or early adolescence, suggesting that this is a crucial stage in life for targeting potential prevention and early interventions programs [5]. Additionally, SAD symptoms are negatively characterized by a high persistence and stability, therefore demanding a need for such interventions [5]. However, access to professional care can be very challenging to achieve since there are barriers that college students have to surpass. Some of those barriers can be the student's perception that they do not need treatment as they perceive their problems to be minor, lack of time due to other responsibilities, preference for using self-help techniques and stigma, among other reasons [6]. One approach to tackle this issue is to have the college provide mental health services itself; however research shows that these services do not provide enough support, which includes a lack of paid mental health professionals in the college campuses and incomplete actionable plans to address the problems [7]. Additionally, colleges do not provide enough education for students, parents, administrators and educational staff about mental illness disorders including their risks, symptoms, prevention, resources for help and others [7].

Digital mental health interventions are considered to be a very important tool in improving mental health on college campuses, be it a computer, web, mobile and virtual reality-based intervention [8]. Their main focuses are on substance use, anxiety, mood and trauma-related disorders, so that for patients with these conditions the flexibility, comfort and routine that digital health

offers is a preferable alternative to traditional in-person visits while maintaining therapeutic effectiveness [9]. These type of interventions have shown to be beneficial for supporting young adults in cases where access to medical care is limited or wait times to access are long [10]. Lehtimaki et al.'s [10] systematic review for instance found that computerized CBT (cognitive behavioral therapy) was especially effective in the treatment of anxiety and depression on college students. Moreover, gamified interventions that integrate CBT concepts have also demonstrated a significant positive impact on anxiety levels [11]. CBT can also be associated with virtual reality where the immersive nature of VR and its capabilities of control and customization of scenarios allows the patient to explore and experience social anxiety inducing situations in a safer environment [12].

This work is motivated by the potential of using VR as a gamified intervention, creating an experience that is both fun and immersive, and also effective in conveying the CBT concepts to the users. To this matter, we designed and developed an artefact that combines both virtual reality and a gaming experience capable of providing college students with CBT concepts and practices through a gamified intervention. In order to assess its effectiveness in relaying CBT concepts and its immersive and interactive nature, we conducted a mixed method study. This study involved twelve college students aged between 18-25, who interacted with the artefact in a single session and filled pre and post questionnaires alongside a semi-structured interview. This study was designed in a way that it would provide essential insights on the participant's experience regarding CBT knowledge and mental health literature gain, as well as design related feedback, thus allowing for a thorough analysis on key aspects that define whether the artefact was capable, or not, of providing the intended experience, and in determining which factors contributed the most.

## 1.1 Contributions

This work contributes with the development and design of the artefact and also contributes empirically with a user study with college students from University of Madeira. Through a mixed methods methodology, the study focuses on the game design, user experience and on knowledge gain of CBT concepts. These contributions not only are of interest to researchers working on the design of digital health interventions, but should also be of interest to mental health professionals looking to include technology into their practice. Additionally, this work was published as a Demo in the IMX 2024 conference [13], where the first mini game was showcased, and has been accepted as short paper in the upcoming GALA Conference 2025.

## 1.2 Structure

When it comes to the thesis structure, the next Chapter outlines other works that provide essential insights about relevant topics to this study. Chapter 3 explains the rationale behind the approach taken, including research questions. In Chapter 4, every aspect of the artifact's design is detailed, while in Chapter 5 the implementation process is explained. Chapter 6 describes the study's procedure, the data analysis methods and shows analysis on both qualitative and quantitative data. Then, the key findings are discussed in Chapter 7, relating them to the previously established research questions. Finally, Chapter 8 addresses limitations and future work ideas, and ends with a brief takeaway of the work.

## 2 Related Work

To be able to properly understand the current state of social anxiety and its interventions, it is essential to study existing literature. The following subsections detail research conducted on social anxiety, CBT treatment, digital interventions and existing works that applied different techniques and approaches, which are themes that represent important areas of study that are crucial in ensuring that this work achieves its intended purpose.

### 2.1 Mental Health & Social Anxiety

As defined by the Mental Health Organization (WHO), mental health is a "*state of mental well-being that enables people to cope with the stresses of life, realize their abilities, learn well and work well, and contribute to their community*" [14]. Therefore, a poor mental health state can affect an individual's life in several negative ways [15]; disregarding proper treatment can lead to repercussions later on like substance abuse, unemployment, suicidal thoughts and in general poor quality of life [15]. Mental health conditions, including depression, schizophrenia, anxiety disorders, bipolar disorder and post traumatic stress disorder (PTSD), can affect people of any age, race, religion or income but there are factors that increase the probability of these conditions like moving out from family home, acclimatising to a different learning institution, use of alcohol and drugs, among others [16]. However they predominately appear when the individual is at the prime of their life, usually during adolescence and young adulthood [16].

Mental health in college students is particularly important to tackle, since most mental conditions start to develop at this age [16]. Throughout college years, mental health difficulties have a tendency to exponentially grow. For example, student's reports of mental health issues in the third year reports are at the highest, while being at their lowest in the first year [16]. Research found that college students are more likely to be faced with barriers when accessing professional care since it is a time in their lives that they have increasingly more responsibilities and commitments, therefore there is a struggle to allocate time for treatment [8]. There is also a lack of mental health services offered by college campuses which means that what could be a very convenient source of mental care to students does not exist or is very rare [17]. Another factor that can prevent students from accessing professional care is stigma [18]. This stigma can be harder to cope than the effects

of the mental illness itself since people can feel that help seeking can be an admission of deficiency and therefore avoid professional care [19].

Anxiety disorders are considered to be the most predominant type of mental health issue among college students, with approximately 11.9% of college students suffering from an anxiety disorder [4]. This type of disorder is characterized by excessive fear and behavioural related issues [14]. There are different kinds of anxiety disorders such as panic disorder, GAD, separation anxiety disorder, social anxiety disorder and many others [14]. Social anxiety, or social phobia, has an early stage of onset meaning that it's usually the first type of anxiety disorder that college students experience, whereas others have a tendency to develop later [4].

Anxiety is a normal emotional reaction to stress that helps people get out of harm's way and prepare for important events like doing a presentation on an important matter. However, when this anxiety becomes excessive, almost uncontrollable and starts to interfere on basic daily activities, the person is considered to have an anxiety disorder [20]. In the context of social anxiety, symptoms can include:

- Tendency to avoid social situations like refusing to accept assignments or arrangements and engaging with other people [21];
- Being excessively afraid/worried about other's opinions and consequently worrying about making a bad impression leading to a high level of anxiety [21];
- Feeling helpless and in fear when faced with social situations [21];
- Being anxious from anticipating a potential social situation in the future with some of the symptoms being elevated heart rate, sweating, panic and shaking [21].

Possible consequences of social anxiety could go as far as higher risk for depression, alcohol abuse, suicide attempts, disrupt family life, reduce self-esteem and limit work efficiency [22]. It is specially punishing when it comes to college students. Due to its nature, college students with social anxiety tend to have decreased academic performance, since interacting with teachers and peers is fundamental in acquiring various skills, avoid social activities like joining a sports team, decline invites from peers and feel excluded [22].

## 2.2 Cognitive Behavioral Therapy (CBT)

As defined by American Psychological Association (APA), CBT is a "*form of psychotherapy that integrates theories of cognition and learning with treatment techniques derived from cognitive therapy and behavior therapy*" [23]. The first CBT models were used to treat depression, but since then new treatment approaches to other mental health disorders, such as anxiety and panic disorder, have emerged [24]. Research on the long term outcome of CBT treatment found a significant symptom reduction up to twelve months after treatment, for anxiety disorders, PTSD and OCD [25]. Another study found CBT to be effective in anxiety related disorders, resulting in benefits even beyond the symptoms of the disorder being treated [26].

This type of therapy is rooted in several core principles such as psychological problems resulting from distorted thinking patterns and learned unhelpful behaviors, and the fact that people are capable of learning effective coping strategies in order to alleviate their symptoms and improve their quality of life [27]. The treatment in CBT involves:

- Changing thinking patterns by identifying the faults present in a patient's mind;
- Using problem-solving techniques to be able to cope with difficult environments;
- Learning to be more confident about one's own abilities;
- Facing fears instead of avoiding them in order to change and build positive thinking patterns.

CBT treatment involves cooperating with a mental health professional such as a psychologist, and attending a limited number of sessions. The exact course of this treatment varies depending on the person's symptoms and circumstances. However, some strategies can involve regular one-on-one or group sessions, doing homework assignments, role-playing activities, gradually increasing exposure to the things the person fears, among others [24].

Overall, CBT has an intention of providing the individual the ability to develop coping skills during sessions with the therapist and also for exercises outside of sessions. This procedure enables individuals to proactively change their thinking patterns, manage emotions and reshape their behaviours in an effective way [27].

## 2.3 Digital Interventions for Mental Health

Digital interventions offer a broad range of mental health practices through various modes of electronic delivery such as websites, games, apps, computer-assisted apps, virtual reality and others [28]. Philippe et al. [9] conducted a comprehensive systematic review to assess the state of digital mental health interventions and segregated them into seven different categories providing a valuable and detailed overview:

- Synchronous and Asynchronous Therapist Contact: Synchronous contact involves direct communication in real time (e.g. phone call or video conference) while asynchronous contact involves delayed responses, such as emails or texts [9]. Although asynchronous communication can encourage patients to attend their appointments, relax, take medication and reduce relapse following remission [29–31], synchronous contact was more effective before remission [32].
- Web-Based Peer Support: Use of web-based groups (e.g. forums, social media and video calls) where people with similar disorders can interact. This enables patients to learn about other people’s experience on their mental health conditions, receive peer support and gain insights on their conditions [33, 34]. However, there is a risk of misinformation spread since web-based content is usually not monitored [35].
- Web-Based or Computer-Based Therapy Programs: Various online content and programs that provide psychoeducation, self-help therapy, medication reminders, peer support and more. This type of intervention delivered with therapist guidance shows to be effective, whereas unguided ones are less effective and have higher dropout rates [36–40].
- Mobile-Based Therapy Programs: Therapy programs delivered through mobile devices with over 2200 claiming to address mental health conditions. However these mobile apps can be associated with a lack of validation, not based on therapeutic principles, may be addictive and even harm recovery [41–45].
- Virtual and Augmented Reality: Through immersive experiences provided by virtual and augmented reality new forms of assessment, treatment, and research on psychological processes are possible [46–48]. Although VR has shown promise for various types of therapy, negative side effects like possible nausea exist but are being addressed by improvements in the technology itself [49].

- Cognitive Training: Training exercises, neurofeedback and games delivered through mobile, web-based, computer devices and virtual reality. Broad cognitive training appears to be more effective than having a single focus [50]. Additionally, cognitive training with VR can be beneficial to various cognitive and motor functions in different mental health conditions and neurological disorders [51, 52].
- Other Technologies: The authors also identified other modes of intervention like monitoring technologies (e.g. smartwatches, breathalyzer, mobile apps) used to monitor psychological symptoms, heart rate, blood pressure, location and sleep on a frequent basis and to alert practitioners of relapse signs [53–55]. Additionally, chatbots for improving quality of life [56] and transcranial direct current stimulation (tDCS) and similar treatments that are delivered remotely for patients that suffer from dementia and schizophrenia [57].

These types of interventions have all been proven to be effective in improving mental health without there being a clear standout in terms of effectiveness [8]. Defining the role a digital intervention should have is important, as highlighted in Dheda et al.'s [58] work where the game developed is meant to be a complementary treatment and not to completely replace psychotherapy and/or medication. This decision finds support in a meta-analytic review of gamified-interventions that argues gamified-interventions may function better as a supplement rather than replacing a traditional professional treatment [59].

In the same meta-analytic review [59], it was mentioned that applying specialized gamified interventions that target a specific anxiety domain and using a validated tool designed for that domain to assess the outcomes has more beneficial effects rather than a generalized anxiety targeted intervention [59]. This means that focusing on social anxiety solely as opposed to a broader approach to anxiety in general has better chances to produce more favourable results.

### **2.3.1 Virtual Reality for Mental Health**

Virtual Reality is considered to be a very efficient tool to treat mental health conditions and with its growing technological advancements, it will become a central component in a lot of mental health treatments in the near future. More specifically, VR has the potential to reduce stress, anxiety and depression, distract from pain and even treat patients who experience chronic illness [9]. Using Virtual Reality for mental health assessments has earned enough evidence to support the benefits

of its application. Delivery of clinical evaluation through VR significantly increases the individual's engagement with the test or assessment due to the novelty of Virtual Reality being very appealing to people, especially in the younger generations [60]. VR's unique capability to manipulate and control environments allows for simulating real-life scenarios, facilitating the assessment and test of relevant variables. Additionally, VR's immersive nature enables user interaction with virtual objects, further enriching the experience [60].

Moreover, recent studies exemplify the potential of VR applications in mental health. For instance Sun et al. [61] designed a VR game for the purpose of making exposure therapy more attractive and accessible to explore the viability of gamification of treatment solutions through a serious game that affords users to access social exposure therapy to improve the at-home exercise and relapse prevention exercise. The game is set on a university classroom setting to simulate a traditional presentation anxiety experience and the player is given a topic and then has to engage in public speaking practices at different levels in order to increase their comfort with this sort of social situation. It was concluded that further work was needed to refine the game and evaluate its efficacy for Social Anxiety Disorder(SAD) therapy, however the results showed that gamified SAD therapy exercises do have potential for high user engagement in virtual social exposure environments. As future work, the authors suggest other implementations of SAD therapy like cognitive restructuring.

Although in a different context than anxiety, Miller et al. [62] used nature scenes in a VR environment to invoke an awe experience in the player. The article describes how the desired feeling is reached and why. The use of surreal events like the clouds shape-shifting into different animals or planet Mars slowly appearing in front of the player helps to create the desired feeling of awe. Overall the results showed a lot of promise in achieving the initial goals of supporting well-being by making the player feel self-transcendent experiences like awe and connection. However, some of the findings alluded to the fact that players had different ways of wanting to interact with the game; for example, some wanted to freely explore without being guided, while others just wanted to sit back and enjoy the experience without interaction. Highlighting to the fact that there is a need to consider the context and target audience in order to define the level of interactivity the game should have.

### 2.3.2 Cognitive Behavioral Therapy in Serious Games

Serious games with CBT elements have proved to be effective in alleviating anxiety as research found statistical significance on the reduction of anxiety levels on patients [11]. In order to prove this, Heng et al. [63] created a serious role-playing game called ReWIND using CBT concepts to design the storylines and the gameplay mechanics in order to evaluate the effectiveness of the game in improving cognitive emotion regulation and anxiety measures. The gameplay consisted taking the role of Lucas, a pathfinder who travels around the game world and encounters six quest givers. From these quests, the player would learn about different anxiety scenarios and learn different ways to overcome them with cognitive behavioral therapy concepts in mind. The participants were divided in two groups where the first one would play the game and the second would work on a non-game task. From the results it was possible to verify that delivering CBT through a story-based game did have better outcomes than a non-game task when it comes to positive psychological changes. One possible reason the authors point out could be due to the level of engagement and playfulness that the game variant proportioned that helped to internalize the CBT strategies.

On a similar note, Báldy et al. [64] studied how to design and evaluate a serious game aiming at awareness of therapy skills (CBT) associated with social anxiety disorder. This game also takes place at a university campus and the different gameplay scenarios portray potential anxiety-inducing environments like an oral presentation, meeting with fellow students and also attending a party with other people. The authors found some of the game designs like the difficulty should have been more challenging, the background sounds needed to be held in more account and immersion and sense of presence were two fundamental aspects in creating believable scenarios to elicit social anxiety.

Another work that also incorporated CBT concepts in their game had the aim to assess the efficacy and acceptability of their game directed to professional clinicians and adolescents that suffer from clinical anxiety disorders [65]. By reshaping the more complex CBT concepts into fun concrete representations, it made the CBT process more suited to the developing needs of adolescents. This also supports the same finding in Heng et al.'s [63] work where the gamification of CBT appears to be an effective way of ensuring more attractiveness and adaptability to younger adults.

### 2.3.3 Integration of CBT into Virtual Reality

A key aspect of CBT involves the exposure of individuals to their fears while removing safety behaviors [66], like avoidance or any specific action or thought that patients employ to reduce anxiety, so that they can realize the feared negative consequences built by themselves are unlikely to happen. However, due to the nature of the disorder reproducing scenarios to practice in CBT is very challenging. To overcome this issue, Virtual Reality Exposure Therapy (VRET) has emerged as a fundamental tool, where its possible to replicate social situations in a therapeutic setting and has shown the capability to evoke social distress experience by patients.

Wu et al. [67] conducted a systematic review and meta-analysis about Virtual Reality-Assisted Cognitive Behavioral therapy (VRCBT) for Anxiety Disorders and found that it has a potential advantage over the normal CBT by providing treatment through virtual environment rather than real-world settings, VRCBT offers a valuable alternative for patients who might be reluctant to engaging in real life situations due to their mental health. This can serve as an intermediary step for people to start participating in real-world scenarios. Another aspect highlighted in this review is the privacy aspect exclusive to a VR environment where the patient does not have to worry about potential embarrassing situations or other concerns related to social anxiety since virtual reality is a confidential space free of observation by others.

In a more practical and direct way, Geraets et al. [12] performed a study to assess the feasibility and effectiveness of VR-CBT for patients with generalized SAD. Each participant would engage in 16 one-hour individual sessions once or twice a week where they would test their approach behaviors and beliefs (CBT concepts) in customised VR environments with the support and feedback of a therapist. The results confirmed that VR-CBT enabled patients to experience social encounters more positively, decreased level on anxiety in social interaction, less depressive symptoms and in general an improved quality of life. The results also show that exposure in VR allowed for a gradual increase in difficulty level by controlling the environment properties whereas *in vivo* exposure such control is not possible. This further supports the same finding in Wu et al.'s systematic review since the ability of gradually increasing the level of exposure could work as a stepping stone for people that avoid social situations. Another study [68] found no difference in effectiveness between traditional exposure and VR exposure when it comes to behavioral measures and on the measures of fear of social interactions, fear of negative evaluation and depressive mood. The results ended

up showing that CBT with VR technology is an efficient and effective alternative to a traditional CBT intervention with immediate effect and in the long term as well [68].

## 2.4 Transformative Games Design

Transformative games are games that seek to manifest a significant change in the player, beyond entertainment, that persists into the real world. To aid the development of such games, Sabrina Gulyba created a framework called Transformational Framework [69], which is based on the work of Schell Games, an independent game studio that specializes in creating games that are both entertaining and educational. This framework's main purpose is to support the design process of a transformational game by providing insights, best practices and tips in order to overcome the challenges of developing a game that can change players in a significant way that persists beyond the gameplay session. This framework is centered around eight exploratory topics (where each topic provides in-depth analysis and insight on good practices):

- High-Level Purpose – Main goal that motivates the game development
- Audience & Context – Ecosystem in which the games makes a difference
- Player Transformations – In what ways will the players change from the game experience
- Barriers – What stands in the way of the purpose and player transformation
- Domain Concepts – Game elements necessary to elicit change
- Expert Resources – Authoritative sources of insight and feedback
- Prior Works – Related work used as reference
- Assessment Plan – How will the game be evaluated

Designing serious games that are both educational and engaging can result in tensions between interaction, enjoyment and content delivery. Several papers address this issue by exploring how this balance affects the effectiveness of such transformative game experiences. For instance, Chen et al.'s work [70] explored the balance between hedonic (fun and pleasure driven) and eudaimonic (meaningful and objective oriented) experiences and their impact. They argue that while hedonic elements are essential to maintain the player's engagement, the learning goals must remain a central part in the game's design. If the fun elements of the game are too prevalent, the learning value will be diminished. On the contrary, overly didactic games can feel boring and lose the player's

attention. The findings suggest that the gameplay mechanics need to be designed in order to bridge enjoyment and reflection, without allowing one aspect to overshadow the other.

Expanding on this challenge, Natucci and Borges [71] analysed the integration of pedagogy, emotion and gameplay mechanics in a serious games context. They argue that a poor alignment of these elements can lead to cognitive overload or player disengagement. For example, overly complex content may result in difficult understanding, while emotionally flat experiences may reduce immersion.

On a similar note, Martey et al. [72] investigated the balance between play and formal training when designing serious games. Even though open-ended, exploratory mechanics can lead to higher level of immersion and motivation, the authors warn that such mechanics need to be carefully designed, as they can lead to confusion and ambiguity regarding the game's objective. Their study found that games that offer rich interaction without providing a clear learning objective risk reducing their intended impact.

Several studies have explored the immersive and transformative potential of gaming experiences. Whitby et al. [73] used systematic self-observation diaries and micro-phenomenological interviews to capture player's lived experience of perspective challenges in purposely sampled games. The authors identified eight games that regularly evoke perspective-challenging moments via the game mechanics. The results showed that endo-game reflections were more frequent than exo-game reflections and that although exo-game triggers only prompted exo-game reflections, endo-game triggers could activate both endo and exo game reflections. It was also found that the triggers were successful when the framing or perspective on a topic or life experience was unexpected to the player, which is also something Jean and Tanenbaum's study [74] reflect on where they claim that transformative play supports a "*process of empathic identification with a new point-of-view or lived experience, which impacts how we understand games as persuasive cultural artefacts*".

Rusch and Phelps [75] argue symbolic enactment as a way to potentially evoke a transformational experience in the player through objects and actions that represent inner issues and thus enabling the player to act upon them. It was proposed a theoretical framework that included design guidelines to aid the process of creating meaningful games. A case study was conducted on the game *Papo & Yo* [76] and throughout this review the authors point out different parts of the game where the game mechanics and different levels symbolized something deeper and real than

just being a game. From the analysis of this game the authors were able to conclude that symbolic enactment had significant potential to evoke transformational experience on the player. From an educational lenses point of view, Barab et al. [77] studied the transformational impact of a game called *Quest Atlantis* on children. Two learning modules were tested and in each one there were two groups of players. One group of players experienced the more traditional way of learning, text on a paper, and the other group played on the *Quest Atlantis*. The children that played *Quest Atlantis* had better results like being more invested, doing the exercise because they wanted to and not because someone told them to, realizing that the decisions they made impacted the world around them and that in turn made them more aware and careful of their decisions. Thus emphasizing the positive impact of gamified interventions when compared to a traditional way of learning.

Chapter 2 showcases an abundance of work for social anxiety and mental health in general, be it games and VR related applications like VRCBT and even VR games. These studies underlined the benefits and challenges of such artefacts in contributing to a better mental health state. With college students in mind, gamification of interventions has proven to be both beneficial in increasing adherence and engagement when compared to traditional ways of learning [60]. CBT, for instance, also benefits from gamified elements since reshaping CBT concepts into fun and interactive representations is an effective way of ensuring more attractiveness and adaptability to young adults [61, 63].

Virtual Reality further augments these types of interventions given the immersion and privacy value it provides. The VR environment not only increases adherence and attractiveness enabling users to better consume the information conveyed, but is also a safe place for those struggling to initially make contact with or that fear creating embarrassing situations to others [67]. VRCBT takes on Virtual Reality and commonly utilizes its immersion as a tool to simulate realistic situations in order to induce specific fears to the users. When combined with gamification, VRCBT also follows the positive trend of higher adaptability and attractiveness to younger individuals [12].

## 2.5 Research Opportunities

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## 3 Methodology

Despite the promising developments of exploring the use of VR and gamification in CBT interventions for social anxiety, there is lack of research in combining these two approaches within a college context. This work addresses that gap by exploring and investigating how a VR-CBT based game can contribute to relaying CBT concepts and practices, but also to study the design implications and challenges when it comes to eliciting a transformative experience in the player. Contrary to the standard methods of CBT treatment, which are conducted and followed by professionals and specifically targeted to individuals suffering from mental illness, this approach focuses on developing a complementary tool tailored for young college students, designed to provide essential information about CBT concepts for social anxiety regardless of their mental health state, since it can also be used as a preventive measure or simply to raise awareness on this issue.

We structure our methodological exploration as two research questions:

- ***RQ1 Can CBT concepts and practices be effectively integrated into a gamified VR-based intervention?*** – This research question focuses on the design aspect of the game, aiming to identify and validate the key factors that contribute to an effective integration of a VR-CBT gamified intervention for Social Anxiety. By analysing the design choices, mechanics and other factors, we hope to understand how well CBT practices can be translated into an immersive and interactive virtual environment.
- ***RQ2 Does a gamified VR-based CBT intervention effectively help college students retain CBT knowledge?*** - This research question investigates the impact of the intervention on the participant’s cognitive and theoretical understanding of the CBT concepts conveyed. More specifically, it assesses whether the intervention’s impact is meaningful enough to leave a significant change in the participant’s ability to retaining CBT knowledge and practices for managing social anxiety.

### 3.1 Research through Design

In this work, and in order to respond to the research questions above, we adopted a research through design approach [78]. Research and design are closely related but they are different in the way they are conducted and the values of the outcomes that they are judged by. There are different relations between them used for various scenarios, like Research for Design, Research into Design and, the

one that this work will follow, Research through Design [79]. This latter approach involves doing design as part of doing research, where the design activities actively contribute to the fabrication of new knowledge. Some of these activities can go from design professionals gaining insight into complex situations, framing and re-framing problems and creating prototypes, or also commonly addressed as artefacts [79]. In this work, an artefact (game) will be developed in order to address the issue and then evaluated in order to assess its ability to satisfy the initial objective. Through research through design, knowledge is gained not only through the artefact (and others experience of it), but also through the process of building the artefact; this allows for the exploration of the research questions, giving insight not only how to design, but also others experience of the design. To aid the development of the game, we used the transformative framework as a design guide to ensure that the intended player transformations were achievable, and to overcome potential challenges associated with creating such changes through gameplay.

## **3.2 Transformational Framework**

Throughout the development process, the transformational framework provided essential support in a few key areas of the artefact's design. Among the eight framework core components, three had a more significant influence in the design: Audience and Context, Player Transformations and Barriers. While the remaining five core components also provided helpful insights into the project, these three components felt the most important to take in consideration, in order to design a game that could provide such transformative experience.

### **3.2.1 Audience and Context**

In the Audience and Context component, young college students were identified as our target audience, given the frequent occurrence of social anxiety appearing during this transitional stage in life, influencing the game's design. Therefore, a party-like environment was designed, a setting familiar to young teenagers, complemented by interactive mechanics in the mini-games. When it comes to context, the game was designed in a way that any college student could benefit from it, regardless of having mental disorders or not, also serving as a preventive measure or raising awareness about social anxiety. Thus allowing this game to be used as an intervention in a college setting, which could benefit students greatly.

### **3.2.2 Player Transformation**

For the Player Transformation component, we intended to provide outcomes beyond the traditional learning results such as skill and knowledge gain. Our aim was to also manifest a meaningful change in behavior and disposition on the players. This meant that the CBT concepts and content needed to be carefully selected to represent real life scenarios, and thus resonate with the player's personal experiences. The change in behavior would involve the player applying the concepts in real situations, whereas the shift in disposition would be in raising awareness and potentially being able to identify social anxiety in themselves or in others.

### **3.2.3 Barriers**

In the Barriers component, identifying potential challenges in the artefact that could harm the player's transformation in some way was one of our main focuses. One of the main challenges was to achieve a balance between entertainment and content learning. It was important to ensure that the entertaining and interactive nature of the game wouldn't obscure the concepts it tried to convey. At the same time, we sought to avoid making the game too focused on content, as it could diminish the overall enjoyment of the gameplay. To address this, the game was designed in way that the players need to actively understand and apply the content in order to progress, thus integrating learning within the game mechanics. Another important barrier to mention is relevance. Just as previously mentioned in the Player Transformation component, the CBT concepts and content need to be representative of real life experiences in college, in order to connect them emotionally to the players.

## 4 Design

This chapter details the structural and conceptual decisions behind the development of the artefact. More specifically, the following subsections explain different aspects of the design process, such as the game's structure, visual appearance, CBT concepts, among others.

### 4.1 High-level Concept

In order to efficiently incorporate multiple CBT concepts into a single game, individual mini-games were developed, each representing a specific concept. In other words, within the game itself the player is able to freely choose which mini-game to play. These mini-games were designed using a modular structure to ensure reusability, flexibility and scalability which allows individual components to contribute independently to the overall system. This modularity is especially important given the context of this project, as each mini-game is designed to represent a specific CBT concept. In other words, each mini-game module operates on its own, with their own logic and assets. Figure 1 shows a diagram that provides an overview of the system architecture.

Maintaining a consistent structure in each mini-game provides a more cohesive and uniform look throughout the game, which enhances overall user experience. As the player goes through each mini-game, they become familiar with the structure, making it easier to navigate and interact with each game. From a development perspective, the modular design also greatly improves debugging and testing as each mini-game can be worked on independently without being affected by the functionality of others. Moreover, if collaborations happen other developers can quickly adapt to the framework when creating additional games. The modular structure eliminates the need to change existing code, which in turn makes the process more efficient and reduces the potential for errors.

### 4.2 Requirements

In this section all requirements, both functional and non-functional, are described in detail leading to an overview on how every aspect of the artefact will function and be implemented.

#### 4.2.1 Functional Requirements

The following requirements (FR-01 to FR-10) are general functional requirements that apply to every aspect of the game, including all mini-games.

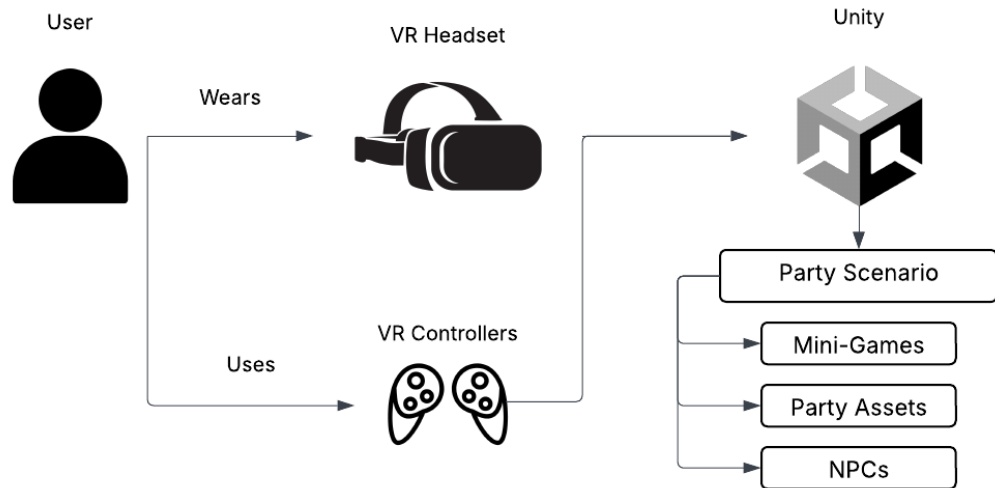


Figure. 1: *System Architecture*

#### – Interaction and Movement

- **FR-01 - The game must provide players with the ability to move using controller**
  - The VR headset tracking allows the player to move within the game using real life movements. However, since the virtual game area exceeds the size of the physical area, it's crucial to enable players to move in the game using a controller as well.
- **FR-02 - The game must provide players with the ability to rotate using controller** - Just like the movement, the VR headset tracking allows the player to look around within the game through real like rotations. However, it is necessary to give players the option to rotate smoothly using the controller since they might prefer it.
- **FR-03 - The game must provide players with the ability to grab objects using either hand** - It's essential to ensure that interactable objects can be grabbed with either since players can be right or left handed.

#### – Tutorials and Instructions

- **FR-04 - The game must provide tutorial for each mini-game** - Before starting each mini-game, it is crucial to provide the player with a tutorial to ensure they understand the objectives and controls of the game.

- **FR-05 - The game must provide starting instructions** - At the start of the game, it is necessary to provide the player with basics instructions about controls and interaction.

– **Game features**

- **FR-06 - The game must provide a score system** - Each mini-game needs to have score tracking system to provide feedback to the player on how they are performing.
- **FR-07 - The game must provide visual and audio feedback** - The game has to provide feedback to the player through audio and visual effects in order to inform them on their actions.
- **FR-08 - The game must provide players with the ability to revisit the mini-games** - After the player completes a mini-game, they should be given the option to replay it.
- **FR-09 - The game must provide a log system** - Log players actions throughout the game, targeting a possible analysis in the future.
- **FR-10 - The game must integrate CBT concepts in mini-games** - Mini-games must be designed in a way that actively engages players to apply the specific concept to successfully complete the mini-game. *Ex: Identifying negative thought patterns.*

In the next section, all specific functional requirements for each mini-game will be presented in detail

– **FR-11 Mini-game A must integrate CBT concept of "Identify your thoughts"**

- **FR-11.1** The game must provide the ability to grab a dart.
- **FR-11.2** The game must provide the ability to throw a dart.
- **FR-11.3** The game must randomly highlight one of the thought patterns.
- **FR-11.4** The game must spawn balloons at random positions.
- **FR-11.5** The game must ensure balloons move randomly.
- **FR-11.6** The game must allow darts to pop balloons.
  - \* **FR-11.6.1** The game must upgrade current thought pattern upon hitting the correct balloon.

- \* **FR-11.6.2** The game must change current thought pattern to a random level 1 thought upon hitting the correct balloon.
- \* **FR-11.6.3** The game must spawn another balloon upon hitting a balloon.
- \* **FR-11.6.4** The game must update score depending on which balloon was popped.
- **FR-11.7** The game must highlight completed thought patterns in a different colour.
- **FR-11.8** The game must provide audio feedback when popping a balloon.
- **FR-11.9** The game must provide visual feedback on the balloon to indicate whether the correct balloon was hit or not.
- **FR-11.10** The game must end once all thought patterns are fully upgraded.
- **FR-12** Mini-game B must integrate CBT concept of "Normalization".
  - **FR-12.1** The game must provide the ability to interact with specific NPCs
  - **FR-12.2** The game must provide the ability to choose a question when interacting with NPCs
  - **FR-12.3** The game must mark explored questions with a check mark
  - **FR-12.4** The game must provide the ability to revisit a question when interacting with NPCs
  - **FR-12.5** The game must provide the ability to grab any type of piece from the board
  - **FR-12.6** The game must provide the ability to attach any type of piece onto any board
  - **FR-12.7** The game must provide the ability to (potentially) combine two pieces by placing them on a specific part of the board
  - **FR-12.8** The game must create a complete piece of information only when combining two incomplete pieces that are linked
  - **FR-12.9** The game must provide audio and visual feedback when trying to combine two incomplete pieces of information
  - **FR-12.10** The game must provide audio and visual feedback when placing a single complete piece of information on a NPC board

- **FR-12.11** The game must provide audio and visual feedback when completing a NPC board
  - **FR-12.12** The game must end upon successfully completing every NPC's board
- **FR-13** Mini-game C must integrate CBT concept of "Cognitive Restructuring"
- **FR-13.1** The game must provide with an initial tutorial phase that demonstrates every aspect of the game at a slower pace
  - **FR-13.2** The game must provide the ability to grab the racket on the table
  - **FR-13.3** The game must periodically spawn a random type of ball
  - **FR-13.4** The game must ensure the balls bounce towards the player
  - **FR-13.5** The game must ensure the balls bounce from the racket
  - **FR-13.6** The game must provide a sound when the balls make contact with the table or the racket
  - **FR-13.7** The game must adjust the anxiety meter based on the players actions, increasing for incorrect actions and decreasing for correct ones.
  - **FR-13.8** The game must update the score based on the players actions, increasing for correct actions and decreasing for incorrect ones.
  - **FR-13.9** The game must start a bonus round upon anxiety meter reaching zero.
    - \* **FR-13.9.1** The game must randomly choose a negative thought for the bonus round
    - \* **FR-13.9.2** The game must display the thought, a question and three different answers about the selected negative thought
    - \* **FR-13.9.3** In the bonus round, the game must periodically spawn default balls for the purpose of choosing answers by hitting a specific wall.
    - \* **FR-13.9.4** In the bonus round, the game must provide audio and visual feedback when hitting the walls.
    - \* **FR-13.9.5** In the bonus round, the game must change the question after the player successfully answers one.

- \* **FR-13.9.6** In the bonus round, the game must ensure that answers that were correctly chosen remain highlighted in green for the remainder of the round indicating they are not available anymore.
- \* **FR-13.9.7** The bonus round must end upon successfully answering all three questions and resume normal gameplay flow.
- **FR-13.9.8** The game must ensure that a negative thought is reframed into a positive thought upon successfully completing the bonus round associated with that thought.
- **FR-13.10** The game must end when successfully re-framing all negative thoughts into positive ones.

#### 4.2.2 Non-functional Requirements

These non-functional requirements represent qualities that the artefact need to possess in order to provide the player with the best possible experience at all times.

##### – Immersion

- **NFR-01 Background music** - The game must have background music that represents the immersive atmosphere of a party-like setting.
- **NFR-02 NPC models and animations** - The game must be filled with animated and realistic looking NPCs that supplement the party environment.
- **NFR-03 Party objects** - The game must be filled with items such as chairs, cups, tables and lighting that create an authentic party scenario.
- **NFR-04 Game objects physics** - Game objects must contain realistic physics, such as collisions and gravity, in order to simulate a real scene
- **NFR-05 Stable frame-rate** - The game must run at a stable frame-rate in order to preserve immersion and provide a smooth experience.

##### – Implementation

- **NFR-06 Platform Compatibility** - The game must run natively on mainstream headset (e.g., Meta quest 3 headset) so that it can be used wirelessly, not needing to be connected to a computer.

- **NFR-07 Modular Structure** - The game must follow a modular structure to ensure flexibility, reusability and scalability, allowing for future features or mini-games to be added with minimal restructuring.
- **NFR-08 Intuitive Interface** - The game must be user-friendly and intuitive, allowing the user to seamlessly navigate the interface without external instruction.
- **NFR-09 Interactive mini-games** - The game must offer different forms of object interactions for each mini-game.
- **NFR-10 Game bugs** - The game must not present any immersion breaking bugs, such as low framerate, input and visual glitches.

### 4.3 Personas

These personas were designed to represent college students with different characteristics that can benefit from the developed artefact. The personas in fig. 24 illustrate two different types of college students. For instance, João, an eighteen year old computer science student, just started college and is now facing various challenges both in his academic and social life due to social anxiety. Learning strategies to manage and overcome social anxiety would greatly benefit him in many ways. On the other hand, Mariana has not been affected by social anxiety but would like to learn about it in hopes to bring awareness and help other people that are struggling with it. By addressing both perspectives, this artefact can be a valuable tool to college students regardless of their mental health state, promoting both personal coping strategies and social anxiety awareness.

### 4.4 Use Cases

To provide a more detailed representation on how the player interacts with the artefact, a Use Case Diagram was created for each mini-game. These diagrams show the different actions the player can take, how the system behaves when responding to those actions and the conditions for certain events to happen. For each diagram, we provide an overview of the diagram's structure and we clarify how the majority of relationships function.

#### 4.4.1 Mini-Game A

For mini-game A (see fig. 25) we have one actor, the College Student, and of course the System. When starting the game, a pre-defined amount of balloons spawn and the Thought Pattern Panel

Figure. 2: *Personas*

is activated. This also leads to a randomly chosen Thought Pattern to be highlighted. The most important action the player can take is throwing a dart.

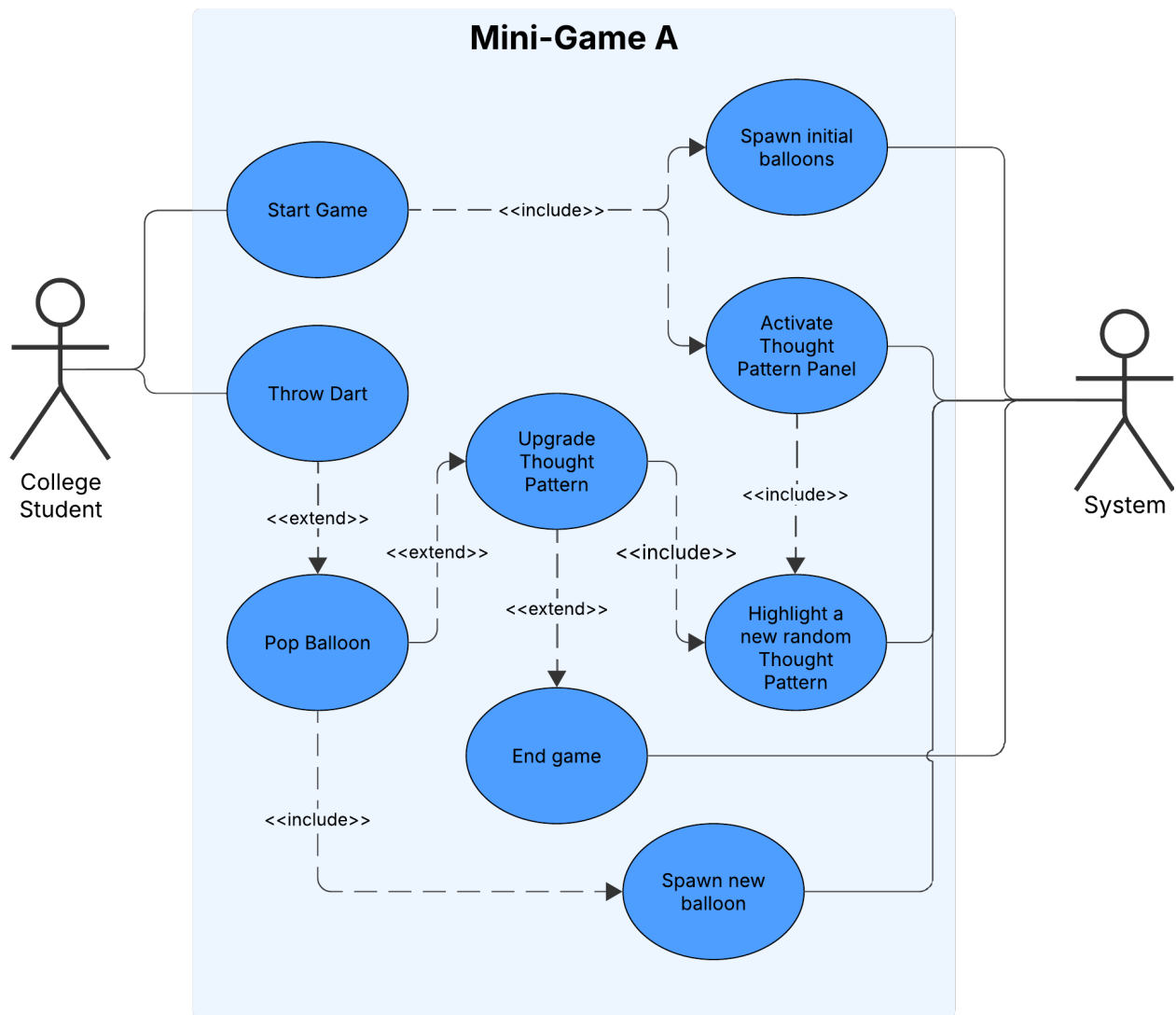


Figure. 3: Use Case Diagram for Mini-Game A

When popping a balloon, the system will always spawn an extra balloon to ensure that the number of active balloons stays consistent and, on the condition of the player successfully hitting a balloon that contains the term associated with the highlighted Thought Pattern, the system upgrades said Thought Pattern. At this point in time, if all Thought Patterns have been upgraded then the system ends the game. Otherwise, a random new Thought Pattern will be highlighted and the game continues.

#### 4.4.2 Mini-game B

In mini-game B two separate Use Case diagrams were created due to its higher complexity and the existence of "two sections". These sections being the NPC conversation part and later on the

puzzle board game. Starting with Section 1 (see fig. 26), we have the addition of the NPCs, with the rest remaining the same when it comes to the actors and the system. Once the game starts, the system marks four NPCs with floating arrows, indicating that they are now available for a conversation. The dialogue works identically for each NPC and when starting a conversation the main dialogue panel shows up. Here, the player gets to read what the NPC is saying and is able to choose between a few different questions. When choosing a question, the NPC provides a response to that question and replaces the questions with new ones. Additionally, the system checks whether the player has explored all questions available, and if so it notifies them.

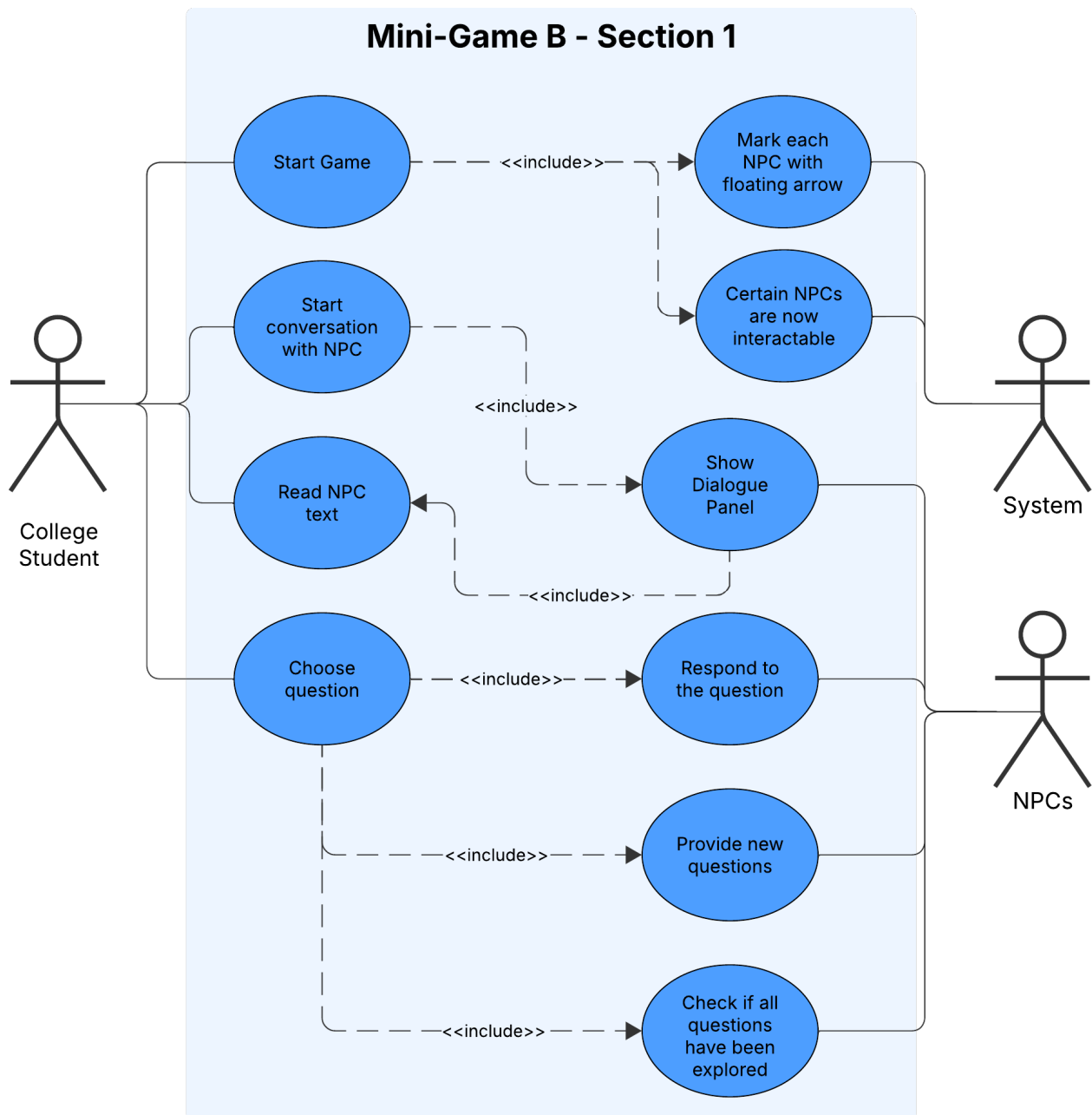


Figure. 4: Use Case Diagram for Mini-Game B - Section 1

Moving on to Section 2 (see fig. 27), the main interaction here happens by grabbing and placing pieces of information in certain parts of the boards, with three different possible scenarios. Firstly, the actor can simply place the pieces of information on any part of the board and they will stay attached (apart from specific slots). Secondly, the actor can place two single pieces of information on the combine slots, which can generate a complete piece of information on the condition that the two pieces of information are compatible. Lastly, the actor can place the complete pieces of

information on a slot of an NPC board, where the system then provides feedback based on whether the complete piece belonged to that slot or not. Regarding the end game condition, the system will check the completion state of each NPC board. When all NPC boards are successfully filled with the appropriate complete pieces of information, the game ends.

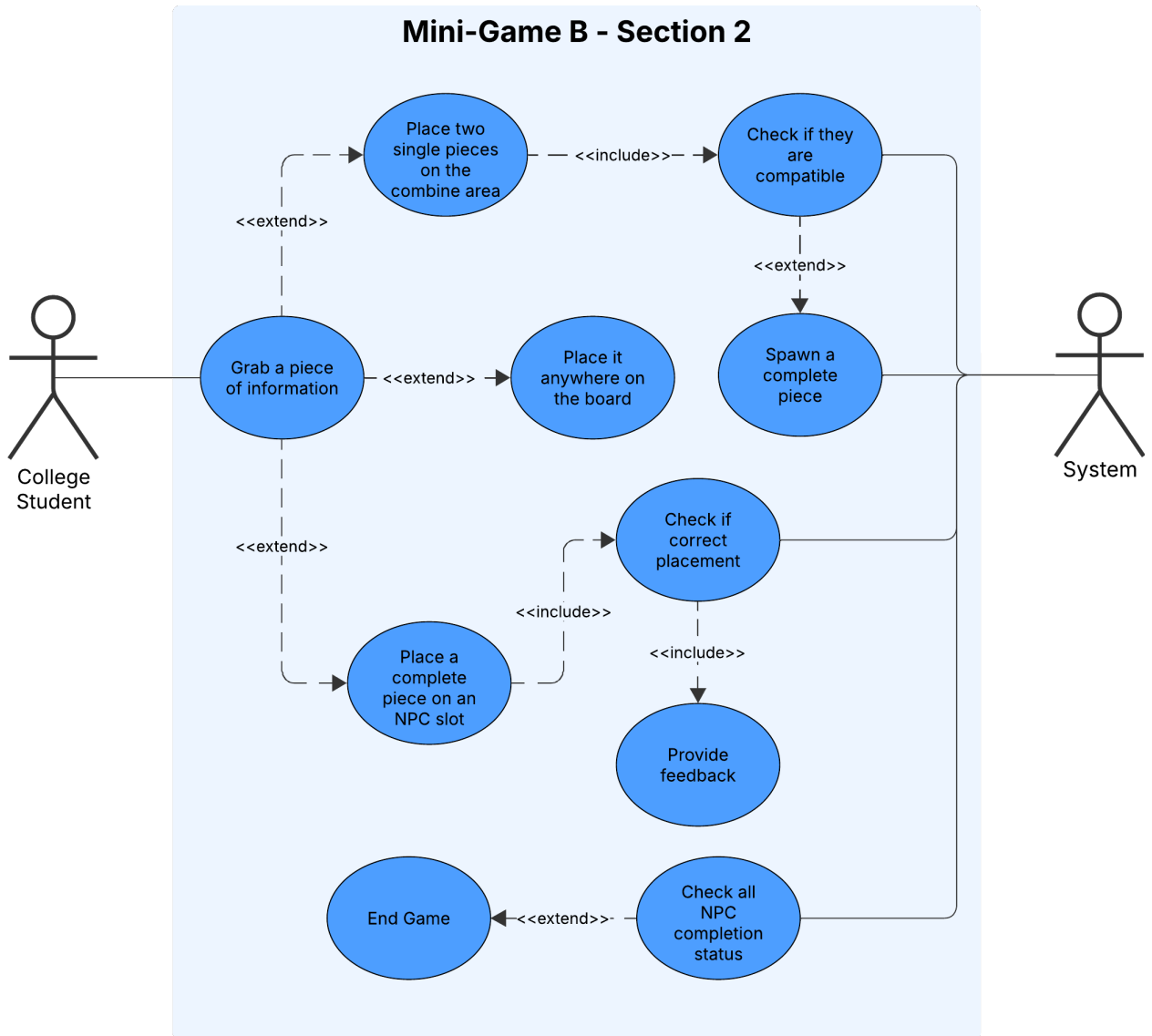


Figure. 5: Use Case Diagram for Mini-Game B - Section 2

#### 4.4.3 Mini-Game C

In Mini-Game C (see fig. 28), just like the other mini-games, we have the College Student as the main actor and the System. When the actor starts the game, the system activates the walls and begins spawning random balls periodically, which are then sent towards the actor. The main me-

chanic here is about using the racket to redirect the incoming balls to a specific wall. Depending on whether the attempt is successful or not, both the score and anxiety meter are updated accordingly.

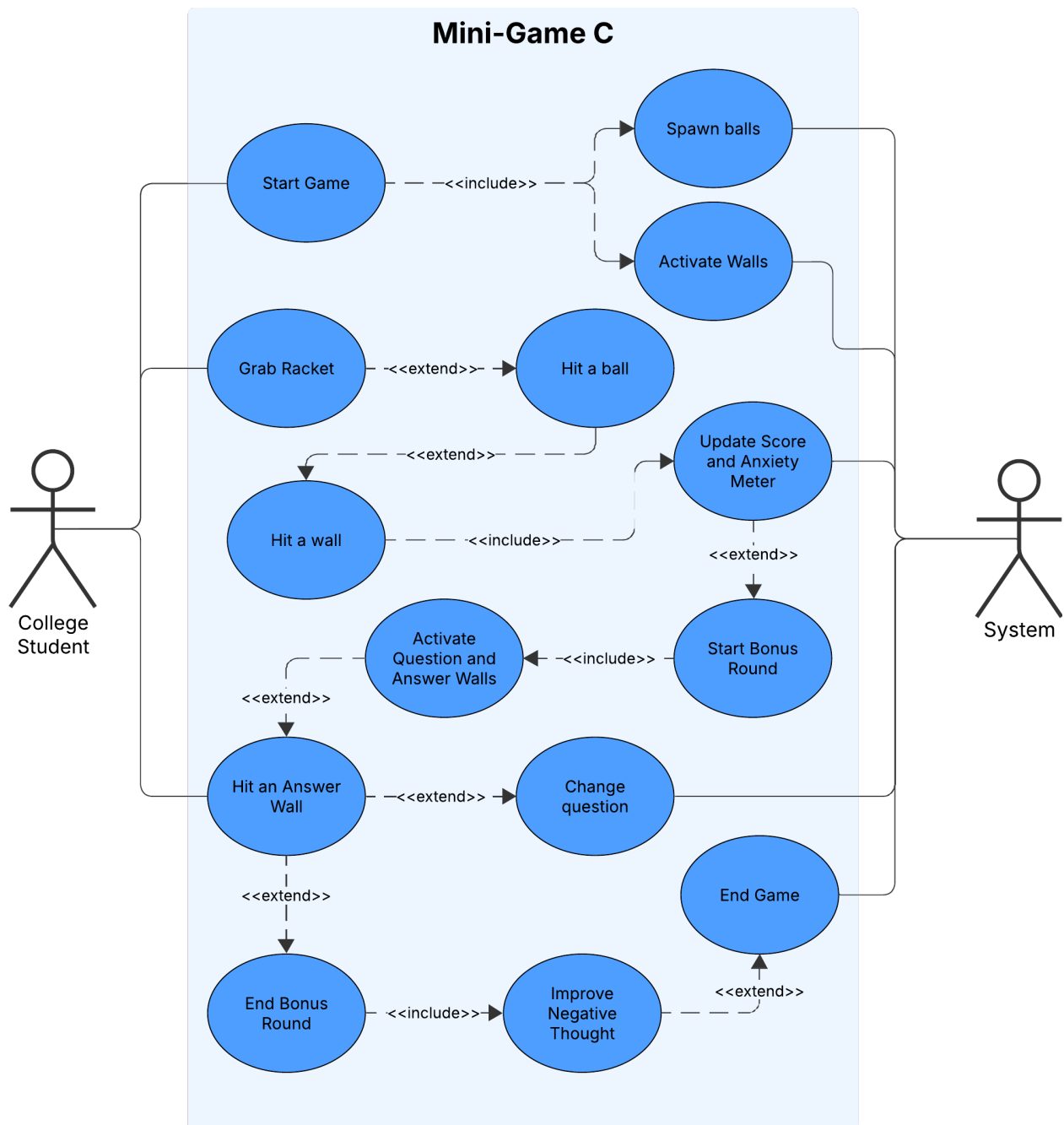


Figure. 6: Use Case Diagram for Mini-Game C

When the anxiety meter reaches zero the system starts the bonus round, with both the answers and question walls being activated. Then, whenever the actor hits a wall with the answer that

corresponds to the active question, two different outcomes are possible. If there are remaining questions available, the system will simply change to the next question and the bonus round continues. Otherwise, the bonus round ends and improves the negative thought in question to a positive thought. Additionally, upon ending the bonus round, the system will check if all thoughts have been improved and end the game if so.

## 4.5 Prototypes

Given the nature of Virtual Reality, developing an early playable prototype did not seem feasible since it would be challenging and time consuming to simulate the immersion and interaction that VR can provide. For this reason, storyboards were created for each of the mini games (see figs. 29, 30, 31). These storyboards illustrate the different mechanics, player interactions, and gameplay transitions each mini-game will have.

## 4.6 Visual Design

For the visual design, a party scenario with dynamic lighting and a large number of young adults was created in order to align with our target audience, and thus create a more engaging and vivid atmosphere for the game. In order to simulate this environment, we carefully acquired and created assets that we considered to be essential in creating an authentic party experience.

### 4.6.1 General Game Assets

Initially, we started by designing the external structure of the party, which simply consisted of a single large room, by adding floor and wall game objects that we obtained from an asset pack in the unity store called "Interior House Assets"<sup>1</sup>. This asset pack was later on used to complement the room with furniture alongside another asset pack called "Furniture FREE - Low Poly 3D Models Pack"<sup>2</sup>.

To populate this party scenario with people, we used the Microsoft Rocketbox Avatar Library [80] which consists of 115 characters and avatars fully rigged. After placing several character models throughout the party, we gave each of them distinct animations that were playing in loop during the game (see fig. 33).

---

<sup>1</sup><https://assetstore.unity.com/packages/3d/environments/interior-house-assets-urp-257122>

<sup>2</sup><https://assetstore.unity.com/packages/3d/props/furniture/furniture-free-low-poly-3d-models-pack-260522>

**Persona:** College student/Player

**Scenario:** Mini Game A gameplay

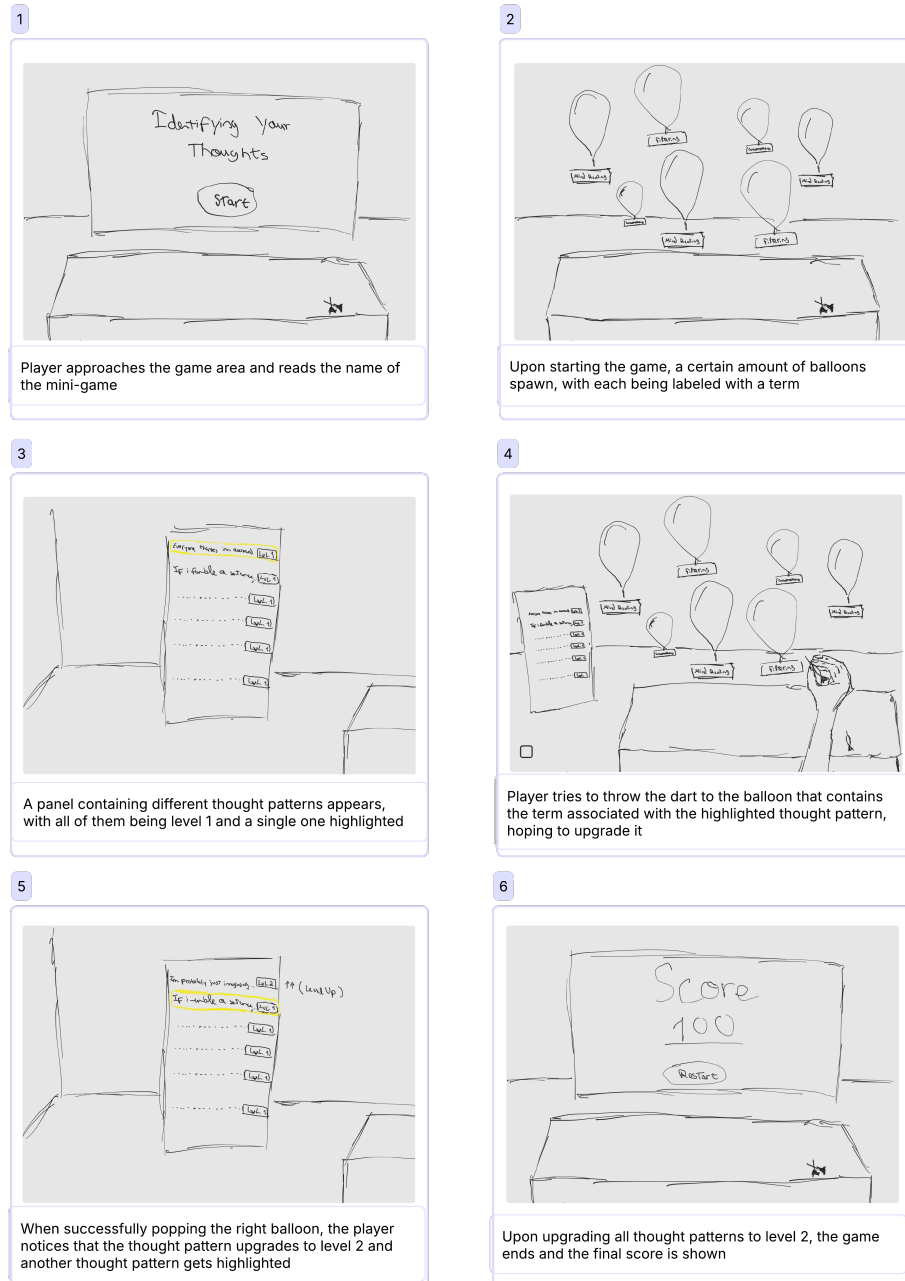
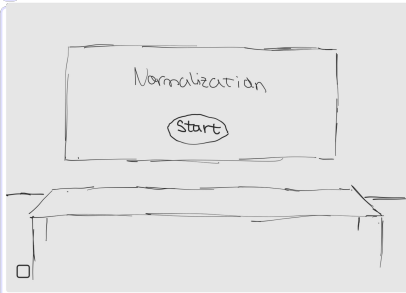


Figure. 7: *Mini-game A Storyboard*

**Persona:** College student/Player


**Scenario:** Mini Game B gameplay

1




Player approaches the game area and reads the name of the mini-game

2



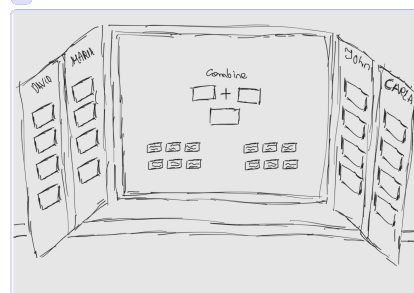
Player is instructed to interact with NPCs marked by an arrow, which are spread out in the party

3



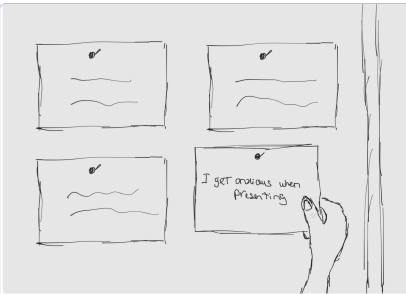
Upon interaction, the player will learn about each NPC's story with social anxiety

4



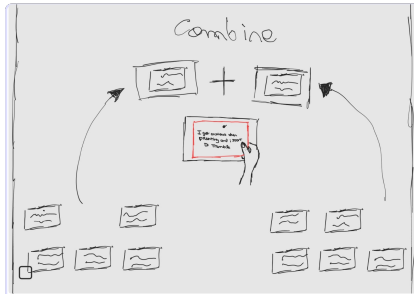
Once done talking to all NPCs, the player can now start the puzzle section of the mini game, which consists of a massive board that contains small pieces of information

5




Upon inspection, the player notices that the paper are incomplete pieces of information about the NPC's stories that can be combined with each other

6



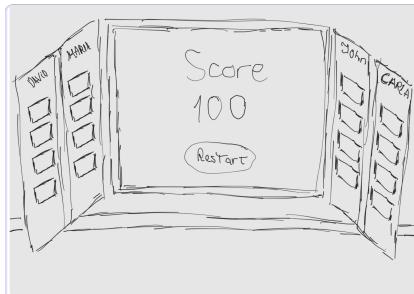
The player grabs two different pieces of information that seem to complement each other about a specific NPC. When placing them in the center, a complete piece of information is created

7



On both sides of the board there are NPC specific boards that contain slots for the complete pieces of information, indicating that the player needs to place them accordingly

8



When all NPC boards are successfully filled, the game ends and the final score is shown

Figure. 8: Mini-game B Storyboard

**Persona:** College student/Player

**Scenario:** Mini Game C gameplay

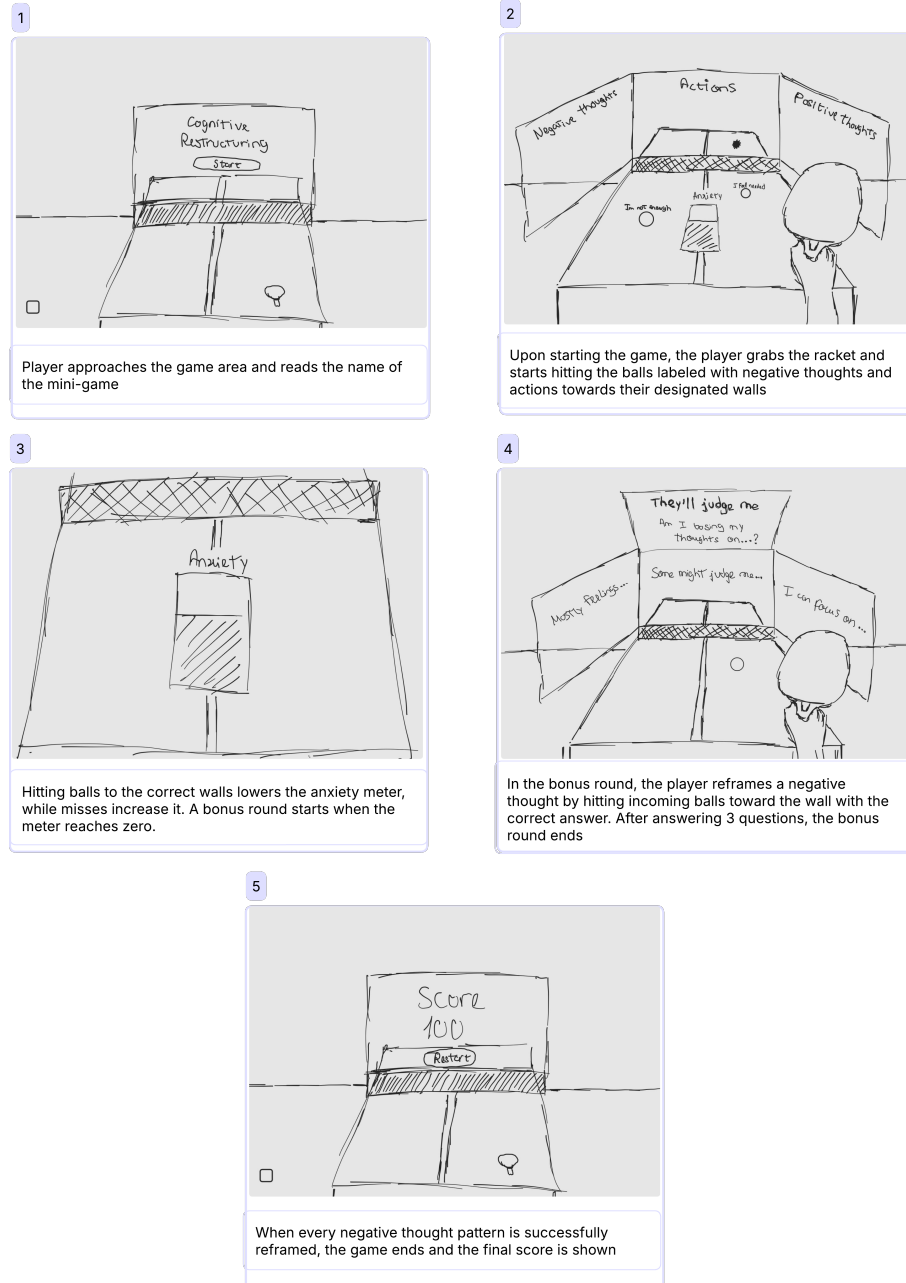
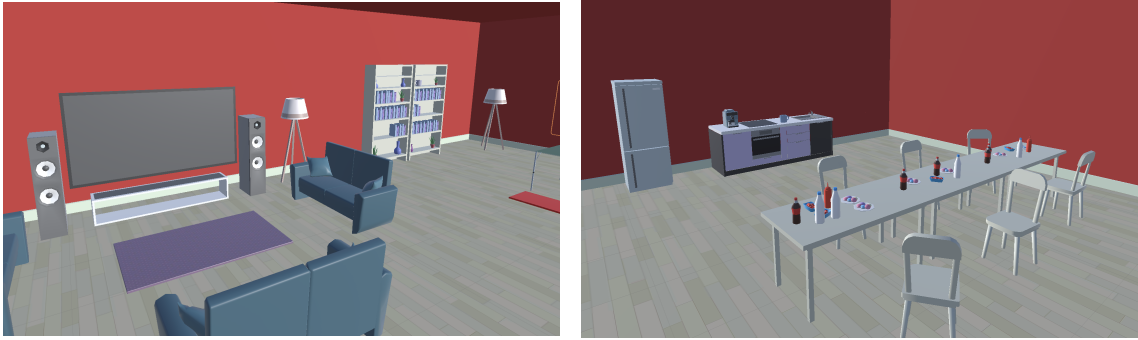


Figure. 9: *Mini-game C* Storyboard

Figure 10: *Party Assets*Figure 11: *Animated NPCs*

The hand model used in this work was obtained from a Youtube tutorial series by Valem Tutorials<sup>3</sup>, who provided a 3D hand model that contained articulations for each finger. This allowed us to program the hand to fit specific objects by rotating the fingers in different ways, thus creating authentic object grab interactions. When it comes to the UI panels, as previously mentioned, these were obtained from the VR template Unity offered, which later on were modified in order to be more visually consistent with the game.

#### 4.6.2 Mini-Game Assets

For each Mini-Game, assets from the previously mentioned asset packs were used for furniture, ensuring that they seamlessly blend into the party scenario without looking out of place. When it comes to the actual gameplay, unique assets were created for each Mini-Game. In the following sections, the most relevant assets for each Mini-Game will be highlighted, showing their source.

##### Mini-Game A Assets

<sup>3</sup><https://www.youtube.com/watch?v=8PCNNro7Rt0&list=PLpEoiloH-4eP-OKItF8XNJ8y8e1as0Jud&index=3>

For Mini-Game A, the two essential assets are the balloon and dart objects. They were obtained for free from Free3D<sup>4</sup>, a website that contains 15000+ 3D models.



Figure. 12: *Mini-Game A Assets*

### Mini-Game B Assets

The most relevant asset acquired for Mini-Game B was the Pinboard along with its pinned papers. It was also obtained for free from a website called TurboSquid<sup>5</sup>.

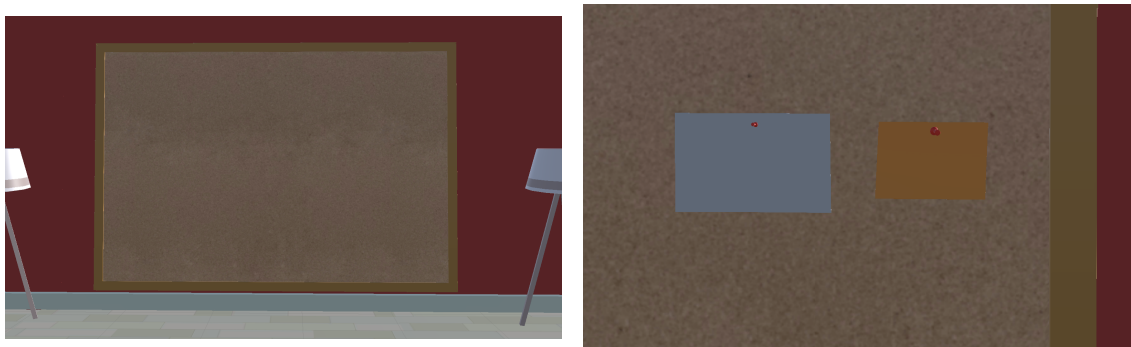


Figure. 13: *Mini-Game B Assets*

### Mini-Game C Assets

Lastly, in Mini-Game C the main assets, being the Ping Pong table and the racket, were obtained from another 3D models website called CGTrader<sup>6</sup>.

<sup>4</sup><https://free3d.com>

<sup>5</sup><https://www.turbosquid.com>

<sup>6</sup><https://www.cgtrader.com>

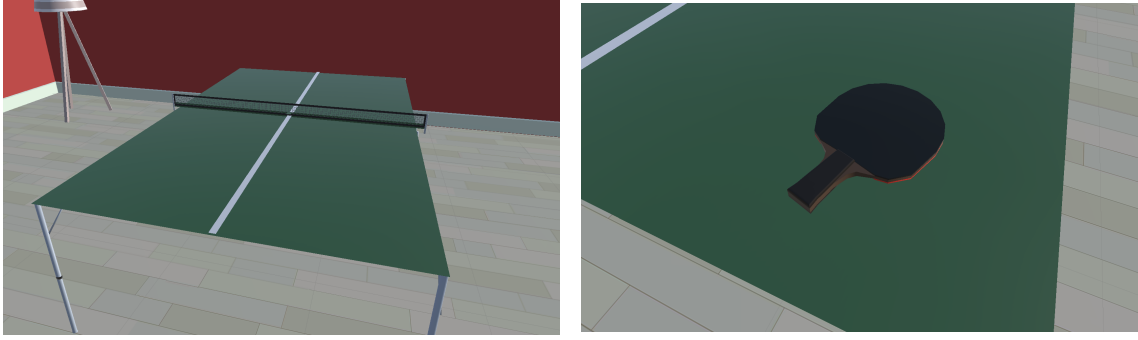


Figure. 14: *Mini-Game C Assets*

The remainder of the Mini-games' assets were, as stated before, either used from already imported asset packs or created in Unity. When it comes to sound design, none of the audio elements were created by us. They were all obtained from Pixabay <sup>7</sup>.

#### 4.7 Mini-games structure

Each of the three mini-games start by introducing the specific CBT concept it represents, which involves explaining what it is and how beneficial it is to the individual, and explaining how the mini-game functions. This introduction is given by an NPC (Non-player character) that is standing next to the mini-game area and it serves to provide the player with basic context about the CBT concept and a brief instruction about the controls and interaction in order to facilitate the understanding of the game's objectives and ensure a quick learning process.

Every mini-game was designed with the intention of maintaining a balance between providing a fun and enjoyable experience while also conveying CBT concepts to the players. This balance is essential since focusing on one aspect could diminish the other. For instance, if a player becomes too absorbed in the interaction and controls, the content of the mini-game might not be interpreted correctly and therefore completely ruin the teaching aspect of it, and vice-versa. So, in order for the player to successfully complete the mini-games, it is necessary to not only understand the controls and the interaction, but also grasp the underlying content and use that information to progress. For that purpose, the mini-games were designed in a way that the player has to understand their content in order to complete them. The following section will detail the reasoning behind the mini-games when it comes to the design and also the CBT concept it represents.

<sup>7</sup><https://pixabay.com/sound-effects/>

#### 4.7.1 Mini-Game A - Identify your thoughts

Individuals with anxiety tend to have thinking patterns characterized by an increased perception of danger and threat and a lack of perception when it comes to their ability to cope with said danger, and often include themes of vulnerability, loss of control, fear of social ridicule, among others [81]. These thoughts can also be defined, as the traditional language of CBT summarizes it, as negative automatic thoughts (NATs) [81].

NATs are spontaneous and involuntary thoughts that unconsciously surface in our minds [82] and are capable of causing adverse changes in a person's mood which can be translated to an increase in anxiety and/or depression and also lead individuals to reduce doing activities that once gave them pleasure. This can be seen as a reciprocal relationship since a mood change can also worsen the thinking. A key part of the treatment involves guiding the individual to become aware of their unhelpful thoughts and their associated impact [81].

Being able to identify and dispute these NATs is an essential step towards managing social anxiety. With practice, the individual will be able to more easily recognize these thoughts when they occur, eventually leading to higher levels of confidence and less feelings of anxiety [83]. This mini-game was designed with the concept of identifying NATs for social anxiety. When the player reaches the game area (see fig. 15), the player is presented with a panel labeled with the name of the mini-game and a grayed out button that reads "Start Game" and to the right a NPC called Dave. To get started, the player needs to interact with Dave, who is standing beside the play area. Dave will start by giving a brief explanation regarding the concept of identifying negative thought patterns, like what it entails and its importance when it comes to dealing with social anxiety. Following this, Dave gives a run through the mini-game itself, explaining the mechanics and rules. Once the player is done reading every panel, the start game button is no longer grayed out, and the player can finally start the mini-game.



Figure. 15: *Mini-Game A Pre-Game*

The game starts with different colored balloons spawning each labeled with a term that defines a specific NAT (see fig. 16). The spawning is random, all balloons move at the same speed in an erratic manner while colliding with each other. Their color is also random and without any specific meaning. There are always nine balloons in play, meaning that whenever a balloon is popped, another one spawns.

On the left side of the table, there will be a panel containing a list of NATs (see fig. 16), six in total, where one will be highlighted in yellow prompting the player to hit the balloon tagged with the term that defines that specific NAT. At all times, six unique terms will be in play, each displayed on a separate balloon. Additionally, two balloons will contain repeated terms. Each NAT also has a level, which represents the stage that specific NAT is at currently.



Figure. 16: *Mini-Game A Gameplay*



Every time the player successfully pops the corresponding balloon, the highlighted NAT will transform into a positive thought pattern by “leveling up” and then another NAT becomes highlighted. The NATs that have been successfully leveled up are represented with an orange background and a level two label and can no longer be highlighted anymore. Once every NAT has been leveled up the mini-game will be completed.

The main goal of this mini-game is to encourage the player to reflect about negative thought patterns and successfully associate each of them to their corresponding term. When it comes to real life benefits, it is hoped that the individual will be able to more easily identify these automatic negative thoughts when they happen, thus starting the process of replacing them with positive ones.

As said before, these mini-games were designed to transmit CBT principles but also to be interactive and fun. By combining dart throwing, a popular sport and hobby for many, and the satisfying feeling of balloon popping, we hope that the experience is engaging and enjoyable. The colorful balloons are meant to add a visually appealing and lively element to the mini-game, while the interactive dart throwing aspect adds a layer of skill and excitement, resulting in an entertaining and interactive experience. Also to complement these key features, sound effects were added: a pop for the balloons and a sound for the dart throw, adding to the immersion.

#### **4.7.2 Mini-Game B - Normalization**

In CBT, understanding the psychological aspects of social anxiety can help shed light on the impact these can potentially cause regarding avoidance behavior and the way it limits the individual. Offering reassurance by telling the individual that their struggles are normal and treatable is something that therapists can do when treating someone through CBT [84].

This concept is also present in surveys, which are considered to be a very powerful CBT technique where patients can test their beliefs, normalize their symptoms and view other perspectives. Murray et al’s work [85] explores the ways and outcomes of doing surveys for different mental disorders. Social anxiety, for example, is one of the mental disorders that can benefit from this CBT technique given that individuals with social anxiety tend to experience self-critical thoughts and/or shame since they expect people to judge them harshly on their behavior. By showing the patient other people’s struggles, which they can relate to, they will start to feel less isolated and more confident about themselves [85]. Another study examined the effectiveness and acceptability

of mindfulness-based cognitive therapy by conducting a group intervention for individuals with active depression and anxiety. This study brought many interesting findings but one in specific was the fact that many individuals felt the experience to be normalizing. Being surrounded by individuals facing similar challenges brought mutual understanding, which in turn helped reduce feelings of isolation and allowed participants to show their emotions openly without worry [86].

Additionally, a program developed by the National Alliance on Mental Health in the US called “In Our Own Voice” also follows a familiar thought process since this intervention utilizes first-hand testimonials by individuals with lived mental illness experience which are key to reducing public stigma. This approach may also indirectly reduce self-stigma, as a decrease in public stigma can diminish the prejudice that individuals internalize and perceive, thus resulting in a possible reduction of self-stigma [87].

The Normalization mini-game was designed with this concept of sharing personal stories about experiences with mental illness, more specifically with social anxiety. Like the previous mini-games, when the player reaches the game area they are presented with a panel that contains the title of the mini-game and a greyed out button that reads “Start Game”. In order to activate this button, the player needs to interact with the NPC standing on the right called Chris. Chris will begin by explaining what normalization is in the context of social anxiety and its benefits when it comes to managing it. Then he will go through the main mechanics of the game, giving instructions on the controls and other key information the player needs to know. Once the player reads everything, the start button becomes active and it is now possible to start the game.



Figure. 18: *Mini-Game B Pre-Game*

This mini-game is divided into two parts. First the information gathering section, where the player gets to talk with different NPCs about their story with social anxiety, and then a more practical section that involves a puzzle-like game using the information previously obtained about each NPC. Initially, the player needs to find the four NPCs that are spread out in various locations within the party and get to know about their experiences with social anxiety.

These NPCs are marked with a floating arrow on top of their heads (see fig. 19), meaning that the player is able to have a conversation with them. Upon approaching a marked NPC, the game displays a prompt to press the A button on the right controller by showing a visual representation of the controller highlighting it. This action starts the interaction with the NPC, opening up a dialogue panel (see fig. 19). This panel includes a section displaying the NPC's dialogue and a list of questions that the player can ask. To select a question, the player simply needs to point at it and press the right trigger.



Figure. 19: *Mini-Game B Dialogue*

The NPCs begin by introducing themselves and sharing a brief overview of their struggle. The player is then presented with three questions to choose from. When a question is selected, the NPC responds with an answer and the available questions change. There are four questions in total, which cycle as the player makes selections. Once a question is selected, it becomes marked with a check indicating that it has been explored already. After all questions have been selected, the player is notified that they completed all dialogue options but can revisit them if desired.

Each NPC has a different story related to social anxiety and each story is organized into different topics as follows:

1. The Struggle - Provides an overview of the challenges the individual faced.
2. The Thought - Explores the thoughts that arise when experiencing social anxiety.
3. Behavior - Describes the ways the individual acted due to the anxiety.
4. Coping Techniques - Outlines the methods they use to cope with their anxiety.
5. Outcome - Reflects on how they feel after overcoming social anxiety.

Later on, this information will be key for completing the second part of the mini-game, so the player needs to remember them well. However, as said before, the player can always revisit the NPCs if they choose to do so in case they forget something. The second part of the mini-game can be started as soon as the player interacts with at least two NPCs. This action will open a board located next to Chris which contains everything the player needs to complete the mini game.

The board is composed of three different sides. The front side contains single pieces of information scattered into five distinct color-coded groups, each representing a different aspect of the story. The colors represent the following themes: red for struggle, blue for thought, yellow for behavior, green for coping techniques, and orange for outcome. Per each color group there are eight different single pieces of information with two of each being associated with a specific NPC.

In the center, there are two spaces separated by a plus sign with a larger space beneath. Here the player can combine two single pieces of information that are linked to a specific NPC, thus creating a complete piece of information in the space below. If the player places two pieces that don't connect then nothing is created. The single and complete pieces can be grabbed with either hand by holding the grab button. These can be placed anywhere on the board, giving freedom to the player when it comes to organizing the information.

Moving on to the other sides, left and right, these are vertical boards that represent each NPC (two on each side) and are labeled with their names and also contain a photo of the NPC. Here the player will use the complete pieces of information to fill the matching slots of every NPC. The game ends when every segment of each NPC is successfully completed.



Figure. 20: *Mini-Game B Puzzle Section*

To facilitate the gameplay experience, some elements were designed in order to help the player understand and achieve the intended objectives. Examples of this are the visual and auditory feedback when, for instance, the player places a complete piece of information on a NPC's board. This will let the player know if they have placed the correct piece or not. Also there is a sheet containing notes about each NPC's stories that can help the player remember something that they may have forgotten, thus erasing the need to go back to talk to the NPC.

This mini-game aims to demonstrate that social anxiety is a common experience that can affect anyone in various ways and that it's possible to manage or overcome it. In doing so, the game seeks to reduce the feeling of isolation felt by individuals with social phobia. Additionally, this mini-game has the potential to encourage players to learn about other's experiences with social anxiety, just as they explored in the game. This may ultimately inspire players to share their own stories to others, possibly resulting in an increase in confidence and stronger sense of connection and validation from their peers.

This mini-game was built around the concept of normalization, which highlights the value of sharing and interacting with others. The initial part of the game represents this concept by having the player talking with four different NPCs and learning about their own struggles with social anxiety in a way that mirrors potential real life interactions. The second section of this mini-game has a different approach focused on interactive play, incorporating puzzle-solving mechanics and requiring the players to place pieces on a board. The goal is to maintain a balance between content comprehension and practical skill, consistent with the other mini-games.

### 4.7.3 Mini-Game C - Cognitive Restructuring

A fundamental part of CBT treatment is replacing the NATs with positive automatic thoughts which succeeds the identification of NATs (present in the first mini-game). Research shows that individuals with more frequent positive automatic thoughts tend to perceive their lives meaningful when faced with stress. This suggests that reducing negative automatic thoughts leads to better mental health outcomes, underlining the importance in the process of cultivating positive automatic thoughts while letting go of old negative ones [88].

In Chris Williams & Anne Garland's work [81] about identifying and challenging unhelpful thinking, a thought investigation worksheet and a thought challenge worksheet are presented as a support to guide the patients during the process. More specifically, the thought challenge worksheet contains questions that are focused on helping the patient challenge the extreme and unhelpful thoughts. Questions like "Is there anything to make me think that the thought is incorrect?" or "Are there any other ways of explaining the situation that are more accurate?" are meant to encourage the patient to think and reflect about their negative thoughts in hopes of them coming to a healthy conclusion [81]. A key part of this process involves the individual now putting the reached conclusion in practice and testing the validity of their extreme and unhelpful thoughts. This leads to the individual making important changes in their everyday life and new learning can occur [81].

This particular mini-game is set in a table tennis scenario and it's built around the process of reframing NATs by challenging them through questioning their validity. In a way, it can be seen as the sequence to the previous mini-game since, in CBT, it is necessary to initially identify the NATs, which is the concept of the first mini-game, and then proceed to challenge them.

Just like the first mini-game, when the player approaches the game area they are presented with a panel labeled with the title of the game (see fig. 21), Cognitive Restructuring, and a greyed out button that reads "Start Game". On the right, a NPC called Jessica will be standing (see fig. 21). When interacting with her, Jessica will start by explaining what cognitive restructuring is and the potential benefits when it comes to applying it. Then, she will go through the controls and general steps on how to play the mini-game. Once the player reads everything Jessica has to say, the "Start Game" button is activated and thus able to start the game.

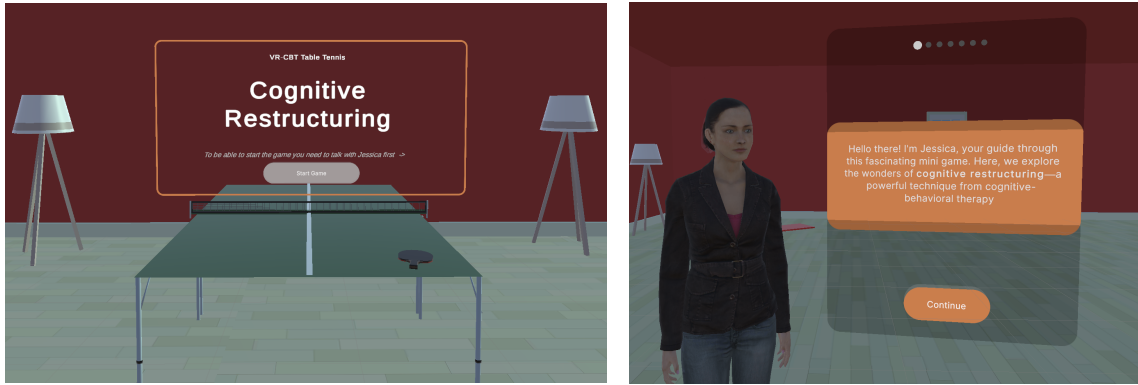


Figure. 21: *Mini-Game C Pre-Game*

The game starts with an additional tutorial, implemented after informal playtesting revealed that it was very challenging to grasp the objective of the game and felt overwhelming as soon as the game started even if the player had paid attention to Jessica. This tutorial goes through the controls and every aspect of the game at a slower pace.

First the player picks up the racket on the table by reaching to it and using the grab button. Then the player will be faced with colored and labeled balls coming their way in a bouncing manner. There are three different types of balls, which include a thought ball, that starts as negative and is characterised by a red color but can be reframed into positive green ball. Action balls are yellow and represent actions that help reduce social anxiety over time and finally spike balls, which the player simply needs to avoid hitting.

An essential feature of the mini-game is the existence of three different walls surrounding the table (see fig. 22), each designated for a specific type of ball. The wall on the left is labeled with “Block” and is meant for the player to hit the negative thought balls towards it. The front wall, labeled “Confront”, is intended for action balls. Finally the right wall is labeled “Reframe” and is where the positive balls should be directed. The player’s goal is to hit the incoming balls with the racket towards the corresponding wall.



Figure. 22: *Mini-Game C Gameplay*

In successfully doing so, the player progresses in two different ways. Firstly, a score display is positioned in front of the player and updates throughout the game. Every successful action the score is incremented a certain amount, while incorrect actions cause deductions, with the amount varying based on the action. Secondly, an anxiety meter is displayed on the table that slowly fills up (see fig. 22), starting halfway full when the game begins. Each successful action the meter is reduced by a certain amount, while unsuccessful actions cause it to fill. If the meter fills completely, the player loses a certain amount of score and the meter resets to its halfway point. If the player manages to completely reduce the meter all the way down to zero, a bonus round starts.

The bonus round, called the “Reframe round”, gives the player the opportunity to transform a negative thought ball into a positive one (see fig. 23). This is achieved by successfully answering three questions about a specific thought. As before, three walls surround the table, but in this round an additional wall appears above the front wall. This specific wall displays the thought being reframed, along with the current question the player needs to answer. The remaining three walls represent the possible answers.

The player’s task is to identify the correct answer and hit a ball toward the corresponding wall. During this round, ping pong balls are periodically spawned, but there are no penalties for missing or ignoring them. When the player hits the wall with the correct answer it turns green and stays that way for the remainder of the round, indicating that the question is done. If the player hits an incorrect answer, the wall briefly turns red for a short amount of time before returning to the normal color. Once all three questions are successfully answered the bonus round ends, returning to the normal game flow. The reframed thought now appears in the game as a positive thought

ball. In order to complete the mini-game, the player needs to reframe all negative thought balls into positive thought balls. There are six in total, meaning that the player has to complete six bonus rounds to finish the mini-game.

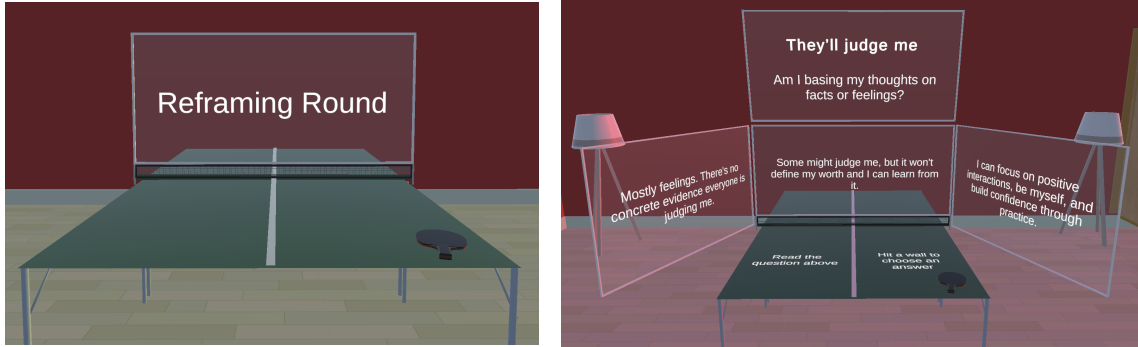


Figure. 23: *Mini-Game C Bonus Round*

The main goal of this game is to encourage players to practice challenging negative automatic thoughts in a real life situations. By demonstrating that negative thoughts can be reframed into healthier ones through simple questions, the game helps the player adopt this concept more frequently and thus be able to more efficiently manage social anxiety in their everyday lives.

As with the previous mini-game, the design of this game follows the same reasoning. Table tennis, which is also a widely popular and highly interactive sport just like darts, was chosen since it provides an engaging experience, fit for the type of mini-games intended in this work. The normal gameplay flow represents the practical skill component, while the bonus round emphasizes the content comprehension. By integrating these two elements, it is hoped that the game achieves a balance between active engagement and meaningful understanding of the content being transmitted.

## 4.8 Game Content

To complement the process of creating the content, we used ChatGPT4, a Large Language Model (LLM), as a fast and effective way to generate adequate content based on each mini-game. This involved generating text such as anxiety related terms, thought patterns and NPC stories related to the CBT concept in question, which was then edited and imported into the game. Although the use of Artificial Intelligence is still being validated in a mental health context, with ongoing

concerns such as ethical and reliability challenges [89] for example, it still shows good promise. One example is a study that evaluated ChatGPT4 in terms of accuracy and treatment efficacy for various mental health disorders [90]. For instance, ChatGPT4 had a 100% diagnostic accuracy when it comes to social phobia.

## 4.9 Requirements

In this section all requirements, both functional and non-functional, are described in detail leading to an overview on how every aspect of the artefact will function and be implemented.

### 4.9.1 Functional Requirements

The following requirements (FR-01 to FR-10) are general functional requirements that apply to every aspect of the game, including all mini-games.

#### – Interaction and Movement

- **FR-01 - The game must provide players with the ability to move using controller**
  - The VR headset tracking allows the player to move within the game using real life movements. However, since the virtual game area exceeds the size of the physical area, it's crucial to enable players to move in the game using a controller as well.
- **FR-02 - The game must provide players with the ability to rotate using controller** - Just like the movement, the VR headset tracking allows the player to look around within the game through real like rotations. However, it is necessary to give players the option to rotate smoothly using the controller since they might prefer it.
- **FR-03 - The game must provide players with the ability to grab objects using either hand** - It's essential to ensure that interactable objects can be grabbed with either since players can be right or left handed.

#### – Tutorials and Instructions

- **FR-04 - The game must provide tutorial for each mini-game** - Before starting each mini-game, it is crucial to provide the player with a tutorial to ensure they understand the objectives and controls of the game.
- **FR-05 - The game must provide starting instructions** - At the start of the game, it is necessary to provide the player with basics instructions about controls and interaction.

– **Game features**

- **FR-06 - The game must provide a score system** - Each mini-game needs to have score tracking system to provide feedback to the player on how they are performing.
- **FR-07 - The game must provide visual and audio feedback** - The game has to provide feedback to the player through audio and visual effects in order to inform them on their actions.
- **FR-08 - The game must provide players with the ability to revisit the mini-games** - After the player completes a mini-game, they should be given the option to replay it.
- **FR-09 - The game must provide a log system** - Log players actions throughout the game, targeting a possible analysis in the future.
- **FR-10 - The game must integrate CBT concepts in mini-games** - Mini-games must be designed in a way that actively engages players to apply the specific concept to successfully complete the mini-game. *Ex: Identifying negative thought patterns.*

In the next section, all specific functional requirements for each mini-game will be presented in detail

– **FR-11 Mini-game A must integrate CBT concept of "Identify your thoughts"**

- **FR-11.1** The game must provide the ability to grab a dart.
- **FR-11.2** The game must provide the ability to throw a dart.
- **FR-11.3** The game must randomly highlight one of the thought patterns.
- **FR-11.4** The game must spawn balloons at random positions.
- **FR-11.5** The game must ensure balloons move randomly.
- **FR-11.6** The game must allow darts to pop balloons.
  - \* **FR-11.6.1** The game must upgrade current thought pattern upon hitting the correct balloon.
  - \* **FR-11.6.2** The game must change current thought pattern to a random level 1 thought upon hitting the correct balloon.

- \* **FR-11.6.3** The game must spawn another balloon upon hitting a balloon.
  - \* **FR-11.6.4** The game must update score depending on which balloon was popped.
  - **FR-11.7** The game must highlight completed thought patterns in a different colour.
  - **FR-11.8** The game must provide audio feedback when popping a balloon.
  - **FR-11.9** The game must provide visual feedback on the balloon to indicate whether the correct balloon was hit or not.
  - **FR-11.10** The game must end once all thought patterns are fully upgraded.
- **FR-12** Mini-game B must integrate CBT concept of "Normalization".
- **FR-12.1** The game must provide the ability to interact with specific NPCs
  - **FR-12.2** The game must provide the ability to choose a question when interacting with NPCs
  - **FR-12.3** The game must mark explored questions with a check mark
  - **FR-12.4** The game must provide the ability to revisit a question when interacting with NPCs
  - **FR-12.5** The game must provide the ability to grab any type of piece from the board
  - **FR-12.6** The game must provide the ability to attach any type of piece onto any board
  - **FR-12.7** The game must provide the ability to (potentially) combine two pieces by placing them on a specific part of the board
  - **FR-12.8** The game must create a complete piece of information only when combining two incomplete pieces that are linked
  - **FR-12.9** The game must provide audio and visual feedback when trying to combine two incomplete pieces of information
  - **FR-12.10** The game must provide audio and visual feedback when placing a single complete piece of information on a NPC board
  - **FR-12.11** The game must provide audio and visual feedback when completing a NPC board
  - **FR-12.12** The game must end upon successfully completing every NPC's board

- **FR-13** Mini-game C must integrate CBT concept of "Cognitive Restructuring"
  - **FR-13.1** The game must provide with an initial tutorial phase that demonstrates every aspect of the game at a slower pace
  - **FR-13.2** The game must provide the ability to grab the racket on the table
  - **FR-13.3** The game must periodically spawn a random type of ball
  - **FR-13.4** The game must ensure the balls bounce towards the player
  - **FR-13.5** The game must ensure the balls bounce from the racket
  - **FR-13.6** The game must provide a sound when the balls make contact with the table or the racket
  - **FR-13.7** The game must adjust the anxiety meter based on the players actions, increasing for incorrect actions and decreasing for correct ones.
  - **FR-13.8** The game must update the score based on the players actions, increasing for correct actions and decreasing for incorrect ones.
  - **FR-13.9** The game must start a bonus round upon anxiety meter reaching zero.
    - \* **FR-13.9.1** The game must randomly choose a negative thought for the bonus round
    - \* **FR-13.9.2** The game must display the thought, a question and three different answers about the selected negative thought
    - \* **FR-13.9.3** In the bonus round, the game must periodically spawn default balls for the purpose of choosing answers by hitting a specific wall.
    - \* **FR-13.9.4** In the bonus round, the game must provide audio and visual feedback when hitting the walls.
    - \* **FR-13.9.5** In the bonus round, the game must change the question after the player successfully answers one.
    - \* **FR-13.9.6** In the bonus round, the game must ensure that answers that were correctly chosen remain highlighted in green for the remainder of the round indicating they are not available anymore.

- \* **FR-13.9.7** The bonus round must end upon successfully answering all three questions and resume normal gameplay flow.
- **FR-13.9.8** The game must ensure that a negative thought is reframed into a positive thought upon successfully completing the bonus round associated with that thought.
- **FR-13.10** The game must end when successfully re-framing all negative thoughts into positive ones.

#### 4.9.2 Non-functional Requirements

These non-functional requirements represent qualities that the artefact need to possess in order to provide the player with the best possible experience at all times.

##### – Immersion

- **NFR-01 Background music** - The game must have background music that represents the immersive atmosphere of a party-like setting.
- **NFR-02 NPC models and animations** - The game must be filled with animated and realistic looking NPCs that supplement the party environment.
- **NFR-03 Party objects** - The game must be filled with items such as chairs, cups, tables and lighting that create an authentic party scenario.
- **NFR-04 Game objects physics** - Game objects must contain realistic physics, such as collisions and gravity, in order to simulate a real scene
- **NFR-05 Stable frame-rate** - The game must run at a stable frame-rate in order to preserve immersion and provide a smooth experience.

##### – Implementation

- **NFR-06 Platform Compatibility** - The game must run natively on mainstream headset (e.g., Meta quest 3 headset) so that it can be used wirelessly, not needing to be connected to a computer.
- **NFR-07 Modular Structure** - The game must follow a modular structure to ensure flexibility, reusability and scalability, allowing for future features or mini-games to be added with minimal restructuring.

- **NFR-08 Intuitive Interface** - The game must be user-friendly and intuitive, allowing the user to seamlessly navigate the interface without external instruction.
- **NFR-09 Interactive mini-games** - The game must offer different forms of object interactions for each mini-game.
- **NFR-10 Game bugs** - The game must not present any immersion breaking bugs, such as low framerate, input and visual glitches.

## 4.10 Personas

These personas were designed to represent college students with different characteristics that can benefit from the developed artefact. The personas in fig. 24 illustrate two different types of college students. For instance, João, an eighteen year old computer science student, just started college and is now facing various challenges both in his academic and social life due to social anxiety. Learning strategies to manage and overcome social anxiety would greatly benefit him in many ways. On the other hand, Mariana has not been affected by social anxiety but would like to learn about it in hopes to bring awareness and help other people that are struggling with it. By addressing both perspectives, this artefact can be a valuable tool to college students regardless of their mental health state, promoting both personal coping strategies and social anxiety awareness.

## 4.11 Use Cases

To provide a more detailed representation on how the player interacts with the artefact, a Use Case Diagram was created for each mini-game. These diagrams show the different actions the player can take, how the system behaves when responding to those actions and the conditions for certain events to happen. For each diagram, we provide an overview of the diagram's structure and we clarify how the majority of relationships function.

### 4.11.1 Mini-Game A

For mini-game A (see fig. 25) we have one actor, the College Student, and of course the System. When starting the game, a pre-defined amount of balloons spawn and the Thought Pattern Panel is activated. This also leads to a randomly chosen Thought Pattern to be highlighted. The most important action the player can take is throwing a dart.



Figure. 24: Personas

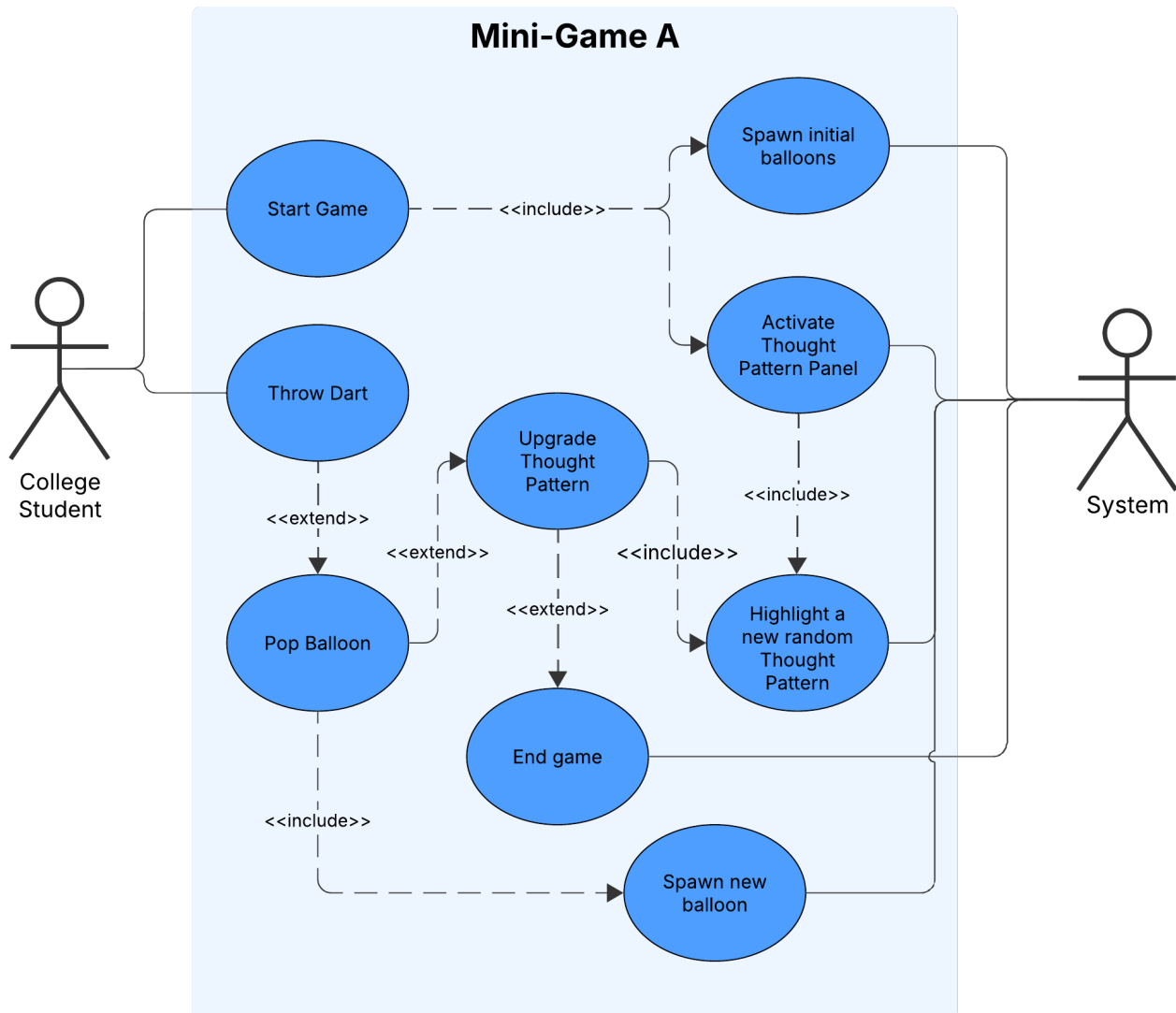


Figure. 25: Use Case Diagram for Mini-Game A

When popping a balloon, the system will always spawn an extra balloon to ensure that the number of active balloons stays consistent and, on the condition of the player successfully hitting a balloon that contains the term associated with the highlighted Thought Pattern, the system upgrades said Thought Pattern. At this point in time, if all Thought Patterns have been upgraded then the system ends the game. Otherwise, a random new Thought Pattern will be highlighted and the game continues.

#### **4.11.2 Mini-game B**

In mini-game B two separate Use Case diagrams were created due to its higher complexity and the existence of "two sections". These sections being the NPC conversation part and later on the puzzle board game. Starting with Section 1 (see fig. 26), we have the addition of the NPCs, with the rest remaining the same when it comes to the actors and the system. Once the game starts, the system marks four NPCs with floating arrows, indicating that they are now available for a conversation. The dialogue works identically for each NPC and when starting a conversation the main dialogue panel shows up. Here, the player gets to read what the NPC is saying and is able to choose between a few different questions. When choosing a question, the NPC provides a response to that question and replaces the questions with new ones. Additionally, the system checks whether the player has explored all questions available, and if so it notifies them.

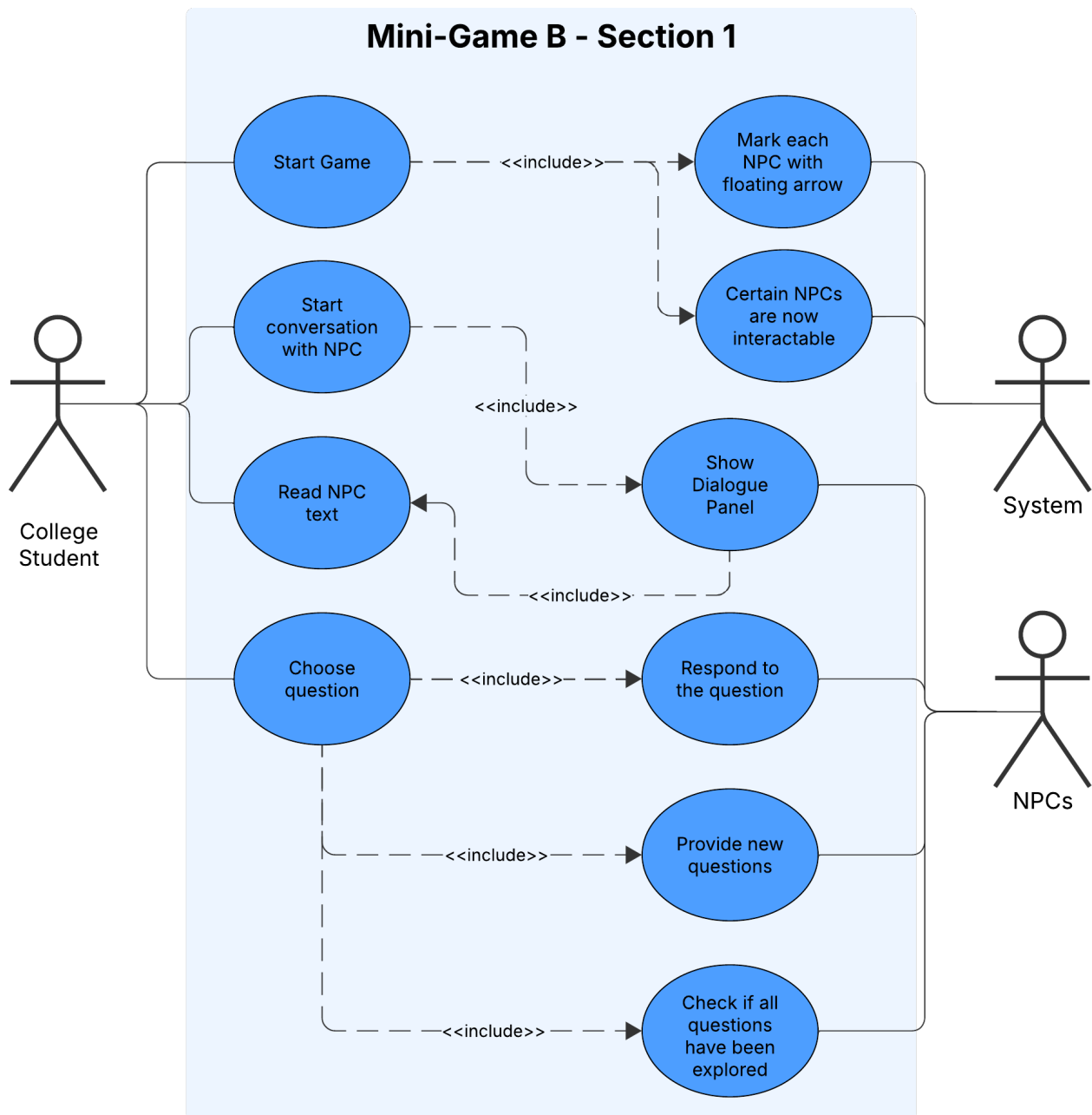


Figure. 26: Use Case Diagram for Mini-Game B - Section 1

Moving on to Section 2 (see fig. 27), the main interaction here happens by grabbing and placing pieces of information in certain parts of the boards, with three different possible scenarios. Firstly, the actor can simply place the pieces of information on any part of the board and they will stay attached (apart from specific slots). Secondly, the actor can place two single pieces of information on the combine slots, which can generate a complete piece of information on the condition that the two pieces of information are compatible. Lastly, the actor can place the complete pieces of

information on a slot of an NPC board, where the system then provides feedback based on whether the complete piece belonged to that slot or not. Regarding the end game condition, the system will check the completion state of each NPC board. When all NPC boards are successfully filled with the appropriate complete pieces of information, the game ends.

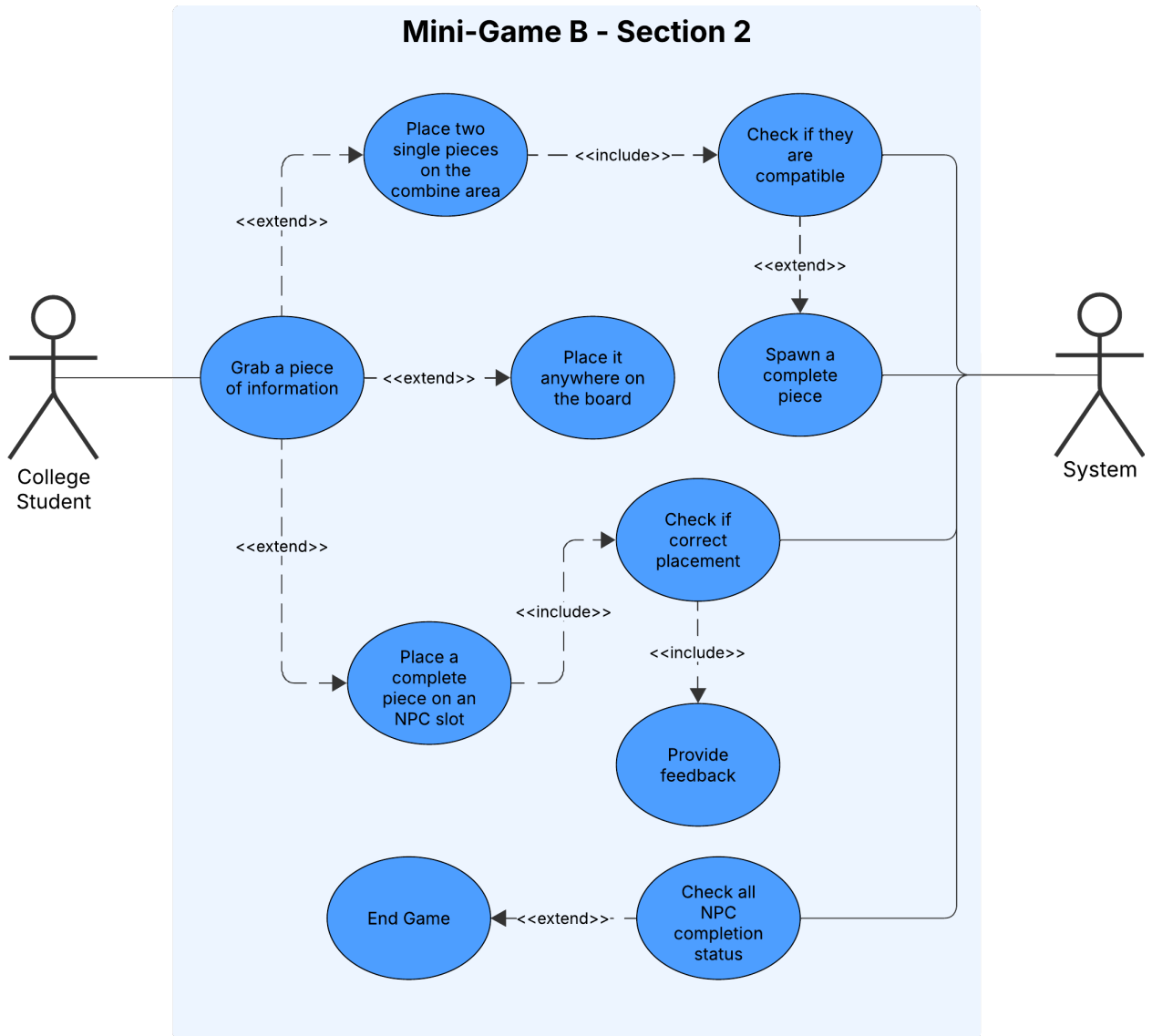


Figure. 27: Use Case Diagram for Mini-Game B - Section 2

#### 4.11.3 Mini-Game C

In Mini-Game C (see fig. 28), just like the other mini-games, we have the College Student as the main actor and the System. When the actor starts the game, the system activates the walls and begins spawning random balls periodically, which are then sent towards the actor. The main me-

chanic here is about using the racket to redirect the incoming balls to a specific wall. Depending on whether the attempt is successful or not, both the score and anxiety meter are updated accordingly.

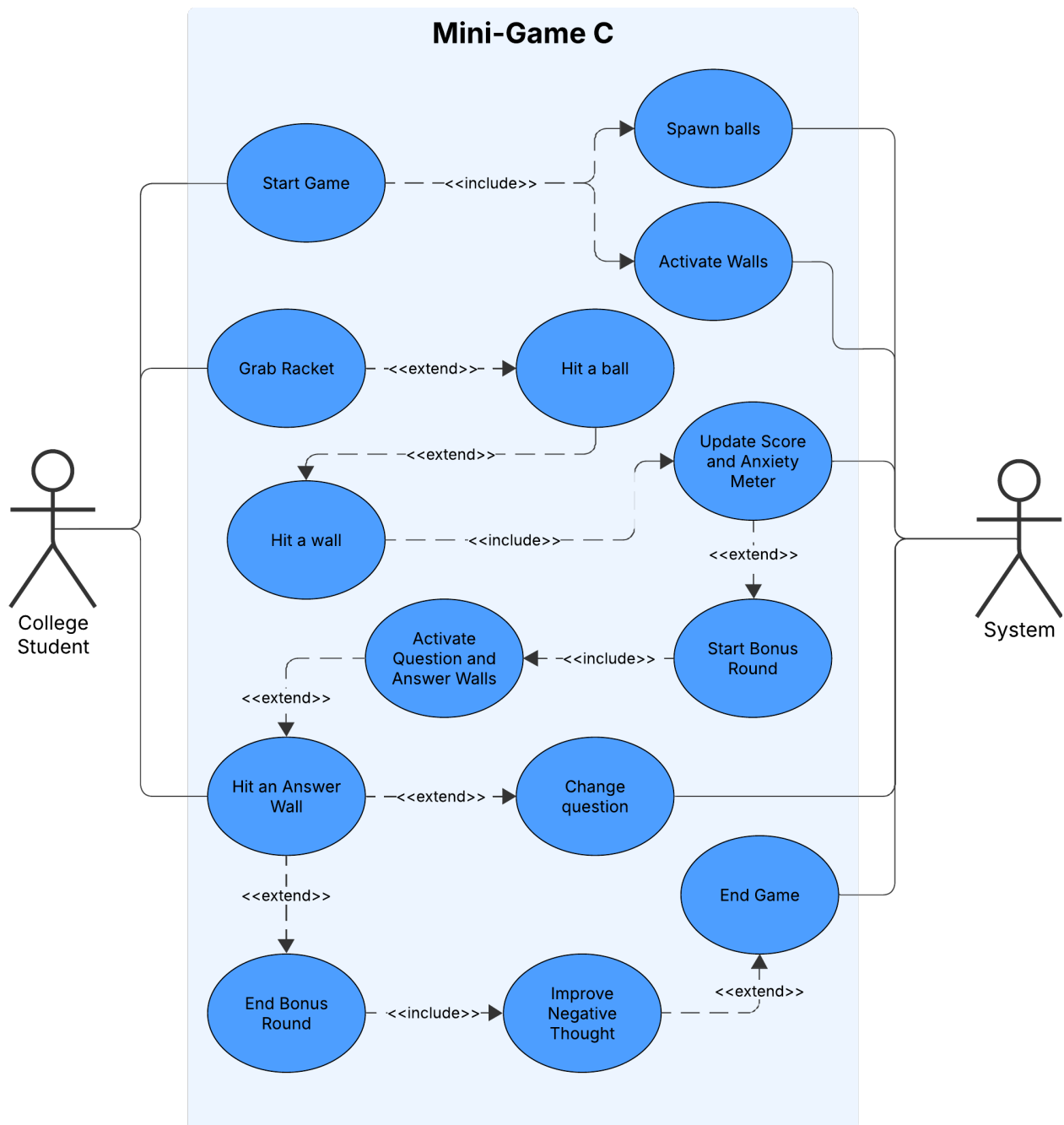


Figure. 28: Use Case Diagram for Mini-Game C

When the anxiety meter reaches zero the system starts the bonus round, with both the answers and question walls being activated. Then, whenever the actor hits a wall with the answer that

corresponds to the active question, two different outcomes are possible. If there are remaining questions available, the system will simply change to the next question and the bonus round continues. Otherwise, the bonus round ends and improves the negative thought in question to a positive thought. Additionally, upon ending the bonus round, the system will check if all thoughts have been improved and end the game if so.

## 4.12 Prototypes

Given the nature of Virtual Reality, developing an early playable prototype did not seem feasible since it would be challenging and time consuming to simulate the immersion and interaction that VR can provide. For this reason, storyboards were created for each of the mini games (see figs. 29, 30, 31). These storyboards illustrate the different mechanics, player interactions, and gameplay transitions each mini-game will have.

## 4.13 Visual Design

For the visual design, a party scenario with dynamic lighting and a large number of young adults was created in order to align with our target audience, and thus create a more engaging and vivid atmosphere for the game. In order to simulate this environment, we carefully acquired and created assets that we considered to be essential in creating an authentic party experience.

### 4.13.1 General Game Assets

Initially, we started by designing the external structure of the party, which simply consisted of a single large room, by adding floor and wall game objects that we obtained from an asset pack in the unity store called "Interior House Assets"<sup>8</sup>. This asset pack was later on used to complement the room with furniture alongside another asset pack called "Furniture FREE - Low Poly 3D Models Pack"<sup>9</sup>.

To populate this party scenario with people, we used the Microsoft Rocketbox Avatar Library [80] which consists of 115 characters and avatars fully rigged. After placing several character models throughout the party, we gave each of them distinct animations that were playing in loop during the game (see fig. 33).

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<sup>8</sup><https://assetstore.unity.com/packages/3d/environments/interior-house-assets-urp-257122>

<sup>9</sup><https://assetstore.unity.com/packages/3d/props/furniture/furniture-free-low-poly-3d-models-pack-260522>

**Persona:** College student/Player

**Scenario:** Mini Game A gameplay

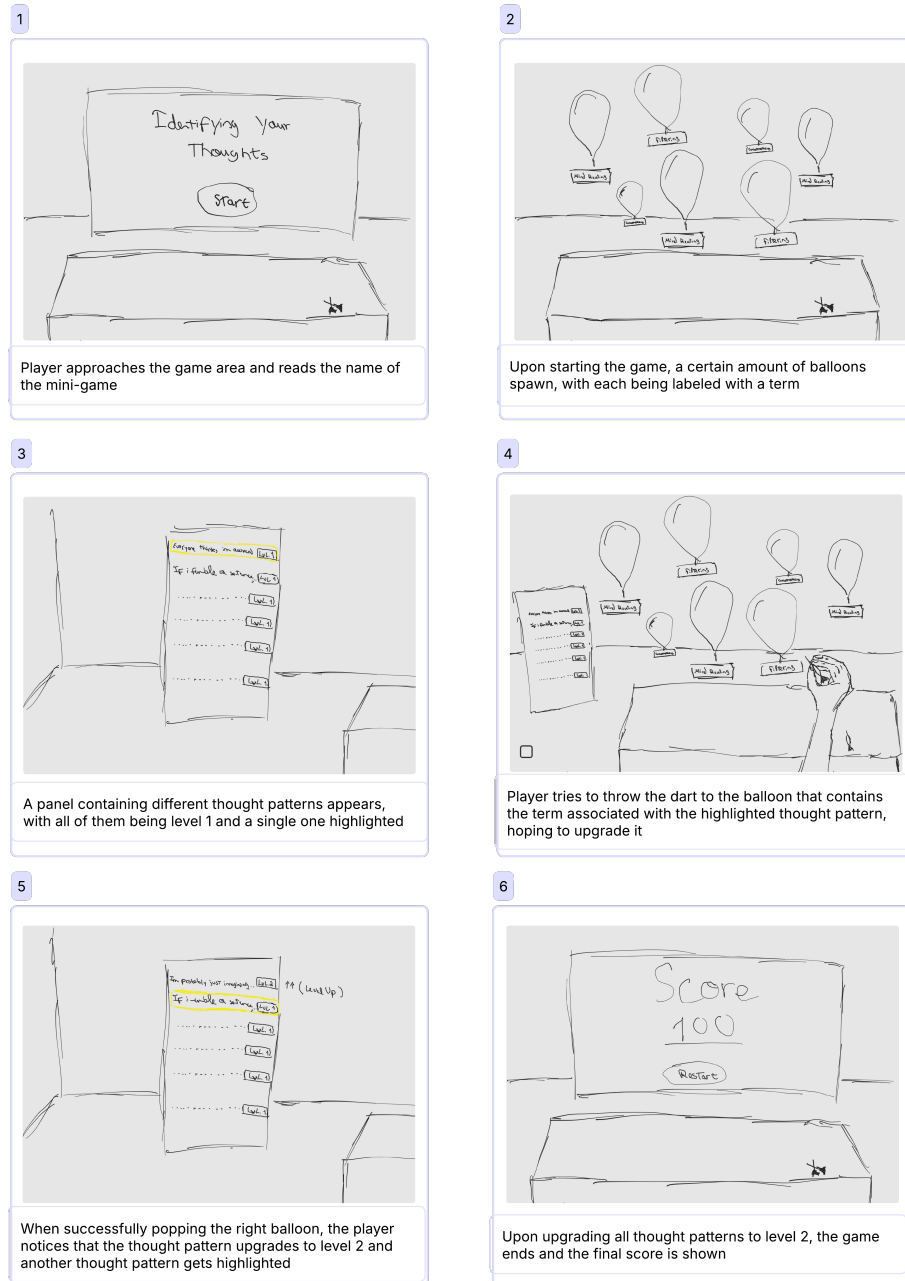


Figure. 29: *Mini-game A Storyboard*

**Persona:** College student/Player

**Scenario:** Mini Game B gameplay

1

Player approaches the game area and reads the name of the mini-game

2

Player is instructed to interact with NPCs marked by an arrow, which are spread out in the party

3

Upon interaction, the player will learn about each NPC's story with social anxiety

4

Once done talking to all NPCs, the player can now start the puzzle section of the mini game, which consists of a massive board that contains small pieces of information

5

Upon inspection, the player notices that the paper are incomplete pieces of information about the NPC's stories that can be combined with each other

6

The player grabs two different pieces of information that seem to complement each other about a specific NPC. When placing them in the center, a complete piece of information is created

7

On both sides of the board there are NPC specific boards that contain slots for the complete pieces of information, indicating that the player needs to place them accordingly

8

When all NPC boards are successfully filled, the game ends and the final score is shown

Figure. 30: Mini-game B Storyboard

**Persona:** College student/Player

**Scenario:** Mini Game C gameplay

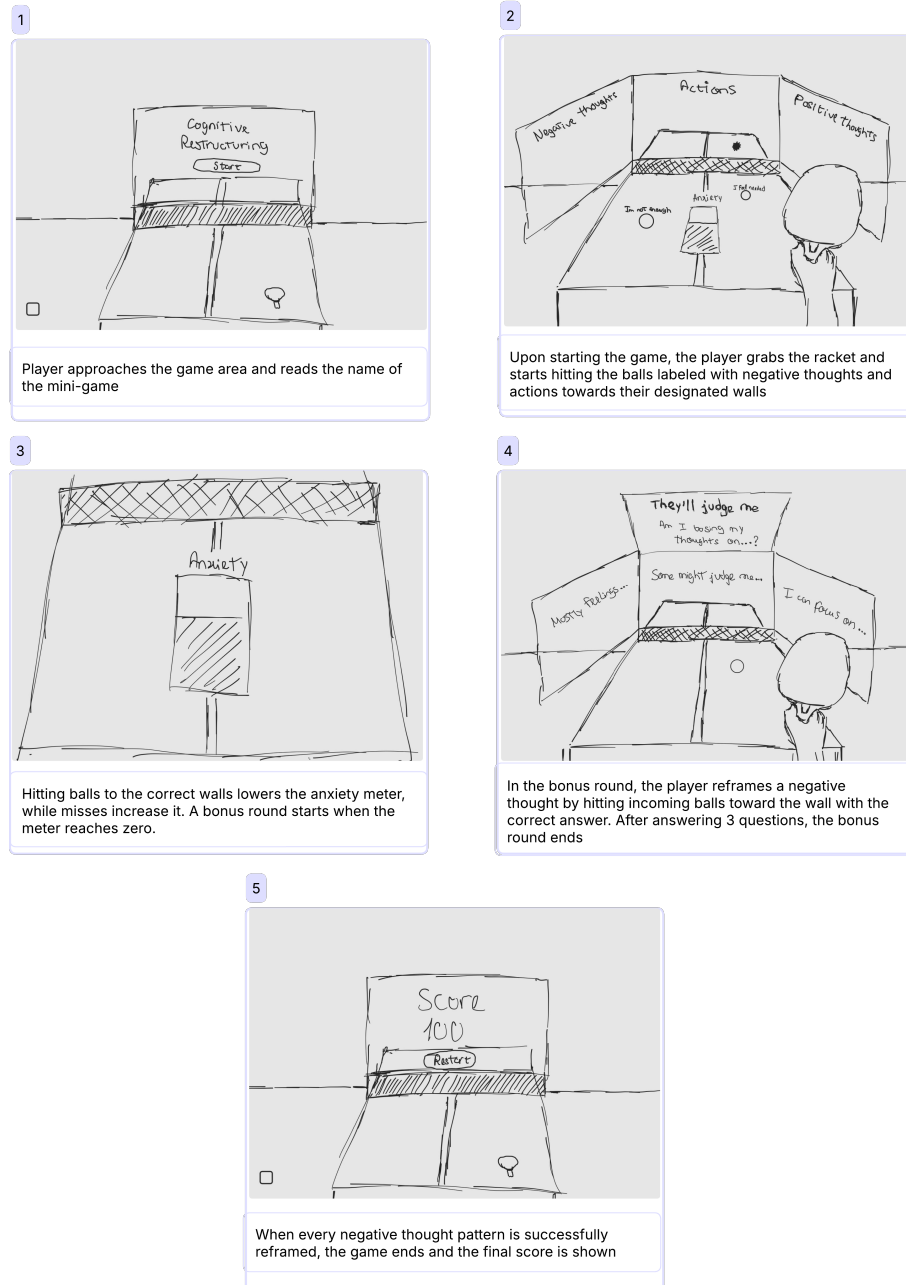
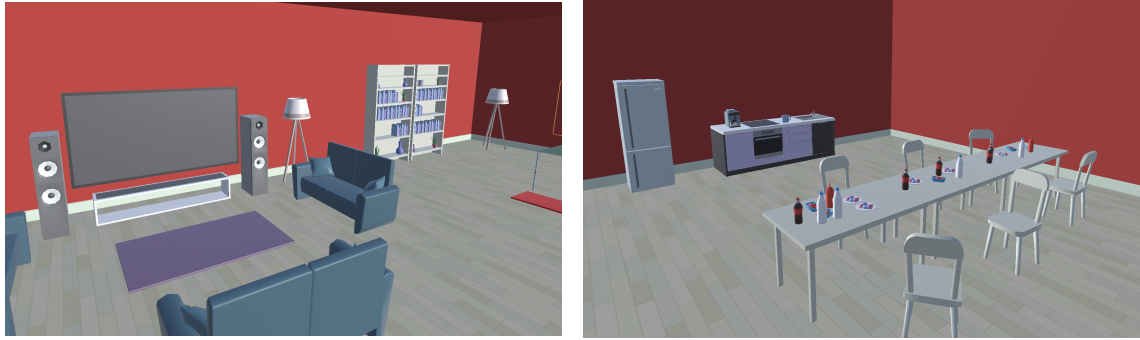


Figure. 31: *Mini-game C Storyboard*

Figure 32: *Party Assets*Figure 33: *Animated NPCs*

The hand model used in this work was obtained from a Youtube tutorial series by Valem Tutorials<sup>10</sup>, who provided a 3D hand model that contained articulations for each finger. This allowed us to program the hand to fit specific objects by rotating the fingers in different ways, thus creating authentic object grab interactions. When it comes to the UI panels, as previously mentioned, these were obtained from the VR template Unity offered, which later on were modified in order to be more visually consistent with the game.

#### 4.13.2 Mini-Game Assets

For each Mini-Game, assets from the previously mentioned asset packs were used for furniture, ensuring that they seamlessly blend into the party scenario without looking out of place. When it comes to the actual gameplay, unique assets were created for each Mini-Game. In the following sections, the most relevant assets for each Mini-Game will be highlighted, showing their source.

##### Mini-Game A Assets

<sup>10</sup><https://www.youtube.com/watch?v=8PCNNro7Rt0&list=PLpEoiloH-4eP-OKItF8XNJ8y8e1as0Jud&index=3>

For Mini-Game A, the two essential assets are the balloon and dart objects. They were obtained for free from Free3D<sup>11</sup>, a website that contains 15000+ 3D models.



Figure. 34: *Mini-Game A Assets*

### Mini-Game B Assets

The most relevant asset acquired for Mini-Game B was the Pinboard along with its pinned papers. It was also obtained for free from a website called TurboSquid<sup>12</sup>.

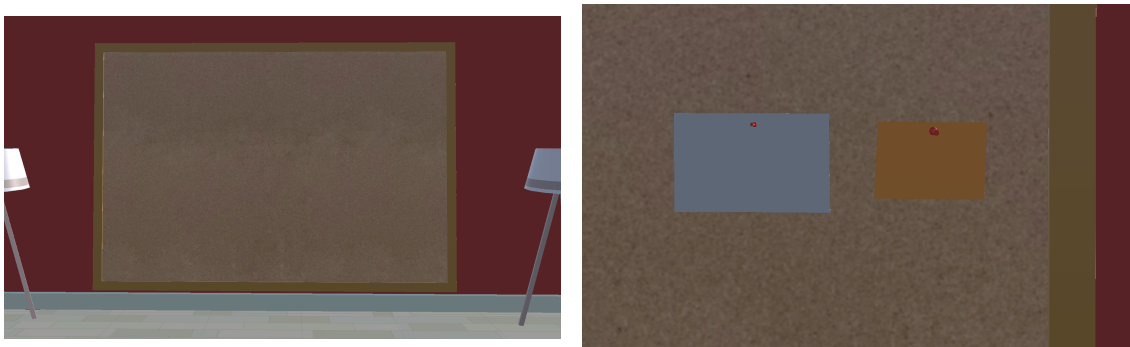


Figure. 35: *Mini-Game B Assets*

### Mini-Game C Assets

Lastly, in Mini-Game C the main assets, being the Ping Pong table and the racket, were obtained from another 3D models website called CGTrader<sup>13</sup>.

<sup>11</sup><https://free3d.com>

<sup>12</sup><https://www.turbosquid.com>

<sup>13</sup><https://www.cgtrader.com>

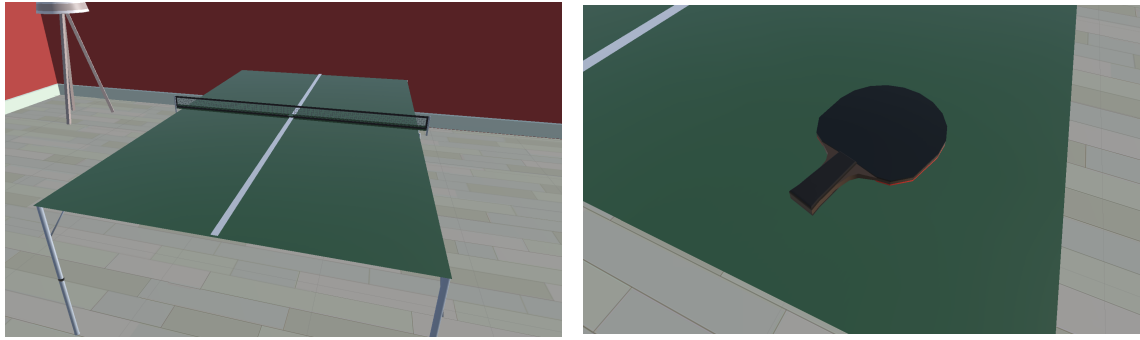


Figure. 36: *Mini-Game C Assets*

The remainder of the Mini-games' assets were, as stated before, either used from already imported asset packs or created in Unity. When it comes to sound design, none of the audio elements were created by us. They were all obtained from Pixabay <sup>14</sup>.

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<sup>14</sup><https://pixabay.com/sound-effects/>

## 5 Implementation

Having explained the design concepts in the previous chapter, this chapter outlines the implementation process of translating those concepts into a functional game. This chapter starts by addressing the technology used for this work, and then provides details on the base template selected, on key code components that enable the game to function as intended, and discusses the attempted implementation of using an LLM in runtime.

### 5.1 Technology Review

In this work, Unity will be used as the game's engine. This decision is supported by BairesDevBlog's [91] analysis. The engines considered for this work were Unity<sup>15</sup>, Unreal<sup>16</sup> and Godot<sup>17</sup>, these being the most popular tools in the market. Each tool has its own advantages, with Unreal excelling in high-end graphical capabilities and Godot characterized by its low budget offers, however Unity stood out as the most accessible and easy to learn tool which is great for novice developers and very time efficient. The intuitive interface and extensive documentation Unity provides makes the development process a swift and straightforward experience.

Unity supports most popular VR systems, these being Meta Headsets, Vive headsets, Valve SteamVR and others [92], however Meta Quest 3 stands out as being one of the most recent VR systems to come out and for possessing a compact structure, being lightweight and wireless. These details significantly enhance the immersion of the experience since the user's awareness of the headset is reduced. For these reasons and for already having a Meta Quest 3 in our possession, we choose Meta Quest 3 as the device to conduct this work.

### 5.2 Unity VR template

Initially, the project started on a non-VR default template and then the necessary plug-ins and packages for VR development were imported into the project. At this point the game was at an initial stage, containing a limited amount of assets and mechanics (figures 37 and 38).

Here the first mini-game was being developed, that being the darts mini-game, and also where the grabbing mechanic was first implemented. This mechanic proved to be quite a challenge since

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<sup>15</sup><https://unity.com/pt>

<sup>16</sup><https://www.unrealengine.com/pt-BR>

<sup>17</sup><https://godotengine.org/>

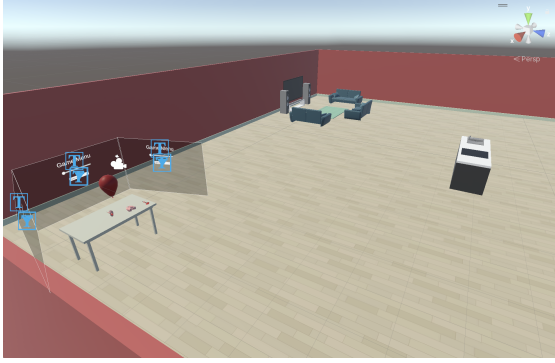


Figure. 37: *Old template scene*

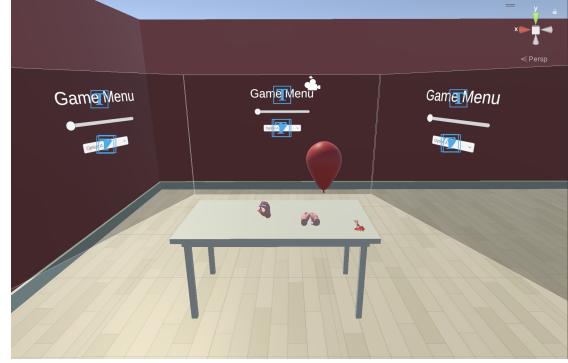


Figure. 38: *Early version of Darts mini-game*

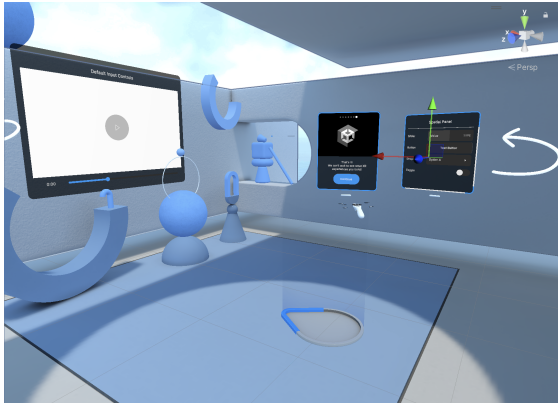
not only it was necessary to grab the dart but also to make the hand and, more specifically, the fingers properly move and rotate to simulate what grabbing a dart in real life would look like. This version additionally had a basic outline on how the party scene was going to be designed and already contained a few assets.

However, after a few tests, the game had a poor performance output which was noticed by the low frame-rate. From this point onwards, every asset and mechanic developed was imported into a new project which was an empty VR template that unity offered as a starting point. The template included all the necessary packages and plug-ins for VR development. The packages used were:

- **Provider plug-ins** - Oculus plug-in was chosen since the hardware being used in this project is the Meta Quest 3.
- **XR Interaction Toolkit** - Contains elements related to the controllers, tracking, rotation and object interaction.
- **XR Core Utilities** - Contains software utilities used by other Unity XR plug-ins and packages.
- **Input System** - Responsible for enabling access to user input from the VR controllers and also XR tracking data and haptics.

This template also included a sample scene that contained various game elements, tailored to teach how each feature of the VR template worked (figures 39 and 40). This scene served as a great additional source of information when it comes to VR development in Unity.

Some of these elements were later incorporated in the actual game, more specifically the UI panels. These panels already functioned well with controller inputs and offered great features like facing the player at all times regardless of movement and the ability to reposition them. They

Figure. 39: *Sample scene*Figure. 40: *UI elements*

were implemented into every tutorial and also modified to function as a dialogue window in the Normalization mini-game.

From a performance perspective, it was possible to observe that the game in this template was far more optimized, maintaining a consistent frame-rate throughout the gameplay loop, which is something that was not possible with the older project.

### 5.3 UML Class Diagrams

Due to extensive nature of the implementation, it is not possible to showcase every attribute and method in the UML Class Diagrams. Only the most relevant ones were highlighted in this section for the purposes of clarity and conciseness. For each game a brief description of the most relevant methods will be provided followed by code screenshots. Additionally, Appendix D shows component diagrams for each mini-game.

#### 5.3.1 Game A - Identifying your thoughts

The following diagram illustrates the most relevant classes and their associated attributes and methods for mini-game A. It's composed of three main classes, where the BalloonGenerator class is responsible for running and managing the core functionality of the game, while the other two classes contain balloon related logic.

**BalloonGenerator Class:** The BalloonGenerator class controls the spawning of the balloons and determines the associated term. The SpawnBalloons() method (see fig. 42) begins by checking whether there's an unused term among the active balloons. If an unused term is found, then the

## Mini-Game A - Identify your thoughts

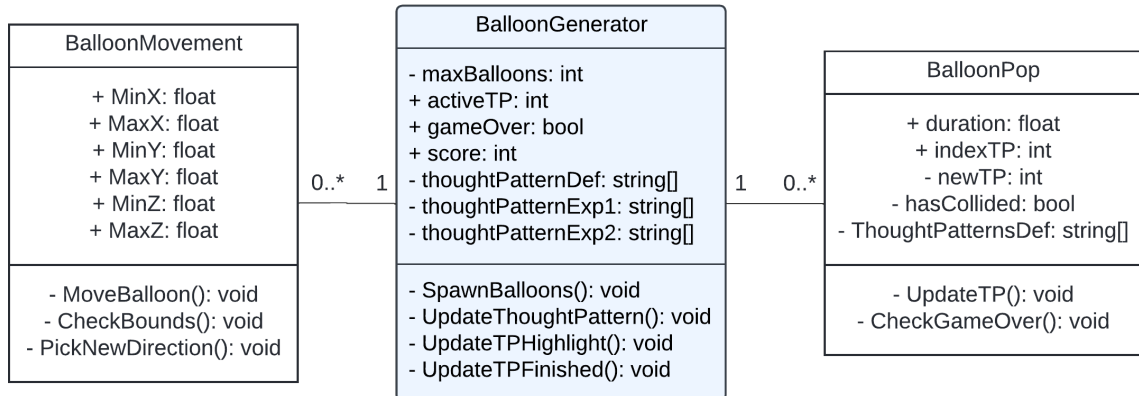


Figure. 41: UML Class Diagram for Mini-Game A

method spawns a balloon with that term. Otherwise, it spawns a balloon with a random term already present in the game.

The `GetRandomPosition()` method returns a random position within set boundaries which makes the balloon spawning random, while the `AssignWordToBalloon()` method is responsible for filling the balloon label with the chosen term. In addition, each balloon is assigned a random color.

`UpdateTPHighlight()`, `UpdateTPFinished()` and `UpdateThoughtPattern()` are methods used to check the state of each of thought pattern. `UpdateTPHighlight()` method (see fig. 43) is responsible for correctly highlighting the current thought pattern selected. It goes through all six thought patterns and activates a specific highlight panel depending on the `activeTP` variable.

On the other hand, `UpdateTPFinished()` method (see fig. 43) also goes through all six thought patterns and checks whether a thought pattern is complete or not, and if so activates the finished panel associated to that specific thought pattern.

Lastly, the `UpdateThoughtPattern()` method (see fig. 45) updates the text for each thought pattern whenever they reach "Lvl.2" depending on the `phaseTP` value.

**BalloonPop class:** The `BalloonPop` class is present in each balloon `GameObject` and is responsible for managing the balloon-dart collision logic. The `UpdateTP()` method is called whenever a collision with a dart happens. It first checks if all six thought patterns are completed, and if so it notifies the `BalloonGenerator` class that the game has ended.

```

void SpawnBalloons()
{
    balloonCount++;

    BalloonPop[] existingBalloons = FindObjectsOfType<BalloonPop>();

    bool[] indexUsed = new bool[6]; //Array with bools to check if theres a thought pattern not present in the game

    for (int i = 0; i < indexUsed.Length; i++)
    {
        indexUsed[i] = false;
    }

    // Mark which indexTP values are in use
    foreach (BalloonPop balloon in existingBalloons)
    {
        if (balloon.indexTP >= 0 && balloon.indexTP < 6)
        {
            indexUsed[balloon.indexTP] = true;
        }
    }

    // Find the first unused indexTP
    int unusedIndexTP = -1;
    for (int i = 0; i < indexUsed.Length; i++)
    {
        if (!indexUsed[i])
        {
            unusedIndexTP = i;
            break;
        }
    }

    if (unusedIndexTP == -1)
    {
        unusedIndexTP = Random.Range(0, 6); // Selects a random indexTP because all were in use
    }

    string selectedWord = thoughtPatternsDef[unusedIndexTP];
    int wordIndex = unusedIndexTP;
    GameObject newBalloon = Instantiate(balloonPrefab, GetRandomPosition(), Quaternion.identity);

    if (balloonColors.Length > 0)
    {
        // Randomly pick a material from the list/array
        Material randomMaterial = balloonColors[Random.Range(0, balloonColors.Length)];

        // Set the balloon's material
        Renderer balloonRenderer = newBalloon.GetComponentInChildren<Renderer>();
        if (balloonRenderer != null)
        {
            balloonRenderer.material = randomMaterial;
        }
    }
    AssignWordToBalloon(newBalloon, selectedWord, wordIndex);
}

```

Figure. 42: *SpawnBalloons Method*

```

void UpdateTPHighlight()
{
    for(int i = 0; i < 6; i++)
    {
        if(activeTP == i)
        {
            GameObject panelToActivate = UIThoughtPatterns[i].transform.GetChild(0).gameObject;
            panelToActivate.SetActive(true);
        }
        else
        {
            GameObject panelToActivate = UIThoughtPatterns[i].transform.GetChild(0).gameObject;
            panelToActivate.SetActive(false);
        }
    }
}

```

Figure. 43: *UpdateTPHighlight() method*

```
void UpdateTPFinished()
{
    for (int i = 0; i < 6; i++)
    {
        if (phaseTP[i] == 1)
        {
            GameObject panelToActivate = UIThoughtPatterns[i].transform.GetChild(1).gameObject;
            panelToActivate.SetActive(true);
        }
        else
        {
            //do nothing
        }
    }
}
```

Figure. 44: *UpdateTPFinished()* method

```
void UpdateThoughtPattern()
{
    for(int x = 0; x < thoughtPatternExp1.Length; x++)
    {
        if(phaseTP[x] == 1)
        {
            thoughtPatternExp1[x] = thoughtPatternExp2[x];
            GameObject obj = UIThoughtPatterns[x];

            TextMeshProUGUI textComponent = obj.GetComponent<TextMeshProUGUI>();

            levels[x].text = "Lv1.2";

            textComponent.text = thoughtPatternExp1[x];
        }
    }
}
```

Figure. 45: *UpdateThoughtPattern()* method

```

void UpdateTP()
{
    previousTP = thoughtPattern.activeTP;

    if (indexTP == thoughtPattern.activeTP)
    {
        thoughtPattern.score += 100;
        thoughtPattern.phaseTP[indexTP]++;
        // Check if the game is finished by comparing each element to 1
        bool allFinished = thoughtPattern.phaseTP.All(phase => phase == 1);

        if (allFinished)
        {
            //All thought patterns are completed
            thoughtPattern.gameOver = true;
        }
        else
        {
            // Attempt to find a new activeTP that meets the conditions
            int attempts = 0;
            const int maxAttempts = 1000; // Prevent infinite loop by limiting attempts
            do
            {
                newTP = Random.Range(0, 6);
                attempts++;
                if (attempts > maxAttempts)
                {
                    break; // Break out of the loop if too many attempts
                }
            } while (thoughtPattern.phaseTP[newTP] == 1);

            // Only update activeTP if a new valid one was found within max attempts
            if (attempts <= maxAttempts)
            {
                thoughtPattern.activeTP = newTP;
            }

            thoughtPattern.activeTP = newTP;
        }
    }
    else
    {
        // Handle the case where indexTP does not match activeTP
        thoughtPattern.score -= 100;
    }

    thoughtPattern.balloonCount--;
    Destroy(gameObject); // Destroy the balloon after the effect is complete
}

```

Figure. 46: *UpdateTP()* method

Otherwise, a different thought pattern will be randomly highlighted. Additionally, it updates the score based on the balloon the player hit and then destroys the balloon.

**BalloonMovement class:** Similarly to the BalloonPop class, the BalloonMovement class is also present in each balloon GameObject. This class provides and controls the movement for each balloon.

```

void MoveBalloon()
{
    transform.Translate(movementDirection * moveSpeed * Time.deltaTime, Space.World); //provide movement to the balloons
}

void CheckBounds() //change direction whenever hitting a limit
{
    Vector3 worldPosition = gameObject.transform.position;
    if (worldPosition.x > MaxX || worldPosition.x < MinX ||
        worldPosition.y > MaxY || worldPosition.y < MinY ||
        worldPosition.z > MaxZ || worldPosition.z < MinZ)
    {
        PickNewDirection();
    }
}

void PickNewDirection() //pick a new random direction with a bias toward the center
{
    Vector3 pos = transform.position;
    Vector3 directionBias = Vector3.zero;

    directionBias.x = DetermineBias(pos.x, MinX, MaxX);
    directionBias.y = DetermineBias(pos.y, MinY, MaxY);
    directionBias.z = DetermineBias(pos.z, MinZ, MaxZ);

    Vector3 randomDirection = new Vector3(
        Random.Range(-1f + directionBias.x, 1f + directionBias.x),
        Random.Range(-1f + directionBias.y, 1f + directionBias.y),
        Random.Range(-1f + directionBias.z, 1f + directionBias.z)
    );

    movementDirection = randomDirection.normalized;
}

```

Figure. 47: *BalloonMovement class methods*

The MoveBalloon() method on fig. 47 gives movement to the balloons based on the variable movementDirection, which is determined randomly in the PickNewDirection() method (see fig. 47). This method is called by the CheckBounds() method whenever a balloon hits one of the limits.

### 5.3.2 Game B - Normalization

The UML Class Diagram on Fig. 48 shows the three most relevant classes for Game B - Normalization. The BoardLogic class is responsible for the all the game logic happening in the puzzle section of the boards. The attachablePaper class is also related to the board section, since it provides the ability to attach any piece of information anywhere on the board. Lastly, there are four different classes, each specific to an NPC. To provide a clear and concise view, we are only showing the DavidConversation class since they all follow the same logic and structure. This class contains all the methods related to the NPC interactions and dialogue.

## Mini-Game B - Normalization

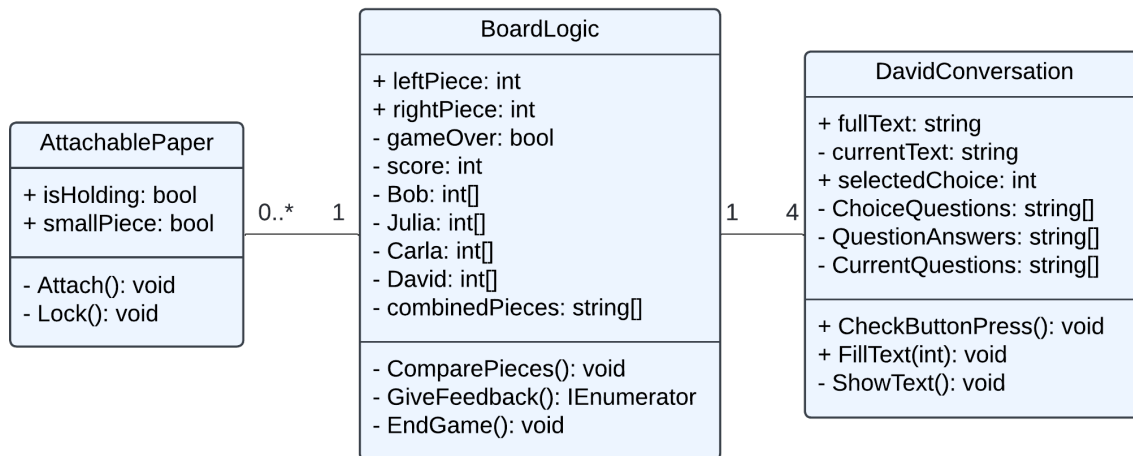


Figure. 48: UML Class Diagram for Mini-Game B

**BoardLogic class:** The BoardLogic class checks whether the two pieces of information placed by the player are combinable or not, and then gives the appropriate feedback depending on the result. Additionally, it checks if every NPC board is complete, and if so the game ends.

The ComparePieces() method (see fig. 49) compares the values of the two pieces in order to check if they match. On a successful attempt, the score is increased, visual and auditory feedback is provided through the GiveFeedback() method and a new piece of information is created and placed on the appropriate slot. On an unsuccessful attempt however, the score is decreased and the GiveFeedback() method again provides the appropriate feedback.

The EndGame() method (see fig. 50) verifies whether the end game condition has been reached or not, which happens when every NPC board has been successfully completed.

**AttachablePaper class:** The AttachablePaper class is responsible for every physical interaction between the boards and all pieces of information, and providing the BoardLogic class with important values regarding the position of the pieces. This is achieved through the Attach() method. This method executes different logic based on the position on where the piece is placed.

There are three different scenarios: placing the piece on either side of the combine area (left or right), placing it on an NPC board and placing it anywhere on the boards.

```

private void ComparePieces()
{
    if(leftPiece == rightPiece) // Right combination
    {
        data.LogToXML($"Player successfully combined two pieces: {leftText} + {rightText} = {combinedPieces[leftPiece]} ");
        AttachablePaper[] pieces = FindObjectsOfType<AttachablePaper>();
        foreach ( AttachablePaper obj in pieces)
        {
            if(obj.id == leftPiece)
            {
                Debug.Log(obj.name);
                Destroy(obj.gameObject);
            }
        }

        Vector3 spawnPosition = new Vector3(-12.95f, 1.649f, -1.2898f);
        Quaternion rotation = Quaternion.Euler(0, -90, 0);

        GameObject finalPiece = Instantiate(FinalPiece, spawnPosition, rotation);
        AttachablePaper fp = finalPiece.GetComponent<AttachablePaper>();
        TextMeshPro text = finalPiece.GetComponentInChildren<TextMeshPro>();
        Renderer[] renderers = finalPiece.GetComponentInChildren<Renderer>();

        foreach (Renderer renderer in renderers)
        {
            if (renderer.gameObject.name == "background")
            {
                int index = (leftPiece - 1) % 5;
                renderer.material = material[index];
            }
        }

        text.text = combinedPieces[leftPiece];
        fp.isHolding = false;
        fp.isTouching = true;
        fp.isAttached = true;
        fp.pointOfContact = new Vector3 (-12.95f, 1.3963f, -0.3359f);
        fp.id = leftPiece;
        leftPiece = 0;
        rightPiece = 0;
        score += 100;
        StartCoroutine(GiveFeedback(0));
    }

    else // Wrong combination
    {
        score -= 100;
        StartCoroutine(GiveFeedback(1));
    }
}

```

Figure. 49: *ComparePieces()* method

```

private void EndGame()
{
    if (!gameOver)
    {
        for (int x = 0; x < 4; x++) //Check each NPC state
        {
            if (finalState[x] != 1)
            {
                break;
            }

            if (x == 3) //If all complete then end game
            {
                InstructionScreen.SetActive(false);
                data.LogToXML("Puzzle game has ended");
                data.PuzzleGameDone = true;
                EndScreen.SetActive(true);
                FinalScore.text = score.ToString();
                for(int i = 0; i <4; i++)
                {
                    Highlights[i].SetActive(false);
                }
                gameOver = true;
            }
        }
    }
}

```

Figure. 50: *EndGame()* method

```

private void Attach()
{
    Vector3 currentPosition = transform.position;

    if (!isHolding && (isTouching || isTouchingDoorL || isTouching2DoorR || isTouchingDoorR || isTouching2DoorL ))
    {
        // when placed in the left side of the combination
        if (smallPiece && 1.85f < currentPosition[1] && currentPosition[1] < 2 && -1.60f < currentPosition[2]
            && currentPosition[2] < -1.4 && !hintSheet)
        {
            transform.position = new Vector3(-12.96f, 1.924f, -1.495f);
            transform.rotation = Quaternion.Euler(new Vector3(0, -90, 0));
            isHolding = false;
            rb.isKinematic = true;
            isAttached = true;
            left = true;
            isTouching = true;
            board.leftPiece = id;

            TextMeshPro label = GetComponentInChildren<TextMeshPro>();
            board.leftText = label.text;
        }
        // when placed in the right side of the combination
        else if (smallPiece && 1.85f < currentPosition[1] && currentPosition[1] < 2f && -1.19f < currentPosition[2]
            && currentPosition[2] < -0.985f && !hintSheet)
        {
            transform.position = new Vector3(-12.96f, 1.924f, -1.083f);
            transform.rotation = Quaternion.Euler(new Vector3(0, -90, 0));
            rb.isKinematic = true;
            isAttached = true;
            left = false;
            isTouching = true;
            isHolding = false;
            board.rightPiece = id;

            TextMeshPro label = GetComponentInChildren<TextMeshPro>();
            board.rightText = label.text;
        }
    }
    //when placed elsewhere
    else if (!smallPiece && coordIndex != 0 && !hintSheet)
    {
        for (int x = 0; x < 100; x++)
        {
            if (coordinates[x] == coordIndex)
            {
                transform.position = new Vector3(coordinates[x + 1], coordinates[x + 2], coordinates[x + 3]);
                transform.rotation = Quaternion.Euler(new Vector3(0, coordinates[x + 4], 0));
                rb.isKinematic = true;
                isTouching = false;
                isAttached = true;
            }
        }
    }
}

```

Figure. 51: *Attach()* method

The Lock() method (see fig. 52) ensures that whenever the player successfully completes an NPC board, its pieces become non-interactable by disabling their grab component.

```
private void Lock()
{
    if (0 < id && id < 6 && board.BobDone)
    {
        XRGrabInteractableTwoAttached grab = GetComponent<XRGrabInteractableTwoAttached>();
        grab.enabled = false;
    }
    else if (id > 5 && id < 11 && board.JuliaDone)
    {
        XRGrabInteractableTwoAttached grab = GetComponent<XRGrabInteractableTwoAttached>();
        grab.enabled = false;
    }
    else if (id > 10 && id < 16 && board.CarlaDone)
    {
        XRGrabInteractableTwoAttached grab = GetComponent<XRGrabInteractableTwoAttached>();
        grab.enabled = false;
    }
    else if (id > 15 && id < 21 && board.DavidDone)
    {
        XRGrabInteractableTwoAttached grab = GetComponent<XRGrabInteractableTwoAttached>();
        grab.enabled = false;
    }
}
```

Figure. 52: *Lock()* method

**Conversation class:** Finally, the Conversation class handles all logic regarding text display and the interactions between the player and the NPCs. Initially, the CheckButtonPress() method (see fig. 53) checks for a player input in order to start the conversation by activating a UI panel with the initial text and questions.

```
public void CheckButtonPress() //check button press to start a conversation with the NPC
{
    bool primaryButtonState;
    if (_inputData._rightController.TryGetFeatureValue(CommonUsages.primaryButton, out primaryButtonState) && primaryButtonState)
    {
        UI.SetActive(true);

        ControllerPreview.SetActive(false);
        conversationStarted = true;
        data.LogToXML("Player started conversation with David");
        checkButton = false;

        fullText = initialText;
        StartCoroutine(ShowText());

        TextMeshProUGUI questionText1 = QuestionSlots[0].GetComponentInChildren<TextMeshProUGUI>();
        TextMeshProUGUI questionText2 = QuestionSlots[1].GetComponentInChildren<TextMeshProUGUI>();
        TextMeshProUGUI questionText3 = QuestionSlots[2].GetComponentInChildren<TextMeshProUGUI>();
        questionText1.text = ChoiceQuestions[0];
        questionText2.text = ChoiceQuestions[1];
        questionText3.text = ChoiceQuestions[2];
        selectedChoice = 0;

        StartCoroutine(TimerWait());
    }
}
```

Figure. 53: *CheckButtonPress()* method

The `FillText()` method (see fig. 54) updates the NPC's responded based on the chosen question and replaces the available questions with new ones. More specifically, it calls the `ShowText()` method (see fig. 55) that fills the NPC's text in a progressive way and the `QuestionsUpdate()` method (see fig. 56 ), which handles the logic when it comes to changing the available questions.

```
private void FillText(int index)
{
    if (index < 0 || index >= ChoiceQuestions.Length) return;

    fullText = QuestionAnswers[index];
    StartCoroutine(ShowText());
    checkIfDone[index] = 1;
    questionColor[index] = 1;

    allChatDone = checkIfDone.SequenceEqual(allOne);

    int[] indices = allChatDone ? new int[] { 0, 1, 2, 3 } : new int[] { 0, 1, 2 };
    QuestionsUpdate(indices);

    if (index == 3) // Special case for the last question
    {
        questionsDone.SetActive(true);
        hint.SetActive(true);
    }
}
```

Figure. 54: *FillText()* method

```
private IEnumerator ShowText()
{
    textWait = true;
    for (int i = 0; i < fullText.Length; i++)
    {
        currentText = fullText.Substring(0, i);
        TextMeshProUGUI textMain = mainText.GetComponent<TextMeshProUGUI>();
        textMain.text = currentText;
        yield return new WaitForSeconds(0.02f);
    }
    textWait = false;
}
```

Figure. 55: *ShowText()* method

### 5.3.3 Game C - Cognitive Restructuring

The UML diagram illustrated in fig. 57 contains the four most important classes for Game C. The `BallSpawner` class is responsible for, as the name implies, the periodic spawn of different types of balls, but also for tracking various game values, such as score and anxiety meter, and handling the bonus round. Both `WallLogic` and `AnswerWall` classes manage ball-wall collision logic, with the difference being that `WallLogic` is used for normal gameplay flow, while `AnswerWall` was

```

private void QuestionsUpdate(int[] indices)
{
    if (indices.Length == 4) QuestionsThree();
    else QuestionsTwo();

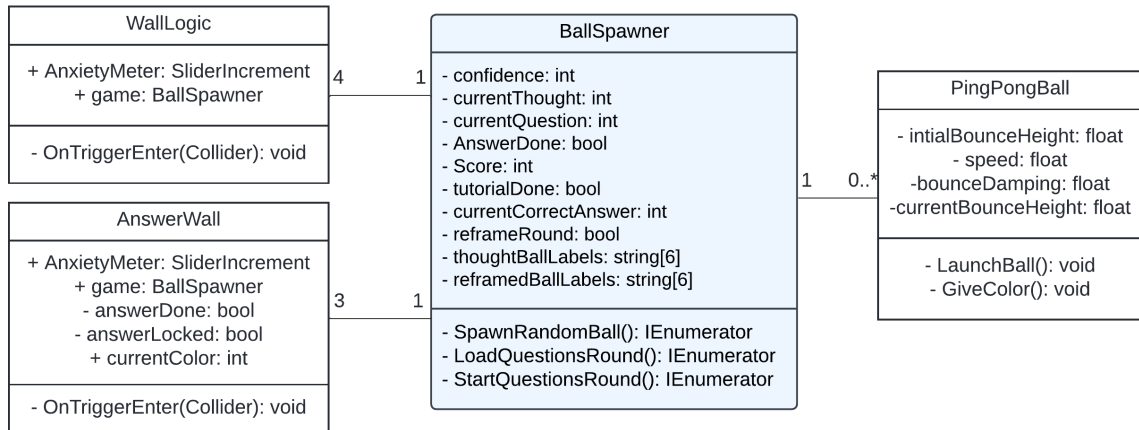
    for (int i = 0; i < indices.Length - 1; i++)
    {
        TextMeshProUGUI questionText = QuestionSlots[i].GetComponentInChildren<TextMeshProUGUI>();
        questionText.text = ChoiceQuestions[indices[i]];
        currentQuestions[i] = ChoiceQuestions[indices[i]];
        ChangeQuestionColor(i, indices[i]);
    }
}

```

Figure. 56: *QuestionsUpdate()* method

specifically designed for the bonus round. Lastly, the PingPongBall class handles ball-movement related properties, like speed and bounce height, and assigns colors based on the ball type.

### Mni-Game C - Cognitive Restructuring

Figure. 57: *UML Class Diagram for Mini-Game C*

**BallSpawner class:** The BallSpawner class, as said before, handles the ball spawning logic throughout the gameplay flow, including the bonus round. The SpawnRandomBall() method ensures that the ball spawning is not too repetitive. More specifically, it means that a scenario where the same ball type keeps spawning more than three times in a row isn't possible. It can spawn a thought ball, an action ball or a spike ball.

The LoadQuestionsRound() method (see fig. 59) prepares the Bonus Round when the anxiety meter is at zero. It deactivates several GameObjects relevant to the normal gameplay flow, and then activates GameObjects pertinent to the bonus round. It also chooses the thought pattern that the Bonus Round will be based around.

```
private IEnumerator SpawnRandomBall()
{
    // Check if all ball types have spawned 3 times
    newBall = false;

    if (IsAllFull(BallSpawnTimes, AllFull))
    {
        BallSpawnTimes = (int[])ResetTimes.Clone();
    }

    int x = Random.Range(0, 3);

    while (BallSpawnTimes[x] == 3)
    {
        x = Random.Range(0, 3);
    }

    switch (x)
    {
        case 0:
            SpawnThoughtBall();
            break;
        case 1:
            SpawnActionBall();
            break;
        case 2:
            SpawnSpikeBall();
            break;
    }

    BallSpawnTimes[x]++;

    yield return new WaitForSeconds(2);
    newBall = true;

    if(reframeRound)
    {
        newBall = false;
    }
}
```

Figure. 58: *SpawnRandomBall()* method

```

private IEnumerator LoadQuestionsRound()
{
    PingPongBall[] existingBalls = FindObjectsOfType<PingPongBall>();
    foreach (PingPongBall obj in existingBalls)
    {
        Debug.Log(obj.name);
        Destroy(obj.gameObject);
    }

    ActivateRefUI();
    line.SetActive(true);

    resetAnswers = true;

    yield return new WaitForSeconds(6);

    GameObject thought = QuestionUIText[0];
    TextMeshPro textComponent = thought.GetComponent<TextMeshPro>();
    for(int x = 0; x < 6; x++)
    {
        if(thoughtQuestionsDone[x] == 0)
        {
            textComponent.text = thoughtBallLabels[x];
            currentThought = x;
            break;
        }
    }

    FrontUIText[2].SetActive(false);
    frontWall.SetActive(false);

    questionWall.SetActive(true);
    instruction.SetActive(true);

    FrontUIText[3].SetActive(true);
    FrontUIText[4].SetActive(true);
    FrontUIText[5].SetActive(true);

    GameObject answer1 = FrontUIText[3];
    TextMeshPro textComponent1 = answer1.GetComponentInChildren<TextMeshPro>();
    GameObject answer2 = FrontUIText[4];
    TextMeshPro textComponent2 = answer2.GetComponentInChildren<TextMeshPro>();
    GameObject answer3 = FrontUIText[5];
    TextMeshPro textComponent3 = answer3.GetComponentInChildren<TextMeshPro>();

    for(int x = 0; x < 3; x++)
    {
        answersCheck[x] = x + 1;
    }

    switch (currentThought)
    {
        case 0:
            textComponent1.text = answers1[0];
            textComponent2.text = answers1[1];
            textComponent3.text = answers1[2];

            break;
        case 1:
            textComponent1.text = answers2[0];
            textComponent2.text = answers2[1];
            textComponent3.text = answers2[2];

            break;
        case 2:
            textComponent1.text = answers3[0];
            textComponent2.text = answers3[1];
            textComponent3.text = answers3[2];

            break;
        case 3:
            textComponent1.text = answers4[0];
            textComponent2.text = answers4[1];
            textComponent3.text = answers4[2];

            break;
        case 4:
            textComponent1.text = answers5[0];
            textComponent2.text = answers5[1];
            textComponent3.text = answers5[2];

            break;
        case 5:
            textComponent1.text = answers6[0];
            textComponent2.text = answers6[1];
            textComponent3.text = answers6[2];

            break;
    }

    StartCoroutine(StartQuestionsRound());
    yield return null;
}

```

Figure. 59: *LoadQuestions()* method

Once the Bonus Round is prepared, the `StartQuestionsRound()` method initiates the Bonus Round. This method is responsible for changing the question whenever the player hits the correct answer, and for controlling the spawn time period of the answer balls. Additionally, it keeps track of which questions have been successfully answered and when no more questions remain, it ends the Bonus Round and starts the process of returning to the normal gameplay flow.

**PingPongBall class:** The `PingPongBall` class is responsible for providing various attributes and behaviors to the ping pong balls, with movement and color being the most essential. Method `LaunchBall()` (see fig. 61) applies velocity in both axis in order to simulate a bouncy-like trajectory, which is characteristic of a ping pong ball.

When it comes to color attribution, the `GiveColor` method (see fig. 62) changes the material of its own ball object based on the tag it is associated with.

**WallLogic and AnswerWall classes:**

`WallLogic` and `AnswerWall` classes possess a similar structure and logic. Depending on what stage the game is at, the walls will have different functionalities. For the normal gameplay flow, `WallLogic` class (see fig. 63) analyses which type of ball hit which type of wall, and depending on the outcome, both score and anxiety meter values are updated accordingly. The code is executed everytime there is ball-wall collision.

The `AnswerWall` class (see fig. 64) follows this same logic, but only handles the bonus round interactions. It checks whether the wall hit by the player contains the right answer or not, and then provides the appropriate feedback and changes the answers and questions if necessary. When all questions are successfully answered, it notifies the `BallSpawner` class that the bonus round has concluded.

## 5.4 LLMs in runtime - LLMUnity

Early in the development phase, an integration of a LLM in the game was being seriously considered. The objective with LLMs was to provide a highly dynamic experience where the game's content would be generated in real time given the users input. This input, for instance, could be something that the player is experiencing when facing social anxiety, and the content generated would be then related to that specific input therefore being more effective at targeting exactly what the user is feeling.

```

private IEnumerator StartQuestionsRound()
{
    FrontUIText[5].SetActive(true);
    data.LogToXML($"Questions round has started - {thoughtBallLabels[currentThought]}");
    reframeRound = true;
    GameObject question = QuestionUIText[1];
    TextMeshPro questionText = question.GetComponent<TextMeshPro>();
    AnswerDone = true;

    while (true)
    {
        List<int> answerRemain = new List<int> {};

        if (AnswerDone) // change the question when the player gets the correct answer
        {
            data.LogToXML($"Current Question: {Questions[currentQuestion]}");

            for (int x = 0; x < 3; x++)
            {
                if (answersCheck[x] != 0)
                {
                    answerRemain.Add(answersCheck[x]);
                }
            }
            int randomIndex = Random.Range(0, answerRemain.Count);
            resetAnswers = false;
            resetAnswerColors = true;

            if (answersCheck.SequenceEqual(answersDone))
            {
                break;
            }
            currentCorrectAnswer = answerRemain[randomIndex];
            questionText.text = Questions[currentCorrectAnswer - 1];
            AnswerDone = false;
        }
        yield return new WaitForSeconds(4);
        SpawnAnswerBall();
    }

    data.LogToXML("Questions round over");
    thoughtQuestionsDone[currentThought] = 1;
    reframeRound = false;
    line.SetActive(false);
    ActivateNormalUI();

    PingPongBall[] existingBalls = FindObjectsOfType<PingPongBall>();
    foreach (PingPongBall obj in existingBalls)
    {
        Destroy(obj.gameObject);
    }
    AnxietyMeter.currentValue = 0.5f;
    questionWall.SetActive(false);
    instruction.SetActive(false);
    yield return new WaitForSeconds(3);
    newBall = true;
}

```

Figure. 60: *StarQuestionsRound()* method

```

private void LaunchBall()
{
    if (isActiveBouncing)
    {
        Vector3 horizontalVelocity = transform.forward * -1 * speed;
        Vector3 verticalVelocity = Vector3.up * currentBounceHeight;
        rb.velocity = horizontalVelocity + verticalVelocity;
    }
}

```

Figure. 61: *LaunchBall()* method

```

public void GiveColor()
{
    if (gameObject.tag == "PositiveBall")
    {
        MeshRenderer my_renderer = GetComponent<MeshRenderer>();
        if (my_renderer != null)
        {
            my_renderer.material = materials[0];
        }
    }

    else if (gameObject.tag == "NegativeBall")
    {
        MeshRenderer my_renderer = GetComponent<MeshRenderer>();
        if (my_renderer != null)
        {
            my_renderer.material = materials[1];
        }
    }
}

```

Figure. 62: *GiveColor()* method

```

private void OnTriggerEnter(Collider collision)
{
    if (game.reframeRound)
    {
        //do nothing
    }
    else
    {
        TextMeshPro label = collision.GetComponentInChildren<TextMeshPro>();

        if (gameObject.name == "FrontWall")
        {
            if (!game.tutorialDone)
            {
                if (collision.gameObject.CompareTag("ActionBallHit"))
                {
                    game.Break = true;
                    Destroy(collision.gameObject);
                }

                if (collision.gameObject.CompareTag("PositiveBallHit") || collision.gameObject.CompareTag("NegativeBallHit"))
                {
                    Destroy(collision.gameObject);
                }
            }
        }
    }
}

```

Figure. 63: *WallLogic* class (only a section)

```
private void OnTriggerEnter(Collider other)
{
    game.resetAnswerColors = false;
    game.resetAnswers = false;

    if (!game.tutorialDone)
    {
        if (other.CompareTag("AnswerBallHit"))
        {
            if (gameObject.name == "Answer1Wall" && !answerLocked)
            {
                if (game.currentCorrectAnswer == 1)
                {
                    gameObject.GetComponent<Renderer>().material = material[0];
                    currentColor = 0;
                    answerLocked = true;
                    answerDone = true;
                    game.Break = true;
                    Destroy(other.gameObject);
                }
                else
                {
                    if (answerDone)
                    {
                        //do nothing
                    }
                    else
                    {
                        gameObject.GetComponent<Renderer>().material = material[1];
                        currentColor = 1;
                    }
                    Destroy(other.gameObject);
                }
            }
        }
    }
}
```

Figure. 64: *AnswerWall* class (only a section)

To this matter, the LLMUnity package [93] was selected as the most suitable solution. Not only is it free but also does not require a remote server since it runs locally in Unity's engine, regardless of having internet connection or not, and is very simple to setup. Some initial testing was done, but not long after we realized that it wasn't possible at its current state. This being due to the fact that at the time LLMUnity did not support android devices at the time of development. Since the Meta Quest 3 headset operates on an Android platform, and our goal was to run the game natively on the headset without any need to connect it to a computer, the integration of LLMUnity in the project was not possible, but remains a potential avenue for exploration in the future.

## 6 Evaluation

The focus of this first study is to gauge interest in this type of digital health intervention, identifying usability and user experience issues. In future studies, the focus would shift to real life scenarios (e.g., multiple sessions or a longitudinal study; lab study to "in the wild" study) to gauge the applicability of the concept.

### 6.1 Study Design

In this work, a mixed method approach was adopted for the evaluation. Mixed method research combines both quantitative and qualitative approaches, taking advantage of the strengths that each approach provide, being especially adequate for complex problems like social and health science related issues. Additionally, the study also follows a pretest-posttest design, meaning that data from the participants was collected before and after the intervention was administered in the same session, with the purpose of assessing any relevant short-term changes in knowledge and/or thinking behavior induced in the participants.

This study did not involve any control groups or manipulation of any independent or dependent variables, meaning that all participants were exposed to the exact same artefact and evaluated under the same conditions. Since the focus of this study is assessing the impact of the artefact on college students, ensuring consistency in the participant pool and uniformity throughout the study was essential. The primary objective of this study is to assess the artefact's effectiveness and usability at transmitting CBT concepts about social anxiety for college students. The research aims to provide insights about the artefact's design, performance and its potential as a gamified learning tool. This study was conducted at our research institution in a sound-isolated room, ensuring that the studies were conducted without any external interference.

Additionally, Mini-game C was not included in the study. This decision was influenced by feedback from a few informal play-tests where the players initially had a hard time hitting the balls and figuring out which wall to hit. Even though the CBT concept in question is completely valid for individuals with social anxiety, the mini-game itself has proven to be very challenging in terms of practical skill and in understanding the flow of the game. This would mean that not only the difficulty of the mini-game could affect the player's understanding of the CBT concept in question but also the session's duration would increase significantly. That being said, this mini-

game is still being included in this thesis since it represents the purpose of this work, which is to gamify CBT concepts, and on a later date can be reworked in order to be more practical and intuitive for both players new to VR and experienced ones.

## 6.2 Procedure

To begin the study, participants were provided with an informed consent (Appendix A) detailing every relevant aspect, such as the study's procedure, theme and other essential information regarding conditions, confidentiality and anonymity, and also a participant ID which will be used throughout the study. Following this, participants were tasked to fill in three different initial questionnaires: a demographic questionnaire for basic information, a questionnaire about mental health literacy and a CBT questionnaire.

Having completed the initial questionnaires, the participant is now provided with the VR equipment and the headset's streaming to the PC is enabled so that it's possible to observe what the participant sees and offer guidance if necessary. Once the game starts, the player is informed that the table-tennis game is not included in the study and therefore not playable. Although there is no in-game time limit for the mini-games, a ten minute limit was attributed to both mini-games in order to ensure consistency throughout the studies and maintain a standardized study duration.

Once both mini-games are complete or the time-limit is reached, the participants are asked to fill out additional questionnaires. They begin by completing two Game Experience Questionnaires (GEQ), followed by a repeat of the mental health literacy and CBT questionnaires. Finally, a semi-structured interview with voice recording is conducted to gather feedback on various aspects of the artefact and the concepts it conveys, thus concluding the session.

Due to issues related to mental health, we submitted the study protocol to a local Ethics committee; this study got approval of the Ethics committee of University of Madeira <sup>18</sup>, with ID P139 (Appendix C).

## 6.3 Measures/Metrics

In this study, we aimed to evaluate the artefact from multiple perspectives to gain a comprehensive understanding of its performance and potential as a gamified learning tool, with the focus on

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<sup>18</sup><https://www.uma.pt/en/sobre/extensao-universitaria/comissao-de-etica/apresentacao/>

assessing both the experiential and educational aspects of the artefact. To this matter, we designed and conducted the study to gain insight on these topics:

- **Effectiveness at conveying CBT concepts:** How well the artefact conveyed and facilitated understanding of CBT concepts integrated into the mini-games.
- **Potential design issues:** Any flaws or challenges in the artefact’s design that might’ve impacted its usability, effectiveness or participant experience.
- **Usability:** Whether participants found the mini-games intuitive and user-friendly, as well any issues they encountered.
- **Engagement/Experience:** Participant’s overall experience with the mini-games, including their level of immersion and enjoyment.

With these main targets in mind, we chose and designed the questionnaires in order to extract the relevant information from the participants. Starting with the demographic questionnaire, it was designed to collect participant’s basic data regarding gender, age, nationality and current academic level thus providing a clear demographic context on the participants.

### **Mental Health Literacy**

To assess the participant’s understanding about knowledge of various aspects about mental health before and after the intervention, we used the Mental Health Literacy Scale [94]. Since the original scale had some questions specifically designed for individuals living in Australia, the questionnaire was slightly adapted by simply replacing references as "Australia" to "Portugal" to increase cultural relevance. However, the questionnaire was not translated to Portuguese as all participants were proficient in English. The scoring is determined by summing all items in accordance with the specific rules set by the scale itself, resulting in a maximum score of 160 points and a minimum score of 35 points. However, due to an oversight in our part, item 12 ("To what extent do you think it would be helpful for someone to avoid all activities or situations that made them feel anxious if they were having difficulties managing their emotions?") was mistakenly not included in the questionnaire. Therefore, the results only represent the remaining 34 items. For this reason, we opted to further explore the results by analyzing the themes represented by the items. This analysis was guided through a theoretical framework of Mental Health Literacy Scale by items. More specifically, table 1 was created by Korhonen et al. [95] in their study to

evaluate psychometric properties of a revised version of the MHLS in South Africa and Zambia. This framework was created based on Jorm's theoretical framework [96] and the MHLS's developers work [94], and it displays which themes are associated with each items, with Knowledge of Self-treatment attribute only being represented by item 11.

| Main Theme  | Attribute  | Item    |
|-------------|--|---------|
| Recognition | Ability to recognise specific disorders                                  | Q1–Q8   |
| Knowledge   | Knowledge of risk factors and causes of mental illness                   | Q9–Q10  |
| Knowledge   | Knowledge of self-treatment  | Q11–Q12 |
| Knowledge   | Knowledge of professional help available                                 | Q13–Q15 |
| Knowledge   | Knowledge of how to seek information                                     | Q16–Q19 |
| Attitudes   | Attitudes that promote recognition or appropriate help-seeking behaviour | Q20–Q35 |

Table 1: Theoretical framework of Mental Health Literacy Scale by items

### CBT Questionnaire

Targeting the CBT concepts, a custom questionnaire was developed in order to assess participant's knowledge about specific terms integrated in the mini-games. This questionnaire was administered before and after the intervention, which consisted of two distinct sections. The first section included eight multiple choice questions - "*Overgeneralization is...*", "*Mind Reading is...*", "*Filtering is...*", "*Should Statements is...*", "*Black-and-White thinking is...*", "*Catastrophizing is...*", "*Cognitive Restructuring is about...*", "*Normalization is about...*" - each with only one correct answer, designed to test the participant's understanding of definitions for the terms presented in the mini-games (primarily focused on Mini-Game A). The second section consisted of five items - "*It's important to identify negative/irrational thoughts*", "*I'm confident in identifying my negative/irrational thoughts*", "*I'm willing to challenge my negative/irrational thoughts*", "*Changing negative/irrational thoughts can have a positive impact in life*", "*It's helpful to know that other people share the same thoughts/feelings*" - based on a Likert scale from "Strongly Disagree" to "Strongly Agree", to assess the participant's cognitive reflection about the CBT concepts conveyed in the mini-games. The items were designed based on the study's objectives and prior research on the CBT concepts and terms but were not derived from any existing validated instrument. When it comes to the scoring process, each correct answer on the first section equals one point. In the second

section however, the points are based on the Likert scale, with "Strongly Disagree" representing one point and "Strongly Agree" representing five points.

### **Game Experience Questionnaires**

The Game Experience Questionnaire(GEQ) was made to assess participant's game experience on different components and meant to be administered immediately after the game session. The GEQ has a modular structure which consists of three different modules: the Core module, the Social Presence module and the Post-game module. In this study, we did not use the Social Presence module, being that, although there are NPCs in the game that the player can interact with, their social presence is not very relevant to the study's objectives.

### **Semi-Structured Interview**

Finally, the semi-structured interview (Appendix B) conducted and recorded at the end of each study consisted of eight open-ended questions designed to collect qualitative insights that were otherwise unobtainable from the other questionnaires. These questions were created according to the study's objectives, giving the participants an opportunity to further elaborate on their overall experience with the artefact, any issues or challenges they encountered, the artefact's potential as a learning tool and any suggestions for improvement.

## **6.4 Sample**

The sampling method used was convenience sampling, where individuals who met the study's requirements and were easy to contact were invited to participate in the study. This involved reaching out to people within the researcher's network who matched the inclusion/exclusion criteria, which consisted of college students aged between 18 and 25, proficient in English and physically capable for VR. The sample consisted of twelve participants from the University of Madeira, all of Portuguese nationality. Figure 65 illustrates the distribution by age, highlighting that most participants were 24+ years old. When it comes to gender, Figure 66 shows that 66,6% of the participants were male, while the remaining 33.3% were female. Lastly, Figure 67 represents the current academic level of each participant, with only three holding a bachelor's degree and the remainder pursuing a master's degree.

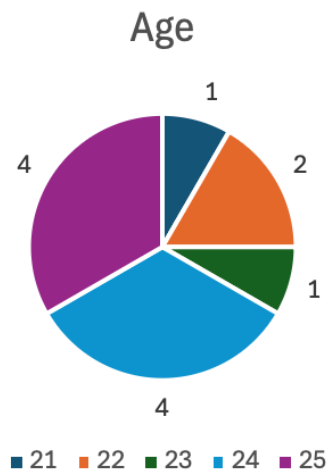


Figure. 65: Age Distribution

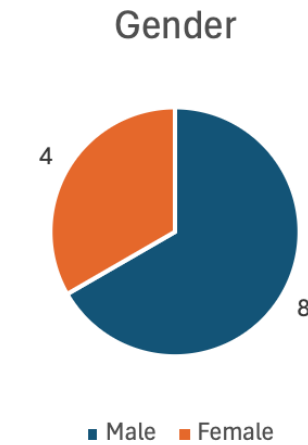


Figure. 66: Gender Distribution

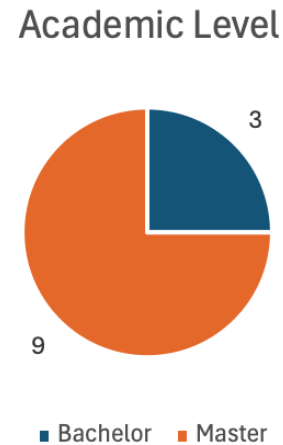


Figure. 67: Academic Level Distribution

## 6.5 Analysis

To evaluate the data collected during the study, both quantitative and qualitative analysis were conducted to identify trends, measure effectiveness and usability, and compare results before and after the intervention.

### 6.5.1 Quantitative Analysis

When it comes to quantitative analysis, all data collected during the study, apart from the semi-structure interviews, were inputted into SPSS. SPSS <sup>19</sup>, short for Statistical Package for Social Sciences, is a popular comprehensive software tool commonly used for quantitative analysis that provides tools for performing a variety of statistical tests, data management and visualization tasks.

For all data sets obtained, we started with basic descriptive analyses and assessed their normality in SPSS using the Shapiro-Wilk test. The Shapiro-Wilk test is an hypothesis test that evaluates whether a data set is normally distributed or not, determined by the size of the p-value, where a larger p-value means that the data set is likely to be normally distributed. For this study, a significance level of  $\alpha = 0.05$  was used, meaning that if the p-value is less than 0.05, then the data is not normally distributed. If its This step is essential since depending on the normality of the data set, only specific analytical methods will be adequate for the data in question.

For each paired data set (before and after measurements) that is normally distributed, we conducted a paired t-test. The paired t-test is an inferential statistics procedure that determines

<sup>19</sup><https://www.ibm.com/products/spss-statistics>

whether the mean change for the paired values is significantly different from zero. Essentially, this test is meant to give an insight on whether there is a statistical difference in results after the intervention took place.

### 6.5.2 Qualitative Analysis

In the qualitative analysis, the relevant information emerges from the semi-structured interviews conducted at the end of each study. The main goal with these interviews was to provide qualitative information about different aspects of the artefact that were otherwise not possible to obtain from the questionnaires. By using open-ended questions targeting specific themes, the interviews provided a deeper understanding of participant's experiences.

More specifically, the key objectives were to explore participants' perception of each mini-game, their interactions with the mechanics, any issues or challenges they faced and whether they were able to relate to the content in any way. Additionally, the interviews also sought to collect insights about the artefact's potential as a tool to help college students, as well as suggestions for improvement.

Before conducting any analysis, first it was necessary to transcribe the audio recordings from each participant. This involved carefully listening to everything that was said throughout each interview and accurately labelling the information with the corresponding participant ID. The interviews and the associated transcriptions were conducted in Portuguese, which means any quotations from the participants' interviews were accurately translated into English. Having each interview thoroughly documented, the data was prepared for the actual analysis.

To aid the qualitative analysis, a free and open source software called Taguette<sup>20</sup> was used, which is a widely used tool designed to specifically facilitate highlighting, tagging and categorization of themes in research material, enabling researchers to effectively organize and identify themes. By using Taguette, we were able to annotate key segments of our interviews, ensuring that theme elements were clearly categorized. This approach not only enhanced the clarity of our interviews but also enabled us to identify connections between the highlighted themes more effectively.

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<sup>20</sup><https://www.taguette.org>

## 6.6 Results

### 6.6.1 Quantitative Results

#### Mental Health Literacy Questionnaires Results

| Pair                        | Mean   | N  | Std. Deviation | Std. Error Mean |
|-----------------------------|--------|----|----------------|-----------------|
| Pre-Intervention MHL Score  | 128.42 | 12 | 12.724         | 3.673           |
| Post-Intervention MHL Score | 133.33 | 12 | 11.081         | 3.199           |

Table 2: Descriptive Statistics for Pre-Study and Post-Study MHL Scores

Table 2 displays the descriptive statistics for the Mental Health Literacy(MHL) scores, measured for the twelve participants, before and after the intervention. The mean score for Pre-Intervention MHL was 128.42 (SD = 12.724), while Post-Intervention MHL mean score was 133.33 (SD = 11.081). This suggests an improvement in the participant's mental health literacy following the intervention. The standard error for the Pre-Intervention MHL score was 3.673, while the Post-Intervention MHL score showed a lower standard error of 3.199, suggesting a more consistent score distribution post intervention. It's also important to remind that item 12 is missing, therefore the total MHL score reported here is based on 34 items instead of the full 35.

| Measure        | Statistic | df | Sig.  |
|----------------|-----------|----|-------|
| Pre_MHL_Score  | 0.948     | 12 | 0.611 |
| Post_MHL_Score | 0.879     | 12 | 0.085 |

Table 3: Shapiro-Wilk results for Pre- and Post-MHL Scores.

Table 3 shows the results of a Shapiro-Wilk test. Using the previously established significance level of 0.05, we can assume that the data set follows a normal distribution since both significance values for Pre-Intervention MHL Score (*Sig.* = 0.611) and Post-Intervention MHL Score (*Sig.* = 0.085) are greater than 0.05.

To further determine whether the difference in Mental Health Literacy(MHL) was statistically significant, we conducted a paired t-test. The results of the paired t-test are summarized in Table 4.

| Statistic                | Value |
|--------------------------|-------|
| Mean Difference (M)      | 4.917 |
| Standard Error Mean (SE) | 2.109 |
| t-statistic (t)          | 2.332 |
| Degrees of Freedom (df)  | 11    |
| p-value (Two-Sided)      | 0.04  |

Table 4: Paired t-Test Results for Pre- and Post-Intervention MHL Scores.

The p-value of 0.04 shows that there is indeed a significant statistical difference ( $p < 0.05$ ) between both data sets. Furthermore, a positive t value ( $t = 2.332$ ) confirms an increase in Mental Health literacy after the intervention took place.

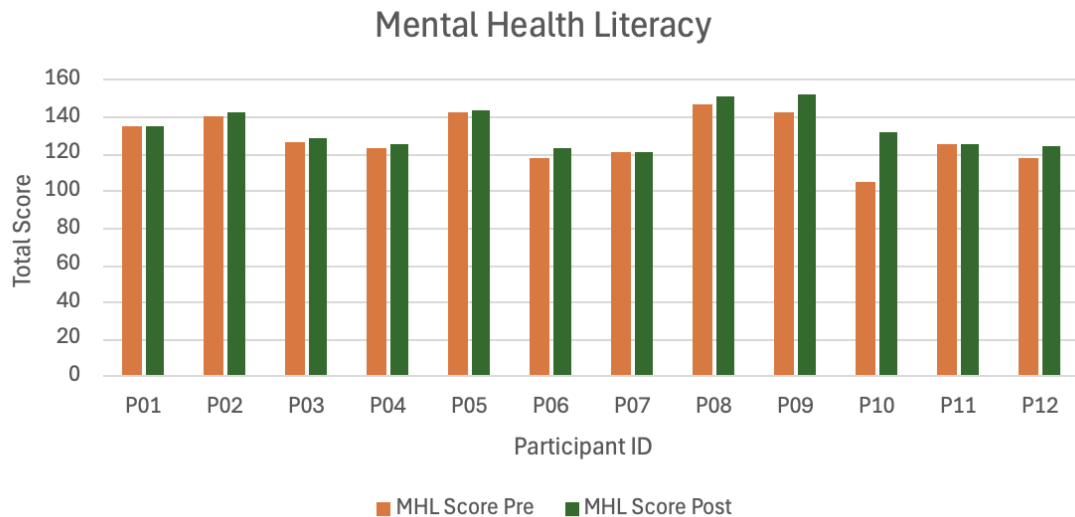


Figure. 68: *Mental Health Literacy Score comparison for each participant*

Figure 68 shows a more comprehensive comparison between pre-intervention and post intervention scores for each participant. Overall its possible to observe an increase in score for the majority of participants, with the exception of participants P01, P07 and P11 where the score remained the same post intervention.

Additionally, we analysed the scores based on six different attributes. Graph 69 illustrates each attribute's total mean score percentage (with 100% representing the maximum value for the component in question) before and after the intervention, with the "Knowledge of self-treatment" attribute being impacted by the omission of item 12.

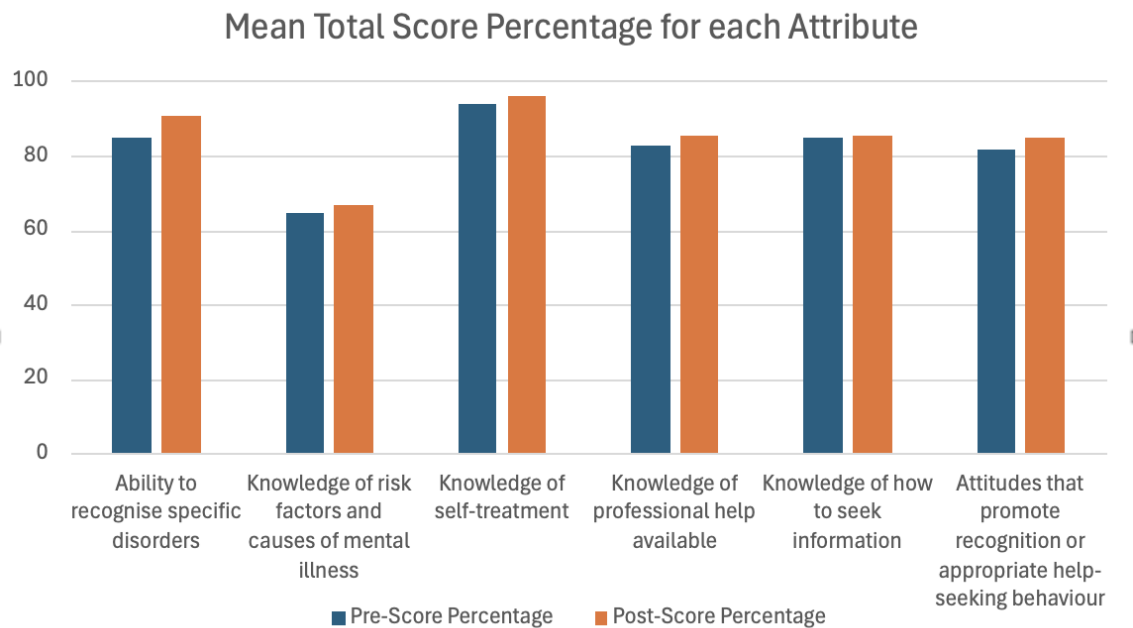


Figure. 69: *Mean Total Score Percentage for each Attribute*

The first theme, Recognition, which consists of a single attribute, showed an increased of 5,99% from an initial score of 84,90% to 90,89%, being the highest increase among all attributes. The second theme, Knowledge, consists of four different attributes:

- **Knowledge of risk factors and causes of mental illness:** Increased by 2.08%, from 64.58% pre-intervention to 66.67% post-intervention.
- **Knowledge of self-treatment:** Increased by 2.08%, from 93.75% to 95.83% (missing item 12).
- **Knowledge of professional help available:** Increased by 2.78%, from 82.64% to 85.42%.
- **Knowledge of how to seek information:** Increased by 0.42%, from 85.00% to 85.42%, showing the smallest increase among all attributes.

Lastly, the third theme, Attitudes, is composed of a single attribute and also showed an increase of 2,92% in score, going from 81,77% to 84,69% post intervention.

#### **CBT Questionnaire - Quiz Section - Results**

Table 5 displays the descriptive statistics for the quiz section of the CBT questionnaire measured for all twelve participants, before and after the intervention. The Pre-Intervention CBT-Quiz mean score was of 6 ( $SD = 1.279$ ), while the Post-Intervention CBT-Quiz mean score was of 6 ( $SD = 1.706$ ). This suggests that there was no improvement/decline in the participant's quiz scores following the intervention. The standard error mean increased from 0.369 to 0.492, suggesting that the distribution of scores is slightly less consistent after the intervention.

| Measure                          | Mean | N  | Std. Deviation | Std. Error Mean |
|----------------------------------|------|----|----------------|-----------------|
| Pre-Intervention CBT-Quiz Score  | 6.00 | 12 | 1.279          | 0.369           |
| Post-Intervention CBT-Quiz Score | 6.00 | 12 | 1.706          | 0.492           |

Table 5: Descriptive statistics for Pre- and Post-CBT Scores.

To determine whether the data set was normally distributed, a Shapiro-Wilk test was conducted. Table 6 shows the results from the Shapiro-Wilk test and from it we can assume that both data sets are normally distributed, since their significance values ( $Sig. = 0.276$  and  $Sig. = 0.122$ ) are both higher than the Significance level previously established ( $Sig. > 0.05$ ).

| Measure                          | Statistic | df | Sig.  |
|----------------------------------|-----------|----|-------|
| Pre-Intervention CBT-Quiz Score  | 0.919     | 12 | 0.276 |
| Post-Intervention CBT-Quiz Score | 0.891     | 12 | 0.122 |

Table 6: Shapiro-Wilk test results for Pre- and Post-CBT Quiz Scores.

The paired t-test results (see Table 7) showed a p-value of 1 which means that there is no significant statistical difference found between the two data sets ( $p > 0.05$ ). Therefore, we can conclude that the intervention had no impact on the CBT quiz section scores in general.

| Statistic                | Value |
|--------------------------|-------|
| Mean Difference (M)      | 0.000 |
| Standard Error Mean (SE) | 0.326 |
| t-statistic (t)          | 0.000 |
| Degrees of Freedom (df)  | 11    |
| p-value (Two-Sided)      | 1.000 |

Table 7: Paired t-Test Results for Pre- and Post-CBT Quiz Scores.

Figure.70 illustrates the score difference between each participant. It's possible to see that after the intervention, four participants increased their score while other four participants got the same score.

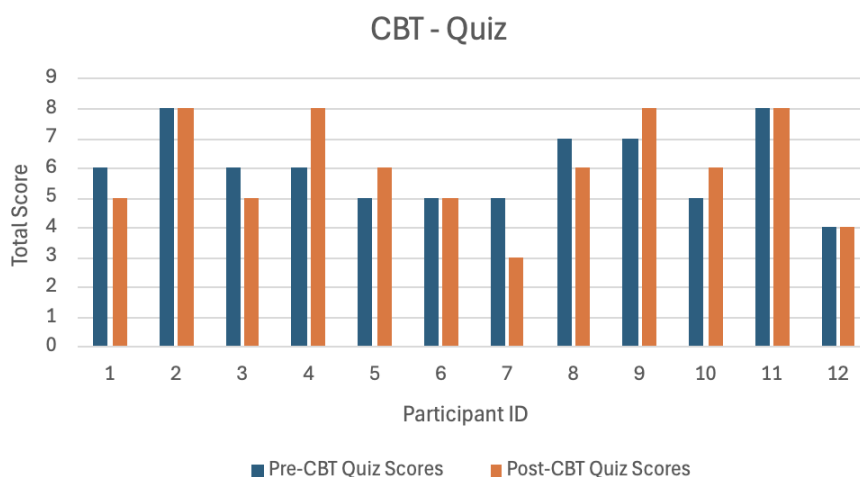


Figure. 70: *CBT Quiz Scores for each Participant*

However, four participants got lower scores than their initial ones. Even though we can identify some changes in scores, they cancel each other since four participants increased their score and four decreased, thus not being able to precisely assess any potential improvement or decline.

### **CBT Questionnaire - Cognitive Section - Results**

Table 8 shows the median, standard error and interquartile range of every item in the cognitive section of the CBT questionnaire, before and after the intervention. In general, the results reveal high median values ranging from 4 to 5, with small increases in medians observed in some items post intervention, such as *It's important to identify negative/irrational thoughts* (Md = 4 pre, 5 post) and *It's helpful to know that other people share the same thoughts/feelings* (Md = 4 pre, 5 post), while some remained the same.

To determine the normality of the data sets, we conducted a Shapiro-Wilk test. The results showed that their significant values were all lower than the significant level established (Sig.< 0.05), so we can assume that all data sets are not normally distributed. Therefore, Wilcoxon signed-rank tests were conducted for each item, where table 9 shows the Z and p-values of each item. It's possible

| Items   | Pre-Intervention |      |      | Post-Intervention |      |      |
|---|------------------|------|------|-------------------|------|------|
|   | Median           | SE   | IQR  | Median            | SE   | IQR  |
| <i>It's important to identify negative/irrational thoughts</i>                  | 4                | 0.49 | 1    | 5                 | 0.45 | 0.75 |
| <i>I'm confident in identifying my negative/irrational thoughts</i>             | 4                | 0.71 | 0    | 4                 | 0.72 | 0    |
| <i>I'm willing to challenge my negative/irrational thoughts</i>                 | 4                | 0.75 | 0.75 | 4                 | 0.85 | 2    |
| <i>Changing negative/irrational thoughts can have a positive impact in life</i> | 4.5              | 0.52 | 1    | 5                 | 0.67 | 1    |
| <i>It's helpful to know that other people share the same thoughts/feelings</i>  | 4                | 0.75 | 1    | 5                 | 0.39 | 0    |

Table 8: Descriptive statistics (Median, SE, IQR) for Pre- and Post-Intervention across the five items.

to notice that there was no significant statistical difference on every item ( $p\text{-value} > 0.05$ ) with the exception of the item *It's helpful to know that other people share the same thoughts/feelings*, where its  $p\text{-value}$  ( $p = 0.038$ ) was lower than 0.05. This lack of significance maybe reflect a ceiling effect, as participant's pre-intervention scores were already high, leaving less space for improvement.

| Items   | Z     | p-value |
|---|-------|---------|
| <i>It's important to identify negative/irrational thoughts</i>                  | -1.89 | 0.059   |
| <i>I'm confident in identifying my negative/irrational thoughts</i>             | 0     | 1       |
| <i>I'm willing to challenge my negative/irrational thoughts</i>                 | -1.34 | 0.18    |
| <i>Changing negative/irrational thoughts can have a positive impact in life</i> | -0.45 | 0.66    |
| <i>It's helpful to know that other people share the same thoughts/feelings</i>  | -2.07 | 0.038   |

Table 9: Wilcoxon signed-rank test statistics (Z) and p-values for the five items.

### Game Experience Questionnaire - Core Module

This module was designed to assess game experience on seven different components: Competence, Positive Affect, Negative Affect, Challenge, Tension/Annoyance, Flow and lastly, Sensory and Imaginative Sensory. Each component was associated to specific items and their score was determined by calculating the mean of the items sum, with a maximum value of 4.



was also determined by calculating the mean of the items sum, with a maximum value of 4. The mean values in table 11 reveal that the Positive Experience component had the highest mean value of 2.38, while the remaining components showed mean values close to 0, with the exception of Returning to Reality component, which had a mean value of 1.38.

A radar chart (see figure 72) was created in order to provide a better outlook on the distribution of component scores for every participant.

| Component            | Mean | Std. Deviation |
|----------------------|------|----------------|
| Positive Experience  | 2.38 | 1.04           |
| Negative Experience  | 0.38 | 0.62           |
| Tiredness            | 0.58 | 0.63           |
| Returning to Reality | 1.36 | 0.66           |

Table 11: Descriptive statistics for GEQ - Post-Game Module

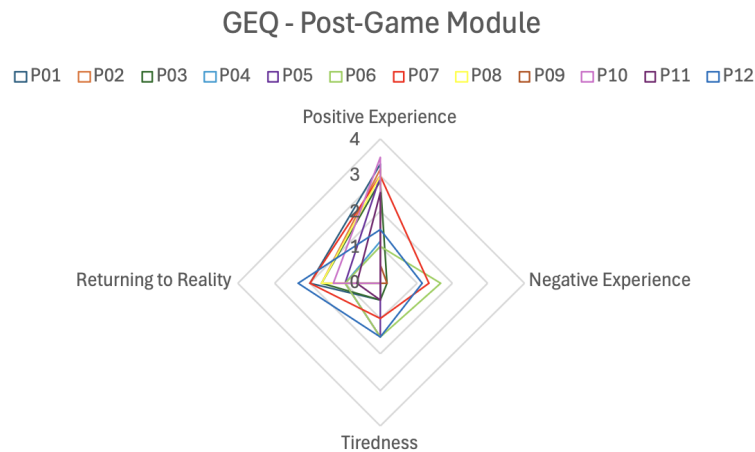


Figure.72: *Component Mean Scores for each Participant*

### 6.6.2 Qualitative Results

Resulting from the qualitative analysis conducted, we were able to group the relevant information into 6 distinct themes.

#### Mini-games overall experience

We asked each participant about their experience with the mini-games and which they preferred. Eleven participants showed enjoyment in playing both games describing them as fun and

interesting. P08 only mentioned their preference for mini-game A. When it came to specific preference, the results were relatively balanced: six participants preferred mini-game A, five participants preferred mini-game B and one participant stayed neutral. P02, P03, P04, P05, P06 and P08 justified their preference to mini-game A by highlighting its mechanical interaction as more engaging and enjoyable compared to mini-game B. P01 just stated that mini-game A was more fun than mini-game B.

On the other hand, P02 and P07 just mentioned their preference for mini-game B over mini-game A, while P09 expressed their preference to mini-game B by stating it *"allows people to make connections between the various types of thoughts, which can sometimes be more difficult for them to do"*. Similarly, P11 noted that mini-game B *"allows the person to see themselves in that NPC—certain things that people actually do, which are right in front of them. It's like looking in a mirror and realizing that there are indeed certain actions a person can take."* which contributed to their preference for this game. Finally P12 found more enjoyment in the back and forth and interpretive nature Game B offered.

Additionally, P10 didn't specifically choose one game over the other, instead stated that *"The balloon one is quite fun and serves as an introductory game, I think, to achieve that, while the other one delves deeper into this association dynamic"*.

### **Positives and Negative aspects about the mini-games**

Throughout the interviews, we were able to collect feedback on the mini-games from a variety of questions, even when the question didn't target them specifically. On a general note, P09 appreciated the modularity of both mini-games by stating that *"They were focused solely... they were modular, which makes it easier for people to understand the purpose and the very theme of the mini-games"*. Additionally, P09 added that *"They were well-structured, able to convey the information effectively, and demonstrated parts of that information in practice"*. On a similar view, P12 found the games to be well implemented.

#### **Game A positives**

In game A, the most shared positive aspect mentioned was the interactivity it provided. P02, P04, P08 and P10 specifically appreciated the dart throwing and balloon popping mechanic as a factor that contributed to their enjoyment. P02 also noted that *"... the balloon-popping mechanic made the game a less heavy and more fun experience"*. P10 and P11 had similar views on the

association part of the game by stating, respectively, *"I found it quite interesting that with the balloons, you had to throw darts to match what appeared on the board."* and *"For example, with the balloons, the person has to think a bit about the context and the question they need to answer. Certain aspects of the context itself are indeed tied to a type of, in this case, let's say, response. It's easy to associate the context with the answer"*.

### **Game A negatives**

From a more negative perspective, P01, P07, P09, P11 and P12 expressed confusion in the association part of the game due to some of the thought patterns appearing to be very similar. P11, for example, stated that *"... there are certain contexts that can be associated with another type of response that is somewhat vague"*, while P07 also mentioned that *"... sometimes it seemed like a term could have more than two or three answers"*. Two participants expressed some complaints about the balloons' movements and their overlapping aspect, with P01 stating that *"I'm also not very good at playing darts in real life, but sometimes the balloons would get in the way and argh!"* and P04 finding the balloons' movement being too fast. P07 and P09 expressed that they felt some confusion initially, with P09 having some trouble in the association part by stating *"In the information given about the game tutorial, for example, it doesn't indicate whether we should start with the one that is orange or if we can view the others. For instance, I didn't realize that it was mentioned"*.

### **Game B positives**

In game B, four participants expressed their enjoyment in interacting with the NPCs and the higher level of depth and relation they provided. P02, for instance, simply found pleasure in being able to talk with the NPCs, while P10 and P11 underlined the game's ability to help the player identify and connect thoughts. P10 stated that *"Also, from the other game, which was about combining thoughts to form a... perhaps a line of reasoning between the two. I think it's good, especially for those who might have mental health issues, to help identify the relationship between two things"*. and P11 mentioned *"And then, for example, the other one, where you have to talk to people to identify the patterns and actions each one took, can help people who have some difficulties, especially students in higher education, who sometimes have doubts about what they need to do and often compare themselves to others, like in the cases of the NPCs who compared themselves to others"*.

### **Game B negatives**

On a negative lenses, the main challenge in game B shared by P01, P02, P06, P08 and P12, was in understanding the concept of combining two pieces of information. For instance, P02 stated *"I think that maybe in the second mini-game, what I found more difficult, but that's why I went back, was understanding that you had to grab the same color and place it on top, that's all".*, and similarly P06 mentioned *"But for the first one, I was a bit confused because, okay, it makes sense that the cards have the same color, but I thought you were supposed to choose a card and place it in the other column. Because at the beginning, he explained how you were supposed to play, but I forgot when I started talking to the others"*. P08 noticed a lack of gamification and required a lot of movement: *"I found the second one a bit more boring because it was just text and didn't have much gamification. It was also a bit difficult in VR because you always have to move around with the joystick, and it's a bit unsettling to constantly go from one side to the other."* Additionally, P12 had some issues remembering the correct information: *"I probably should have focused on one person and then gone straight to the mini-game because... I tried to remember. I spoke to two people during the normalization phase and then started mixing up the information a bit. That's why I had to go back to the person who was doing the combination."*

### **Artefact's potential as a tool for CBT knowledge gain**

We asked the participants if this approach was something that could be beneficial to college students. Participants highlighted the artefact's ability to facilitate the understanding of CBT concepts and its application in real life scenarios. P09, for instance, stated *"...because it allows people to make connections between the various types of thoughts, which sometimes becomes more difficult for people to do"*. On a similar thought process, P02 mentioned *"...because when you try to help others, you might take away a lesson that you can apply to your own life. For example, that thing David mentioned about using flashcards and practising in front of the mirror, that's something I could also do to help myself in my own situations"*.

Another topic mentioned by two participants was the usefulness of such intervention for college students especially during transitional phases. P10 stated *"Yes, quite a lot, especially perhaps for those who are starting a new phase when they enter higher education. They might have to move to a new place, be far from their family, have a heavier workload compared to school, and experience various associated emotions"*.

The importance of fostering awareness and normalizing mental health awareness was a shared feeling among participants, with P08 stating: *"...because we increasingly see that students have these problems with anxiety and so on. I think it's good for people to know that they are not alone and that it's something normal, that other people experience it too, and to normalize this issue."* Additionally, P12 suggested a potential integration in a casual setting: *"Yeah, I think in a relaxation room or something like that, and having a VR setup with something like this"*.

### **Personal experience with social anxiety**

We asked each participant whether they were able to recall a specific experience with social anxiety during the gameplay. Out of all participants, only three reported not recalling any such experience. A common experience shared among the participants was anxiety derived from presentations, relating to David's story. P02, for example, stated: *"When I spoke to that guy—oh, I forgot his name—when he started saying that he felt anxious during presentations, talked really fast, and forgot things, reading that made me realize it was something I did too"*.

Worrying about what others think about themselves was also another topic shared among the participants, with P01 stating: *"There were so many things, but the part where the girl said, 'thinking that people would be looking at me,' that was also a bit like me—I would think about what others were going to think of me"*. P11 was also able to see himself in Carla's story regarding the behaviour of comparing oneself to others: *"I saw myself a bit in David but also in Carla, who, therefore, looks at social media and compares herself to others"*. Additionally, P08 mentioned suffering a bit from anxiety in party scenarios: *"Hmm, at parties, I don't like talking to people I don't know, and I feel a bit anxious"*.

### **Design improvement suggestions**

We asked each participant whether they would change or add anything to the game. 4 participants didn't suggested any changes or improvements while the rest made suggestions for specific mini-games but also in a general way. In game A, suggestions were varied. P11, for instance, suggested: *"Maybe improving the context of the questions in the balloon game"*, while P12 criticised the balloons' movements by stating: *"I think in the first game the balloons move a bit suddenly, like the turns they make are very... sometimes I was about to hit one, but it immediately swerved. It would be better if it had more of a floating movement"*.

More in a quality of life perspective, P08 suggested changing the position of the terms sheet in the first game: *"I think the way the instructions were set up in the first game could be improved. They could be in a pocket or somewhere closer, so when you're looking at the text and the balloons, you don't have to go to the other side of the table. Since you're already far away, having to get closer to grab the instructions feels inconvenient. I think they could be placed somewhere more accessible"*. For game B, two participants suggested improvements regarding more visible instructions and adding more gamification. P06 stated: *"Maybe, like where the board and things are, make it more visible with clear instructions on what to do"* and P08 mentioned: *"In the second mini-game, as I mentioned, it would be more engaging to have a bit more gamification instead of just reading what people said. I'm not sure what exactly, but I think it would make it more fun"*.

In a general view, the suggestions were also varied, with P03 suggesting an indicator for controls: *"If there were some kind of indicator with the controls displayed on the side, I think it would help a bit, making it less likely for someone to get lost"*, while P06 proposed a defined order of mini-games: *"I think it would be better to maybe start with the balloon game because it has the explanation sheet about mental illnesses, which could help with the rest"*. Additionally, P08 suggested replacing the text tutorial with a voice-guided one: *"I also think the tutorial could be different... Instead of having to read, it could be someone speaking while you're already interacting with things—a teaching level, rather than having to read it before starting. People just want to start playing"*.

### **Virtual Reality Environment role**

Given the novelty of VR technology, we asked participants whether being in a virtual environment impacted the learning aspect of the concepts transmitted. Only two participants didn't feel like it played an important role when it comes to teaching these concepts. P08 justified this idea by stating: *"But I don't think it's my preferred form of media, it's more uncomfortable, harder to access, and for other people to use. ... For learning, I'm not sure if it's that relevant to be in VR"*.

The majority of participants highlighted the immersive nature of virtual reality as a very appealing characteristic, leading to a higher level of engagement with the game. P07 and P10, for example, expressed this idea by stating: *"I forgot about everything around me and focused only on the game, and I found it appealing"* and *"I think so, quite a lot. Maybe even more than reading a book or something on the internet"*, respectively. Furthermore, P04 found that the interaction was

better in VR: *"Yes, because I entered a virtual reality and it felt like I was closer to the people, and the interaction was better"*.

P09 reinforced their opinion on the immersion of VR by comparing 2D media with the 3D experience of VR by stating: *"Yes, the environment in VR allows it to convey 3D information to the person in the real world. Even though it's a virtual medium, if the person is able to immerse themselves in VR, they can act as if they are really in the real world, performing the right movements and actions. This makes them perceive the actions as real movements, not virtual, and that makes it easier to convey information than if it were in 2D"*.

Two participants commented that VR is still a novelty to them, with P03 stating: *"It was a different experience that I had never tried before, VR games"* and, on a more negative note, P07 said: *"In my case, since it was the second time I used VR, I felt a bit dizzy at first, but then I got more used to it"*.

## 7 Discussion

With this study we intended to assess the artefact's ability to effectively convey CBT concepts to college students for social anxiety in an immersive and engaging way. Both the questionnaires and the semi-structured interviews gave us enough data to evaluate the artefact in various aspects and from different perspectives. Overall, the results were positive in a sense that we were able to measure some increases in the participants CBT knowledge while providing an immersive and enjoyable experience. However, certain findings raised some important points for discussions, which will be initially explored by relating them to the research questions.

### 7.1 RQ1 - Can CBT concepts and practices be effectively integrated into a gamified VR-based intervention?

To provide the player with CBT concepts and practices in a clear and effective way, modular mini-games were developed, each representing a CBT concept and containing a unique design and mechanics. This approach also aimed to engage the player in an immersive and interactive experience.

To determine whether the artefact's design is capable of effectively incorporating CBT concepts in a gamified VR based intervention, we analysed the data from the GEQ-Core and GEQ-Post modules, and the interviews. Based on this data, and consistent with previous works on serious games toward social anxiety [61,65], our findings suggest that the artefact was capable of providing an immersive and enjoyable experience. More specifically, the results reveal that the large majority of participants experienced high levels of immersion, positive engagement, competence and flow, which are key components when it comes to gamified interventions. Additionally, insights from the semi-structured interviews follow this positive trend, with all participants reporting enjoyment, and many highlighting the interactivity of the artefact and the immersion nature of VR as key factors contributing to their positive experience.

However, the novelty of VR might've played a bias role in the participants experience. In other words, some participants may have been more influenced by the immersive nature of VR rather than the design and content of the artefact itself, possibly impacting the accuracy of the results. Meaning that conducting this study with individuals possessing a considerable amount of prior experience in VR might have been more efficient in evaluating the artefact itself, removing the

novelty effect of VR from the equation. Nonetheless, it is important to note that the novelty effect is not necessarily detrimental, as it may have positively contributed in increasing adherence and attractiveness. The positive feedback and the lack of reports of discomfort or negative experience further suggests that VR was a successful medium for delivering the intervention. These findings further reinforce the potential of gamified VR experiences in enhancing engagement, particularly among college students, consistent with the findings of Heng et al. [63].

Moreover, we were able to identify an important design tension between the two mini-games. While mini-game A was praised by the mechanical skill and interaction it offered, mini-game B was highlighted by its meaningful content. This is further reinforced by the participant's reflections on the artifact's potential as a tool for CBT knowledge gain, where the majority considered Mini-Game B as particularly helpful in that regard. They emphasized its ability in applying CBT strategies in their own situations and in helping normalize these experiences for others. This suggests an even split in preference over interaction and cognitive engagement between the players, which leads us to believe that Mini-game A focused more on an hedonic experience, while Mini-Game B provided more of an eudaimonic experience. This mirrors key points in various works about serious game design [70–72], where attaining a balance between these two types of experiences is essential in providing a transformative change in the players. The disparity in our results suggests that the mini-games require additional refinement in order to reach a more effective balance and enhance the impact of the intervention.

## **7.2 RQ2 - Does a gamified VR-based CBT intervention effectively help college students retain CBT knowledge?**

Assessing the artifact's ability to support CBT knowledge retention is essential in evaluating its educational and therapeutic impact. Our findings suggests that the artefact was able to enhance both mental health literacy and CBT knowledge. As said previously, to mitigate the impact of the omitted item 12 in the Mental Health Literacy questionnaire, we used a theoretical framework created by Korhonen et al. [95] to gain a deeper understanding. The results revealed a positive increase in every theme that did not include item 12. Additionally, several participants mentioned the artefact's ability to facilitate the understanding of the concepts conveyed and their application in real life situations, thus greatly contributing to knowledge gain.

However, the CBT-Quiz section results alerted to a lack of significant statistical difference. The post-intervention results reveal a significant inconsistency among the participants, with some increasing their score, some lowering and the rest remaining the same. This inconsistency most likely originates from mini-game A, which focused on identifying NATs. While the balloon popping mechanic was engaging and interactive, several participants felt like some NATs were ambiguous, leading to a difficult association between the terms and NATs. Given that the CBT-Quiz section mainly targets terms conveyed in Mini-Game A, it's possible that this ambiguity mislead some participants into changing their initially correct answers, thus creating the observed inconsistency. This result is a foreseen issue in Natucci and Borges work [71], where complex content can result in difficult understanding. Therefore, refining and clarifying these terms in mini-game A could further improve knowledge retention.

As for the CBT-Cognitive section, results show that the participants were able to recognize the importance in identifying and changing negative thought patterns. However, the most significant increase was noticed in the importance of knowing that other people share the same thoughts or feelings. Although most CBT practices focus on self reflection and individual cognitive restructuring, this finding highlights the value of normalization and sharing experiences, which is directly linked to the CBT concept in mini-game B.

In fact, most participants were able to connect to certain struggles they have faced before, with David's story being the most relatable one. David's anxiety is related to doing presentations, which is considered a common anxiety inducing scenario for college students. This relatability leads us to believe that the game mechanic of interacting with NPCs, particularly with David, was successful in obtaining empathy and engagement from the players, supporting the intended CBT goal of normalization. The absence of mentions to other NPCs' stories suggest that they were less relevant to the participants, implying that, in a college context, only David's story had a meaningful impact. Consequently, the other NPCs' stories may require rewriting to better align with students' experiences. Based on this assumption, tailoring the content towards the most common social anxiety scenarios in a college setting can leave a bigger impact since it is something that most college students have probably gone through. This finding aligns with Báldy et Al's work [64], who found that designing serious games based on relatable situations helped players understand and internalize CBT concepts.

This imbalance in results between the quiz and cognitive sections of the CBT Questionnaire might also suggest that the artefact is more effective at improving or changing an individual's attitude towards a specific concept rather than teaching theoretical knowledge, such as understanding definitions and terminology. While this imbalance may suggest room for improvement in the artefact's design, it does not significantly reduce its effectiveness. As while being aware of what specific terms in mental health mean is beneficial, it's not essential when applying CBT concepts in real life situations. The most important aspect is the ability to proactively change their thinking patterns, emotion management and behavioural reshaping [27], which is more in line with the CBT-Cognitive section.

### 7.3 Implications for Design

Based on our findings, we were able to identify certain design choices that were successful and others that needed additional attention when it comes to the artefact's design. These practices are as follows.

The party atmosphere and the presence of NPCs were successful in increasing immersion and engagement in the participants, highlighting the need to create environments that are relevant to the target audience. The content in mini-game B, especially David's story about presentation anxiety, proved to be very relatable to the participants, where they were able to show empathy and in a way see themselves in their struggle. Tailoring the content towards situations that are common occurrences in the target audience seems to be a very effective way of conveying the CBT concept.

When it comes to the ambiguity observed in mini-game A towards the terms conveyed, having a psychiatrist validate the terms and their definitions could have prevented the created confusion, instead of relying solely on CBT literature. The reported lack of interactivity and entertainment in mini-game B probably originates from the text heavy nature of the NPCs conversations, suggesting a necessity in reducing this overload of text, possibly by integrating speech in the NPCs.

### 7.4 Limitations

While this study provides interesting and valuable insights about gamifying VRCBT for Social Anxiety in college students, its essential to identify and analyse limitations in the study that may have influenced the results.

One important limitation is an oversight that happened when creating the questionnaire form for the Mental Health Literacy scale, which resulted in item 12 not being included. As a result, the scores obtained are incomplete, which makes it impossible to draw valid direct comparisons with external works. Additionally, the CBT questionnaire was custom-designed since there were no validated scales specific to CBT knowledge, thus affecting reliability and comparability.

About the study methodology itself, a higher number of participants could have possibly improved the results. Since no exclusion or inclusion criteria were implemented for VR experience in the recruiting process, the novelty effect of VR might have lead the users to partially base their experience on the excitement of using VR rather than being based solely on the artefact itself. Additionally, assessing the intervention's effect over a longer period of time would have provided deeper insights into determining whether the participants knowledge would have persisted over time.

## 8 Conclusion

This study aimed to assess whether a gamified VRCBT based intervention could effectively convey CBT concepts to college students about social anxiety. The analysis of the data revealed that this approach has potential to benefit college students in many ways, be it CBT knowledge, mental health literacy and even raising awareness, given its ability to recreate complex CBT concepts in an immersive and interactive way, increasing adherence to young adolescents.

However, both the artifact design and the study methodology can be further reworked. Mini-games A and B appeared to need some balancing to reach the intended middle ground of interaction vs content, while mini-game C requires further development. Additionally, future research should evaluate the effect of this intervention over a prolonged period of time and assess its impact specifically on college students experiencing social anxiety, as this would provide deeper insights into its effectiveness.

That being said, this study still contributes as an important step in understanding the potential of gamified VRCBT based interventions. While further research is necessary for validation, these findings suggest that such interventions are capable of providing valuable insights about mental health education and self-help strategies to college students.

### 8.1 Future Work

Looking ahead, when it comes to design, the artefact can be further developed by increasing the number of mini-games and, consequently, the number of CBT concepts it teaches. As said before, due its modular structure, integrating other mini-games can be done with ease and without affecting other existing mini-games.

Another interesting addition would be the integration of LLMS. As stated before, LLMS were being considered for this work since they can provide the game a lot of depth and unique user-specific experiences. An example would be to allow the user to input a description of their personal experience with social anxiety, enabling the game's content to be tailored towards that description.

A potential quality of life improvement could be adding a narrator voice to the tutorials making it easier for the players to understand the mini-game. This idea originated from some feedback gathered at the IMX 2024 Conference during the demo section where a few players felt that they would prefer to hear the instructions rather than read text.

As for a future study, several changes could significantly improve results or obtain different and important insights. These would include increasing the number of participants, focusing specifically on college students experiencing social anxiety and also assessing the intervention's impact on participants over a defined period of time.

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## A Study - Informed Consent



## **Consentimento Informado, Esclarecido e Livre para Participação em estudos de Investigação**

**Identificação do Investigador:** Élton Gonçalo Rodrigues Camacho, Universidade da Madeira, [2032317@student.uma.pt](mailto:2032317@student.uma.pt); Paulo Bala, ITI-LARSyS, [paulo.bala@tecnico.ulisboa.pt](mailto:paulo.bala@tecnico.ulisboa.pt); Pedro Campos, Universidade da Madeira, ITI-LARSyS;

**Título do estudo:** Social Anxiety in VR-CBT: Transformative Insights for College Students

**Enquadramento:** Foi convidado a participar numa experiência gamificada de VR para explorar a complexidade da ansiedade social num ambiente imersivo e interativo. Terá oportunidade de testar três mini-jogos relacionados com a aplicação de conceitos CBT (Cognitive Behavioral Therapy) direcionados a ansiedade social.

### **Explicação do estudo:**

Este estudo tem como objetivo testar três diferentes mini-jogos em VR no headset Meta Quest 3 onde cada mini-jogo representa um conceito de CBT para ansiedade social. Pretende-se verificar se a gamificação destes conceitos num ambiente VR tem resultados significativos quanto à transmissão dos mesmos para estudantes universitários. Será pedido ao participante para preencher vários inquéritos, antes e após de testar o protótipo, relacionados com dados demográficos, experiência do jogo, literacia de saúde mental e conceitos de CBT. Adicionalmente no fim da sessão o participante irá participar numa entrevista breve sobre o estudo em si. O estudo terá lugar nas instalações do ARDITI e com uma duração de aproximadamente 1h10m.

### **Condições e financiamento:**

A sua participação será voluntária e sem contrapartida de recompensação. Tem o direito de a qualquer momento terminar a sua participação.

O risco e o desconforto associado a este estudo poderá envolver uma eventual motion sickness devido à natureza do VR. Caso sinta muito desconforto ao manusear o headset VR, o mesmo será retirado de imediato e a sessão será anulada caso o participante não se sinta confortável em continuar o estudo.

Este projeto tem financiamento de uma bolsa de investigação por parte do projeto E-Games Lab. Este estudo foi aprovado pela comissão de ética da Universidade da Madeira.

A sua participação no estudo poderá não trazer benefícios diretos, além de um possível aumento na sua literacia em saúde mental. No entanto, o conhecimento obtido poderá ser valioso para a sociedade. Em particular, contribuirá para a compreensão, aprimoramento e desenvolvimento de jogos em realidade virtual com conceitos de CBT incorporados.

### **Anonimato e confidencialidade:**

A informação obtida será utilizada unicamente para o estudo deste projeto e não para outros fins. Apenas membros da equipa de investigação terão acesso a estes dados, onde os mesmos serão guardados em pastas com acesso restrito e/ou em um espaço físico fechado a terceiros. Nenhuma informação pessoal será cedida a terceiros ou tornada pública. A informação recolhida será guardada por dois anos após tornados públicos os resultados do projeto, sendo depois eliminada (físicos e/ou digitais). Qualquer dúvida não hesite em pedir mais informações. Agradecemos a sua participação neste estudo.

**Por favor, leia com atenção esta informação. Se achar que algo está incorreto ou que não está claro, não hesite em solicitar mais informações.**

Élton Camacho, Universidade da Madeira, [2032317@student.uma.pt](mailto:2032317@student.uma.pt), elton8@live.com.pt;

Paulo Bala, ITI-LARSyS, paulo.bala@tecnico.ulisboa.pt;

Pedro Campos, Universidade da Madeira;

**Se concorda com a proposta que lhe foi feita, queira assinar este documento.**

Assinatura de quem pede consentimento: \_\_\_\_\_



### **Declaração de Consentimento do Participante**

Eu, [*nome*] declaro ter lido e compreendido este documento, bem como as informações verbais que me foram fornecidas pela/s pessoa/s que acima assina/m. Foi-me garantida a possibilidade de, em qualquer altura, recusar participar neste estudo sem qualquer tipo de consequências. Desta forma, aceito participar neste estudo e permito a utilização dos dados, que de forma voluntária forneço, confiando em que apenas serão utilizados para fins científicos e publicações que delas decorram e com as garantias de confidencialidade e anonimato que me são dadas pelo/a investigador/a.

Assinatura legível e manuscrita: \_\_\_\_\_

Data: \_\_\_ / \_\_\_ / \_\_\_\_\_

## B Study - Semi Structured Interview

### Semi Structured Interview Guide

1. How did you find the mini games?
2. Which mini game did you like the most and why?
3. Was there anything you found confusing or difficult to understand?
4. Did you feel that the VR environment enhanced your understanding of the CBT concepts presented?
5. Was there any moment during the gameplay that made you reflect on your own experiences with social anxiety?
6. Do you think something like this can be beneficial to college students?
7. What improvements or changes would you suggest for these mini-games?
8. Any final remarks?

# C Study - Ethics Commission Approval

## PARECER N.º 139/CEUMA/2024, DE 19 DE SETEMBRO

Sobre o pedido de apreciação pela Comissão de Ética da UMa do projeto de investigação: “*Social Anxiety in VR-CBT: Transformative Insights for College Students.*”.

### A – RELATÓRIO

O pedido de apreciação do processo n.º 139 de 2024 relativamente ao projeto de investigação intitulado: “*Social Anxiety in VR-CBT (Cognitive Behavioral Therapy): Transformative Insights for College Students.*”, a ser desenvolvido no âmbito de um Mestrado em Engenharia Informática, tendo como Principal Investigador o mestrando **Élton Gonçalo Rodrigues Camacho** e os orientadores os Professores Doutores Pedro Filipe Ferreira Campos, da Faculdade de Ciências Exatas e Engenharia da Universidade da Madeira e Interactive Technologies Institute (ITI), Laboratório de Robótica e Engenharia de Sistemas (LARSyS) e Paulo Bala, do Instituto Superior Técnico, Universidade de Lisboa e ITI, LARSyS.

O pedido em análise é constituído pelos documentos dirigidos à Comissão de Ética da UMa, que integram o formulário do pedido, a saber:

- a) Pedido de Parecer à CEUMa, datado de 10 de agosto de 2024;
- b) Documento de informação ao participante e consentimento informado, livre e esclarecido para participação em estudos de investigação;
- c) Instrumentos a ser usados para recolha de dados;
- d) Parecer favorável emitido pelo Encarregado de Proteção de Dados da Universidade da Madeira;
- e) A indicação do número Ciência ID ou ORCID do investigador principal e outros membros da equipe de investigação;
- f) Declaração/termo de responsabilidade do orientador Prof. Doutor Paulo Alexandre Câmara Bala;
- g) Compromisso de honra do investigador principal.

Este estudo, com data de início prevista para 20/09/2024 e término a 30/11/2024, tem financiamento de uma bolsa de investigação por parte do projeto E-Games Lab.

O racional do estudo justifica a pertinência do mesmo.

Os investigadores pretendem explorar a complexidade da ansiedade social num ambiente imersivo e interativo, através da participação numa experiência gamificada de Realidade Virtual (VR) com a testagem de três diferentes mini-jogos em VR no *headset*

*Meta Quest 3*, onde cada minijogo representa um conceito de CBT (*Cognitive Behavioral Therapy*) direcionados à ansiedade social e, deste modo, verificar se a gamificação destes conceitos num ambiente de VR tem resultados significativos quanto à transmissão dos mesmos para estudantes universitários e contribuir para a compreensão, aprimoramento e desenvolvimento de jogos em realidade virtual com conceitos de CBT incorporados.

A população alvo serão estudantes da Universidade da Madeira, entre os 18 e os 25 anos, com capacidades físicas para Realidade Virtual e competentes em inglês. O tamanho estimado para a amostra será de 21 participantes, numa amostragem de conveniência e de “bola de neve”, sendo recrutados pessoalmente pelo investigador principal.

Será solicitado aos participantes para preencher inquéritos em língua inglesa, através do *Microsoft Forms*, antes e após testar o protótipo, relacionados com dados demográficos, experiência do jogo, literacia de saúde mental e conceitos de CBT. Adicionalmente, no fim da sessão, o participante irá participar numa entrevista semiestruturada sobre o estudo em si.

A recolha de dados decorre na Universidade da Madeira e nas Instalações da Agência Regional para o Desenvolvimento da Investigação, Tecnologia e Inovação (ARDITI), com uma duração de aproximadamente 1h10m, e integra:

- 1 – Questionário sobre dados sociodemográficos (e.g, idade, género, nacionalidade);
- 2 - *Game Experience Questionnaire – Core Module* – Para recolher informação geral acerca da experiência do participante no fim da sessão;
- 3 - *Game Experience Questionnaire – post-game module* – Para recolher informação sobre como o participante se sente depois de jogar;
- 4 – Questionário sobre os conceitos de *Cognitive Behavioral Therapy*. antes e após a sessão para perceber se o participante adquiriu informação nova;
- 5 – *Mental Health literacy scale* – Antes e após a sessão para analisar se houve alguma alteração no que respeita ao conhecimento do participante sobre saúde mental;
- 6 – Entrevista semi-estruturada (com distorção de voz) – No final da sessão para recolher informação mais detalhada sobre a experiência que o participante teve com os mini-jogos e possivelmente explorar outros tópicos relevantes que surjam por parte do participante.

É assegurada a participação voluntária, sem contrapartida de recompensação e o direito de desistir a qualquer momento. Os participantes são informados da probabilidade de eventual desconforto/mal-estar associado ao manuseamento da VR e que o mesmo será suspenso caso o participante não queira continuar no estudo.

A participação poderá não trazer benefícios diretos, além de um possível aumento nos participantes na literacia em saúde mental, porém o conhecimento obtido poderá ser valioso para a sociedade.

A informação obtida será utilizada unicamente para o projeto e não para outros fins. Apenas membros da equipa de investigação terão acesso aos dados, que serão guardados em pastas com acesso restrito e/ou em um espaço físico fechado a terceiros. Os dados serão anonimizados contendo apenas um identificador para a conexão dos dados. Nenhuma informação pessoal será cedida a terceiros ou tornada pública. A informação recolhida será guardada por dois anos após tornados públicos os resultados do projeto, sendo depois eliminada (físicos e/ou digitais).

Não prevê o retorno direto dos resultados ao participante. Está prevista a divulgação e disseminação de resultados na dissertação de mestrado e em outras formas de publicações científicas.

## **B - CONCLUSÃO**

A CEUMa deliberou, por unanimidade, emitir **parecer favorável** à realização do estudo, tendo em conta os pressupostos indicados pelo principal investigador.

Foi relatora deste parecer: Professora Mestre Clementina Morna

Aprovado, por unanimidade, em reunião do dia 19 de setembro de 2024

A Presidente da CEUMa

Professora Doutora Liliana Maria Gonçalves Rodrigues de Góis

## D Components Diagram

